INDUSTRIAL HYGIENE SURVEYS OF OCCUPATIONAL EXPOSURES TO MINERAL WOOL

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ABSTRACT

The exposures of mineral wool production workers and user workers in 11 facilities to mineral wool fibers, total suspended particulate material, respirable particulate material, and trace metals were evaluated by detailed industrial hygiene surveys. Their exposures to noise and heat were evaluated in several of these surveys.

Five production sites and six user sites of mineral wool were selected for study, based upon the representativeness of the operations and the conditions of exposure of the workers in those sites. Study methods included breathing-zone air sampling for airborne particulate material (total, fibrous, and respirable) with analyses to determine total and respirable airborne particulate levels (gravimetric); airborne fiber concentrations and fiber size distributions (optical and scanning electron microscopy); and airborne trace metals (atomic absorption). Limited evaluations of worker exposure to carbon monoxide, heat, noise, and miscellaneous other materials were performed in some site surveys. In addition to the environmental evaluation, samples of bulk materials being produced and used were taken for analysis. Analysis included optical microscopic determinations of fiber diameter, determination of bulk sample elemental content by atomic absorption (AA) and x-ray fluorescence (XRF), elemental analyses of separated fibrous and compact particles by AA and XRF, and elemental analyses of individual particles by x-ray microprobe.

The production workers surveyed were found to have relatively low exposures to all forms of airborne particulate material, with few exceptions. The user workers had higher, but more variable exposures. It was generally not possible to separate exposure categories on the basis of different exposures; there was significant overlap of the confidence limits on mean exposures across the facilities surveyed.

Past exposures in this industry were probably higher than at present, and asbestos exposure was relatively common.

In addition to exposures to airborne particulate material, exposures to excessive noise levels were universal in the cupola areas of the production plants. Heat stress was a potential problem for the installers of blown mineral wool insulation.

Exposures to small diameter (<1.0 μm) fibers were not common, except in the installation of blowing wool. In those installation situations, electron microscopically visible airborne fibers were present in concentrations up to ten times greater than optically visible fibers.

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INTRODUCTION

Recent animal studies have given some evidence that any respirable mineral fiber may be potentially carcinogenic. Increasing demands for energy conservation have led to increasing public and commercial utilization of insulation products containing mineral wool fibers. In contrast with other mineral fibers, such as asbestos and fibrous glass, mineral wool has not been extensively studied. Neither the potential occupational exposures to mineral wool, nor the health consequences of such exposure have been widely studied. As part of its ongoing research program emphasis on respirable fibers, the National Institute for Occupational Safety and Health contracted with Stanford Research Institute (now SRI International) to study, evaluate, and report upon occupational exposures to mineral wool.

Five production sites and six user sites of mineral wool were selected for study, based upon the representativeness of the operations and the conditions of exposure of the workers in those sites. Study methods included breathing-zone air sampling for airborne particulate material (total, fibrous, and respirable) with analyses to determine total and respirable airborne particulate levels (gravimetric); airborne fiber concentrations and fiber size distributions (optical and scanning electron microscopy); and airborne trace metals (atomic absorption). Limited evaluations of worker exposure to carbon monoxide, heat, noise, and miscellaneous other materials were performed in some site surveys. In addition to the environmental evaluation, samples of bulk materials being produced and used were taken for analysis. Analysis included optical microscopic determinations of fiber diameter, determination of bulk sample elemental content by atomic absorption (AA) and x-ray fluorescence (XRF), elemental analyses of separated fibrous and compact particles by AA and XRF, and elemental analyses of individual particles by x-ray microprobe.

The resultant data were compared and evaluated, and this report is a presentation of the background of the study, detailed descriptions of the methods, and comparisons of exposures within this industry.

BACKGROUND

HISTORY OF MINERAL WOOL PRODUCTION AND USE

Mineral wool is a generic term that denotes any fibrous glassy substance made from minerals (e.g., natural rock) or mineral products (e.g., slag or glass). For the purposes of this project, mineral wool has been defined to include only those fibers made from natural rock (rock wool) or from slag (slag wool), thus fibrous glass is excluded.

Production

Mineral wool has been produced and used for over a century. Thoenen (1939) reported that mineral wool was first produced in Wales in 1840. Production began shortly thereafter in Germany. The first U.S. mineral wool plant began operation in Cleveland, Ohio in 1888. In 1890, a plant was in operation in Salem, Virginia. The first successful commercial production operation was started in 1897 by C. C. Hall in Alexandria, Indiana. The product began to find a substantial market by the end of the first world war (Pundsack, 1976). By 1939, there were 71 companies operating 82 plants manufacturing slag, rock, and glass wool.

In the late 1930s Corning Glass Works and Owens-Illinois joined forces to become Owens-Corning Fiberglas; and the company invested heavily in technology to produce glass wool by processes superior to those that had been used in the past. The paths of rock wool and glass wool partially diverged at this point--the rock wool and slag wool manufacturers continued mainly with the processes and markets of the past, and the glass wool manufacturers opened new markets, including textiles (Smith, 1976). However, the two products continued to compete in the thermal insulation market.

The basic process by which mineral wool is made today is similar to that used in the 1890s. The raw material (slag and/or natural rock) is loaded into a cupola in alternating layers with batches of coke and small amounts of other raw materials used to give the fibers special characteristics of ductility or size. The coke is burned, generating high temperatures (about 3,000°F) and melting the slag. The molten stream of slag issues from a hole in the bottom of the cupola and is "fiberized." Currently, approximately 70% of the mineral wool sold in the United States is produced from blast furnace slag. Most of the remainder is produced from copper, lead, and iron smelter slag. A small amount is produced with natural rock, which is also usually added to the slag to impart desired qualities of flexibility to the fibers.

Figure 1 shows a "typical" mineral wool cupola (Carroll-Porczynski, 1960). In the past, the usual practice was to direct a stream of steam (or of air) to intercept the falling stream of slag, breaking it into many small globules

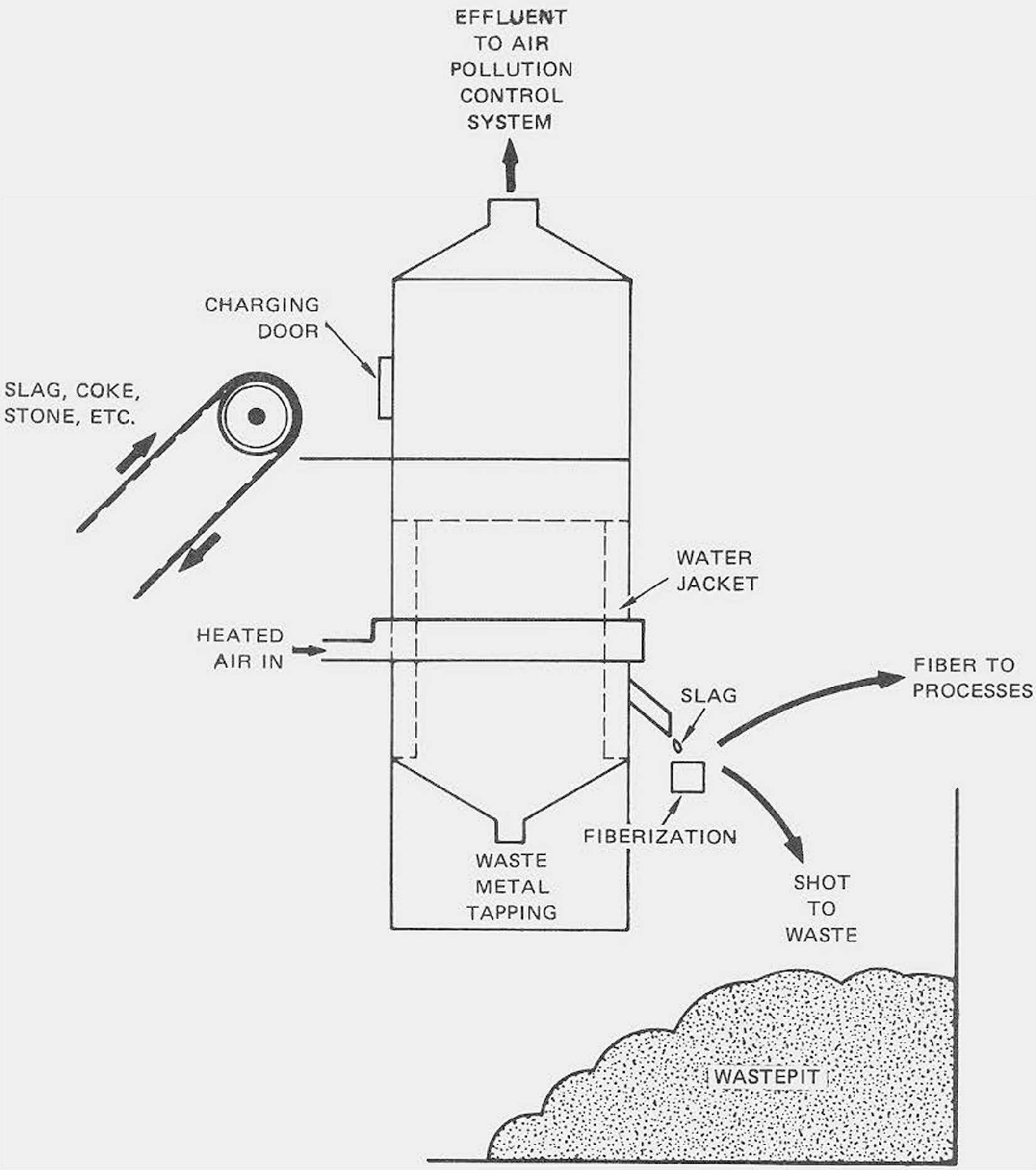


Figure 1. Slag wool cupola

which then "tailed out," producing fibers with a semispherical head. The heads broke off as the material cooled, producing fibers and "shot" (the cooled) heads). Figures 2 and 3 are representations of this process.

Currently, most of the mineral wool in the United States is made by variations of the process shown in Figure 4. The stream of molten slag or rock falls onto a spinning rotor and the partially fiberized slag or rock is further attenuated by an annular stream of steam or air. The configuration of the rotor may be varied, as may be the point at which the stream of molten material contacts it. In some processes, the rotor spins in a vertical plane and the molten stream falls onto the edge of the spinning rotor. In other cases the rotor may be horizontal, with a beveled edge, onto which the stream falls.

Figure 5 shows the "dry spinning" process used by a minor fraction of the producers. This is a mechanical attenuation process that does not use fluid attenuation for additional separation. In all of these processes, a substantial fraction of material is not made into fibers, but becomes shot, which is a waste product of limited commercial use. Some use of the shot has been made for sandblasting, but in general, it represents a significant problem to the producers. Commercial standards for mineral wool insulation generally specify an upper limit on the shot content of the product because the shot is an ineffective insulator, taking up space that could be better used as air space (see section on mineral wool use below). The shot is usually removed from the fibrous material by gravity, immediately following the rotor, and carried to waste.

As the fiber is formed, it may be further treated to increase its utility for one or more of its intended uses. In general, these treatments are applied immediately following the rotor, by the atomization of liquids that are "sprayed" onto the newly formed fibers. In almost all cases, an oil will be applied in this manner to reduce the "dustiness" (tendency to become airborne) of the bulk products. The oil applied may be either a proprietary product developed for this use (e.g., "Mulrex"®) or a medium-weight fuel or lubricating oil. Where the wool is intended for use in a matrix (e.g., Portland cement) requiring effective matrix-fiber bonding, a hydrophilic agent (e.g., maleic acid) may be used in place of the oil. If the wool is intended to be used in bulk, this will be the only chemical treatment applied.

The fiber is then conveyed (by skip hoist, belt, or air lift) to temporary bulk storage or directly to a compression baling machine or bagging station. For some uses (e.g., "pouring wool," to be emptied by hand onto attic floors) the loose wool may be granulated and "pelletized." In this case, the bulk, loose fiber will be passed between counter-rotating toothed drums forming approximately 1-inch diameter wool pellets that can be more easily handled without excessive dusting and do not pack into dense mats before application.

Where the mineral wool product to be produced is required to have moderate or substantial structural rigidity or stability (as in equipment insulation and building insulation batts and blankets), a "binder" may be added immediately following or in place of the oil treatment (see Figures 2, 4, and 5). This binder is usually a phenol-formaldehyde resin that is also atomized. The resin-coated fibers are drawn onto a travelling steel mesh belt (see Figure 2) by a down-draft ventilation system. The speed of the belt is set to give the

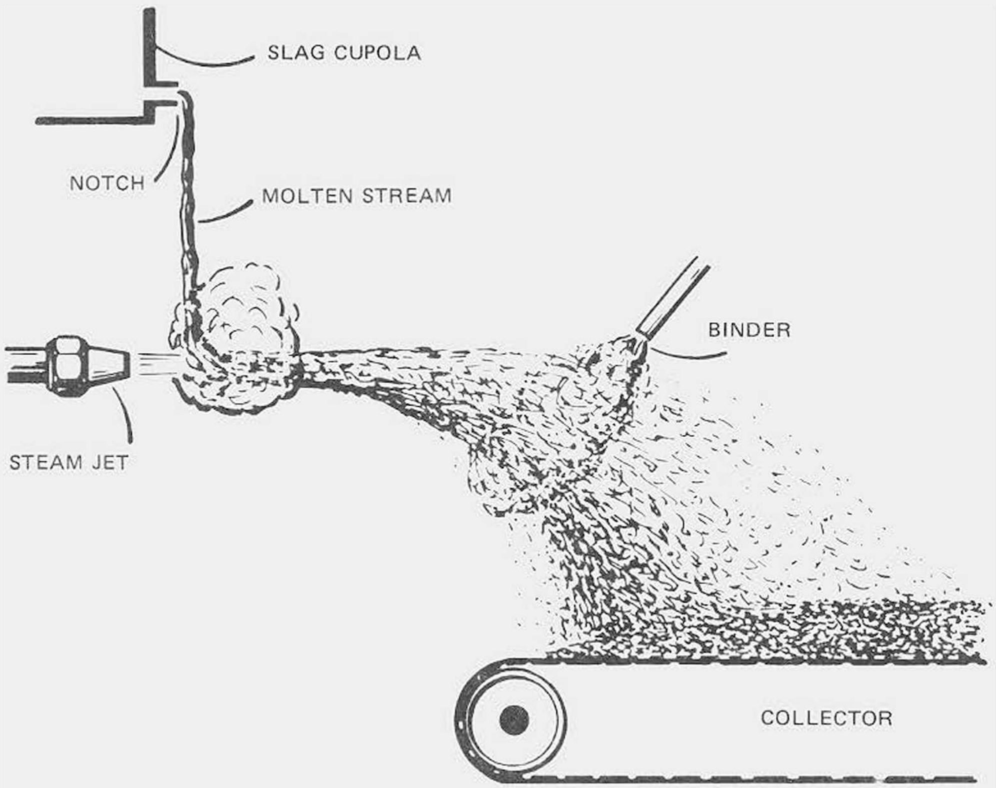
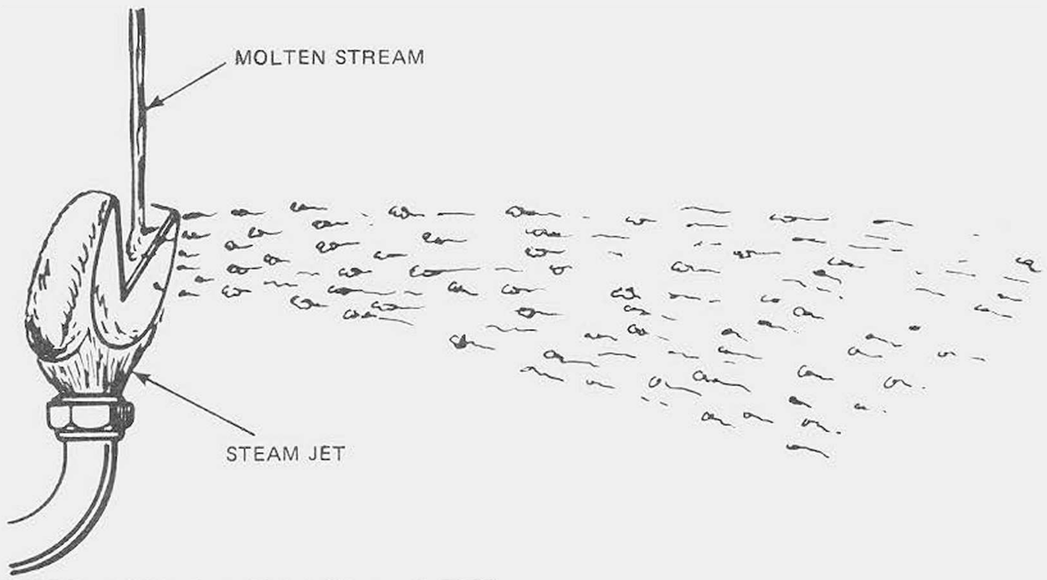


Figure 2. Steam jet fiberization



SOURCE: NIOSH Publ. 76-151 (Pundsack, 1976)

Figure 3. Shot propelled fiberization

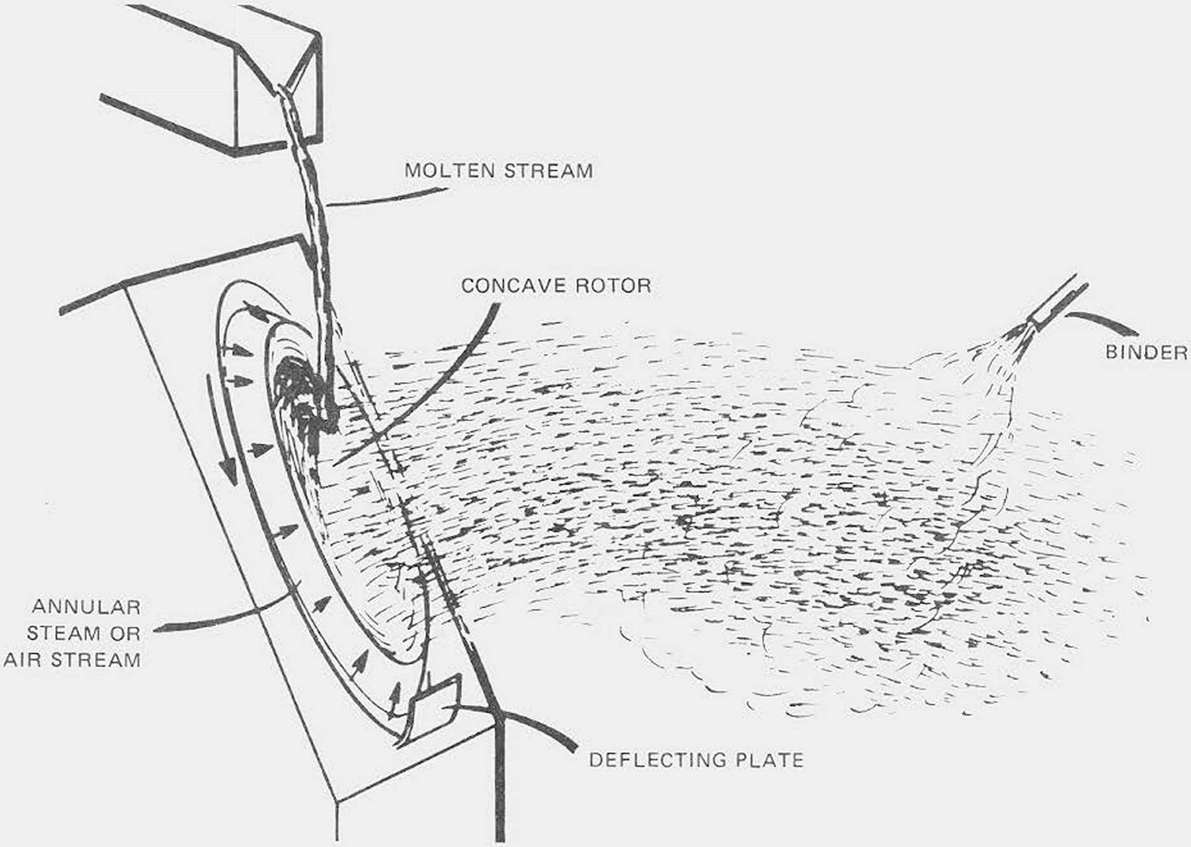
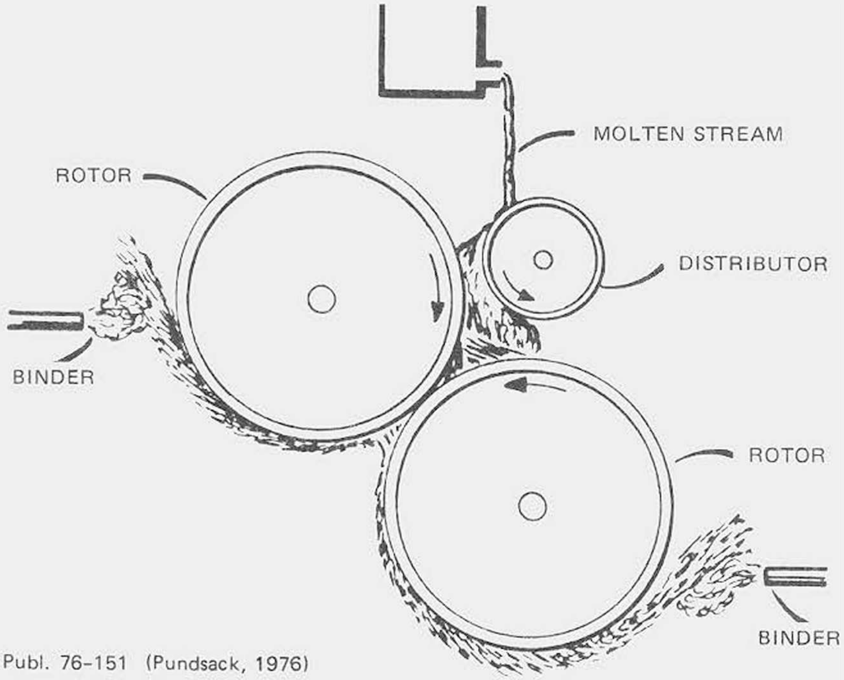


Figure 4. Downey process



SOURCE: NIOSH Publ. 76-151 (Pundsack, 1976)

Figure 5. Powell process

appropriate thickness of fibrous mat for the desired product. The mat is compressed to the appropriate density and then passed through a "curing oven" where the binder is baked. A cooling section (with down-draft air) follows. The continuous mat is then cut longitudinally and transversely to the desired size.

Those products that are to be used without additional covering (such as high-density equipment insulation and some residential insulation batts) are packed for shipment. Other products require further covering, for example, residential structural insulation is often covered with a vapor barrier (e.g., Kraft paper treated with asphalt or aluminum foil) on one side and untreated paper on the other side. For industrial insulation (e.g., boilers), a wire mesh covering is often desirable. In the former case, the vapor barrier and paper covering is done continuously after longitudinal splitting of the mat, but before transverse cutting. In the latter case, the wire mesh may be applied to cut blankets and batts by hand, after they are cut to size. A process flow diagram for a typical mineral wool plant producing both batts (with vapor barrier) and wool is shown in Figure 6.

Although technical innovations in the century-old cupola slag-melting process have been reported, their adoption has been slow.

In some plants, the use of electric arc furnaces has been reported. However, substantial technical difficulties are associated with more wide-spread usage of these furnaces, although such usage would reduce the air pollution problems associated with cupola operation. In particular, refractory furnace linings suitable to resist the aggressive action of molten slag must be commercially developed (Cobble and Hansen, 1974). Suggestions have been made that commercial quality mineral wool might be produced from incinerator residues (Goode et al., 1972), recycled container glass (Abrahams, 1972), coal ash (Humphreys and Lawrence, 1970; Office of Coal Research, 1975), and natural basalt rock (Raff, 1974). This last suggestion has apparent merit as major basalt fiber production plants are now in operation in the U.S.S.R. However, the use of raw fiber-forming materials other than smelter or blast furnace slag is unlikely to become commercially viable soon because of the difficulties in controlling the quality of raw materials and the costs of transporting basalt to current plants.

Mineral Wool Use

Mineral wool is widely used in structural and industrial insulation products, as well as in cements, mortars, ceiling tiles, and other products where its characteristics of thermal and structural stability are desirable. The products in which mineral wool is used include:

- "Blowing" wool and "pouring" wool, loose bagged wool (either granulated or not) that can be blown by pneumatic blowers or poured by hand into residential or commercial building structural spaces.
- Batts and blankets, relatively loose and light (low density) material shaped to fit between structural members of residential or commercial buildings.

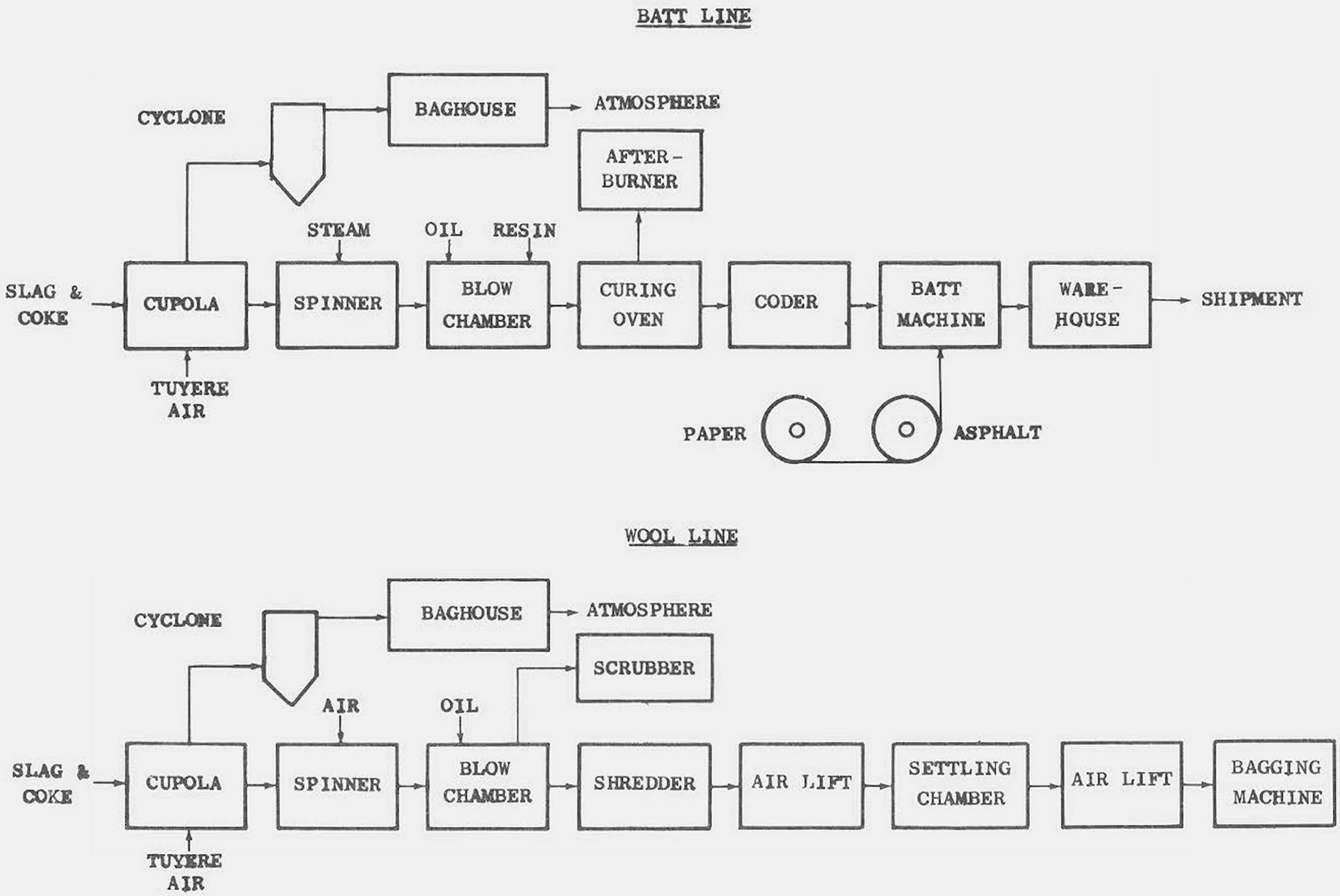


Figure 6. Typical mineral wool plant process flow diagram

- Bulk fiber, produced for cement, mortar, or ceiling tile producers, who add the fiber to their product to impart structural strength and qualities of fire resistance and thermal and sound insulation.
- Industrial and commercial insulation products for covering pipes, ducts, boilers and other equipment. High density material with significant amounts of binder added.

Transportation costs are a signficant fraction of the costs of insulation products; to reduce these costs, the industry has become highly regionalized. The most directly competitive product is fibrous glass. Because of its greater density, mineral wool is a more effective sound insulator than fibrous glass, and is thus often specified in industrial applications. However, this greater density can be a drawback in the insulation of residential and commercial structures, particularly where framing is light and the required thermal insulation effectiveness is high. In addition, the "shot" found in mineral wool (but not in fibrous glass) makes it "dirtier" to install and thus less desirable in some applications.

As can be seen in Figure 7 and Table 1, fibrous glass has steadily increased its share of the total insulation market over the past 30 years. If the insulation market is examined in detail, as was done for 1973 in Table 2 (Arthur D. Little, 1976)*, it can be seen that the most probable future market for mineral wool is in the industrial sector, with relatively limited usage in residential and commercial products. In general, the residential and commercial market fraction for mineral wool is continuing to decline, with strength only in those regions where it has marked economic advantages over fibrous glass. This trend is expected to continue, with mineral wool consolidating its position in the industrial market and gradually relinquishing part of its present share of the commercial and residential insulation market. It may be expected that mineral wool will find increasing use as a substitute for asbestos, as asbestos is "phased out" of some industrial thermal insulation products because of its known adverse health effects. Thus, it may be expected that those workers who have been exposed to asbestos in the past may in the future be exposed to mineral wool fibers.

One aspect of the potential problem associated with the human exposure to this material has been an increasing demand for small fiber diameter. Figure 8 shows the effect on bulk thermal conductivity (the inverse of insulation effectiveness) of fiber diameter in these products. Because of the costs associated with attaining smaller fiber diameters, most U.S. commercial products, particularly those used in home insulation, have a median fiber diameter near 4-5 μm. In Europe, however, and particularly in the Soviet Union, mineral wool fibers are being commercially produced with median fiber diameters $<1\mu$m (SRI, 1976). Some interest has been expressed in these processes by U.S. producers.

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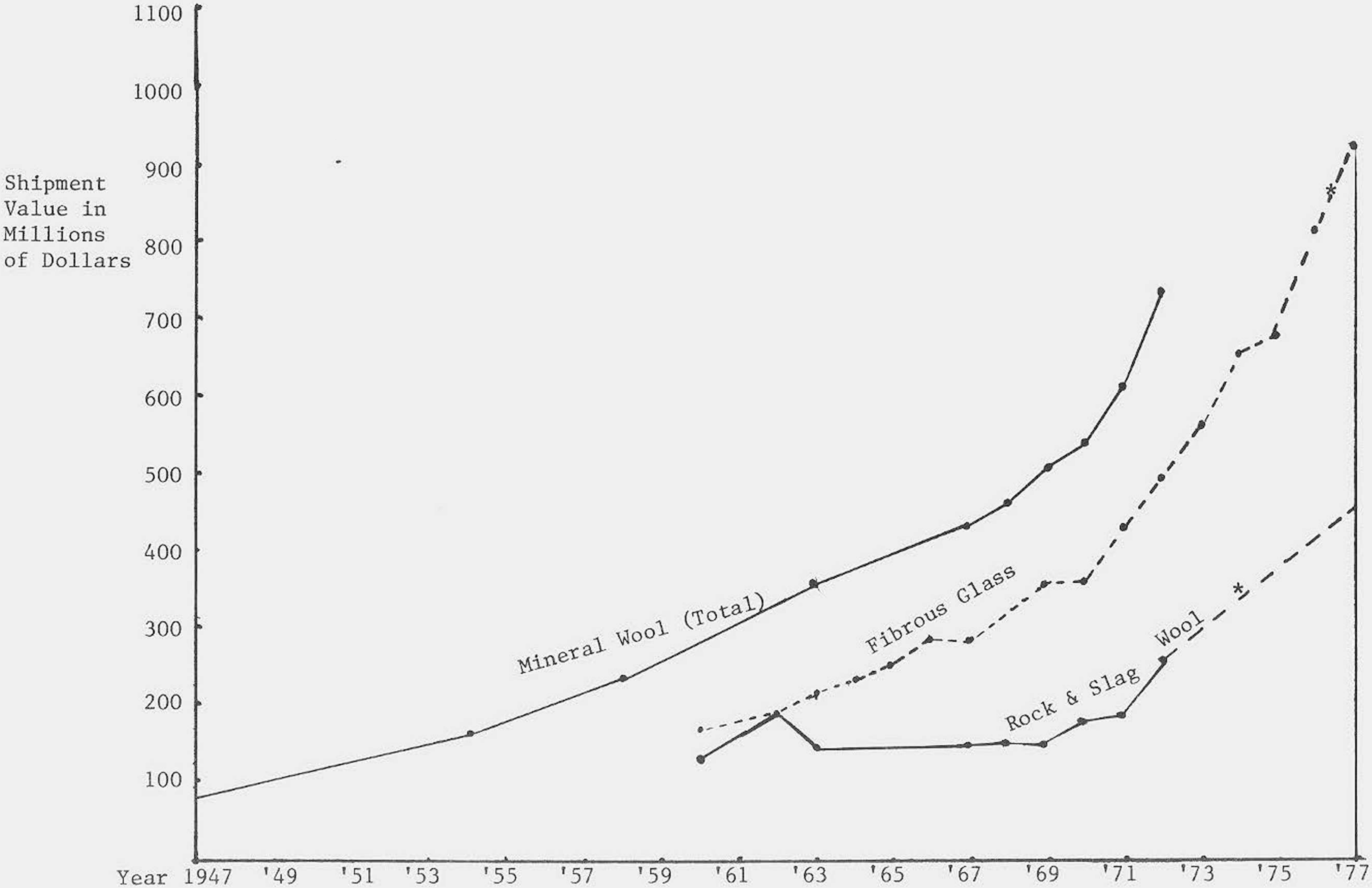
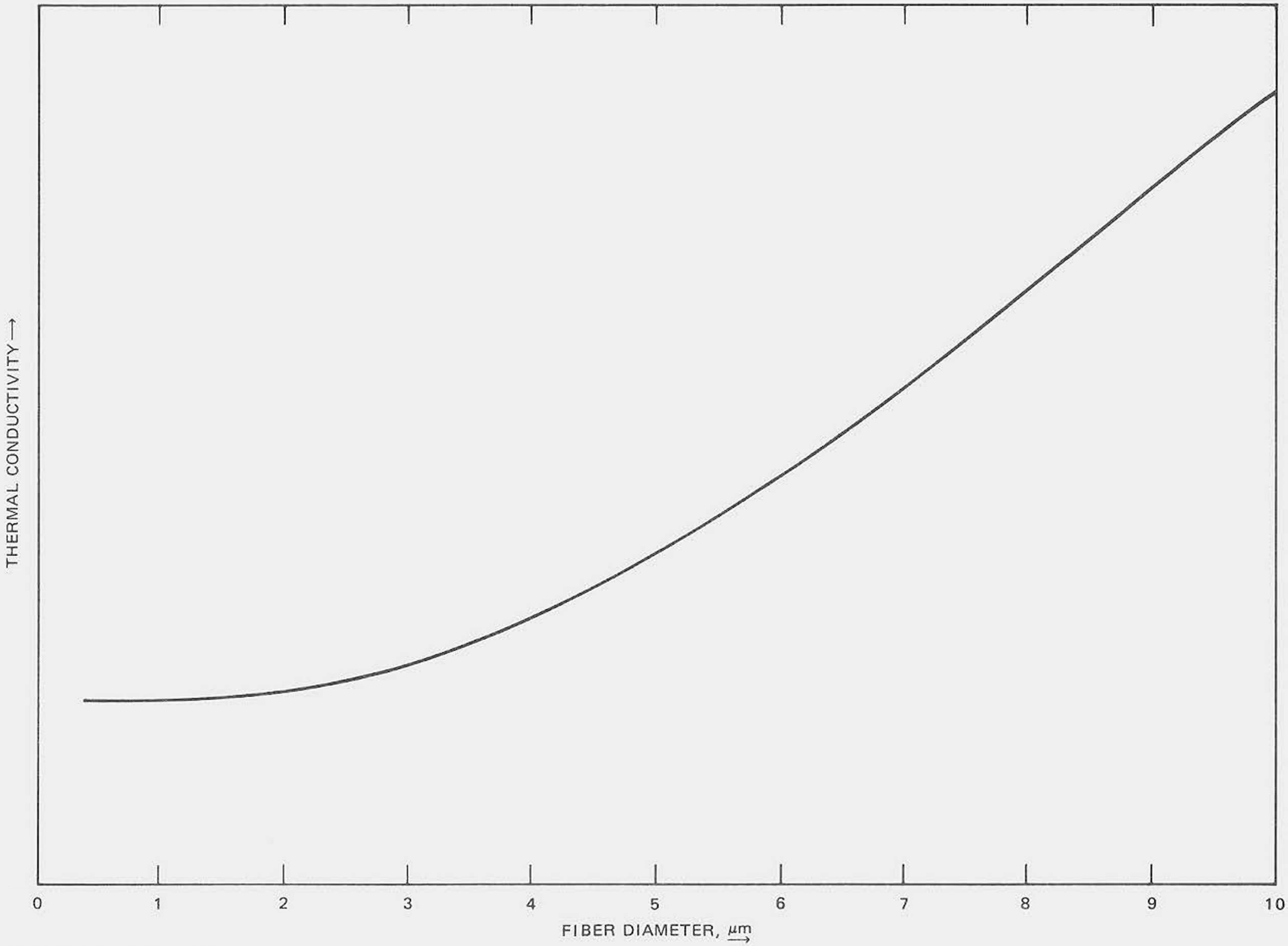
*Tables 1 and 2 do not agree because of differing assumptions used in their construction. The value of mineral wool production and use is uncertain.



From Table I: Data derived from Bureau of Census

*SRI Estimates

Figure 7. Value of shipments, amorphous mineral fiber insulation materials, 1947-1976



SOURCE: Pundsack, 1976

Figure 8. Thermal conductivity as a function of fiber diameter

Table 1. Shipments of mineral wool, 1947-1976*

Year	Mineral wool†		Fibrous glass‡		Rock wool and slag wool§		
	Quantity#	Value**	Quantity#	Value**	Quantity#	Value**	Price††
1947		79					
1954		160					
1958		236					
1959		(286)‡‡					
1960		(284)	674	163		121	0.06
1961		(322)					
1962		(369)	873	187		182	0.06
1963		356	972	213		143	0.06
1964		(367)	938	226		141	0.06
1965		(398)	1046	250		148	0.06
1966		(431)	1076	282		149	0.07
1967		425	1039	179		146	0.07
1968		461	1124	312		149	0.08
1969		504	1203	355		149	0.08
1970		533	1186	356		177	0.08
1971		606	1517	425		181	0.08
1972		739	1738	487		252	0.08
1973			1904	558			0.08
1974			1944	650			0.09
1975			1675	676			0.11
1976			1992	817			0.11

* Includes all amorphous mineral insulation fiber; does not include textile fibers (±15%).
† From 1967 and 1972 Census of Manufacturers--SIC 3296 Mineral Wool (includes rock wool, slag wool and glass wool used for structural, industrial and equipment insulation).
‡ From Current Industrial Reports MA-32J(76)-1, Fibrous Glass (June, 1977), includes insulation fibers, but not textile fibers.
§ Derived by subtracting value of fibrous glass from that of mineral wool.
\# Millions of pounds.
** Millions of dollars.
†† Dollars per pound.
‡‡ Estimated by SRI

Source: U.S. Department of Commerce, Bureau of Census.

PRIOR STUDIES OF OCCUPATIONAL EXPOSURES

Human exposures to mineral wool fibers have been examined only in a few studies. In the first of these, by Carpenter and Spolyar (1945), dust concentrations in a mineral wool production plant were measured by Greenburg-Smith impingers in 1934. The dust counts so measured ranged from 12-26 million particles per cubic foot (mppcf) with limited dust control equipment installed. When more effective controls had been installed, a resurvey by the same investigators found dust concentrations of 5-10 mppcf.

In 1962, Sheinbaum reported the preliminary results of surveys in the building trades, including the application of "asbestos-rockwool cement" as a

Table 2. Sales of mineral fiber insulation materials, 1973 (millions of dollars)

	Fibrous glass	Mineral wool
Residential and commercial insulation products		*
Structural	310	--
Rigid board	50	--
Pipe and duct insulation	50	10
Subtotal	410	10
Industrial and other		
Pipe and duct insulation	70	30
OEM	55	--
Ceiling panels	25	130
Subtotal	150	160
TOTAL	560	170

* Quantity greater than zero.

Source: ADL, 1976

fireproofing and sound insulation agent. He found "extremely dusty conditions," with average breathing zone impinger dust counts "about 200 mppcf."

Both of the above studies share a major disadvantage--the method of measurement does not differentiate between mineral wool fibers and general particulate material. Thus, it is difficult to ascertain how much of the inhalation burden imposed upon the workers in these operations resulted from mineral wool fibers and how much resulted from other material. Total particulate mass concentrations and fiber size were not determined in the above studies.

In 1976, Corn et al. published the results of extensive industrial hygiene surveys in two mineral wool production plants. With the use of personal sampling pumps, measurements were made of total suspended particulate matter concentrations and of fiber concentrations. The latter analysis was performed with optical and electron microscopy, and the sizes of the fibers observed were determined.

In Plant A, ceiling and wall panels and tiles containing about 50% fiber were produced. Optically visible ($\gtrsim 1$ μm diameter) total fiber concentration ranges were 0.2-1.4 fibers/cm^3; electron microscopically visible ($\lesssim 1$ μm diameter) total fiber concentrations ranged from 0.0056-0.16 fibers/cm^3. Total suspended particulate material levels were 0.53-23.64 mg/m^3.

In Plant B, where specialized thermal insulation materials were produced, total suspended particulate matter levels were 0.045-6.88 mg/m^3. Fibers $\gtrsim 1$ μm (diameter) were found in concentrations from 0.11-0.43 fibers/cm^3. The concentrations of those fibers less than 1 μm diameter were 0.0059-0.089 fibers/cm^3.

In both plants, the fraction of respirable fibers (less than 3 μm diameter) was approximately 75%. The total airborne dust concentration (mg/m^3) was found to be a poor indicator of airborne fiber ($fibers/cm^3$) concentration.

Recent European studies were discussed at a Workshop in Copenhagen (JEMRB, 1976). It was stated in the discussion of those studies that the "... concentrations of fibers in the respirable range encountered in the production industry vary between averages of about 0.03 and 0.2 fibers/ml" (Hill, 1977).

The National Institute for Occupational Safety and Health has engaged in several additional studies that are now being presented. This report presents one such study, and a NIOSH report on one ceiling title production plant has recently been presented, with information on an epidemiologic study of the workers at that plant (Ness, 1977).

HEALTH EFFECTS OF MINERAL FIBER EXPOSURE

The health effects attributable to mineral fibers have been the subject of major international conferences in the past 10 years (New York, 1964; Dresden, 1968; Lyon, 1972). Other conferences such as the Johannesburg conference in 1969 and the ILO Helsinki conference in 1971 have also devoted substantial portions of time to the same and associated topics.

The majority of these reports, however, deal with only one category of mineral fibers, asbestos. [We will set aside, for the moment, Harington's (1975) objection to the use of "mineral fiber" as a generic term to include the amorphous man-made fibers.] Little attention has been paid to the health effects of other mineral fibers with the exception of limited work on fibrous glass.

Health Effects of Asbestos

Cancer--

The most serious potential consequence of mineral fiber exposure is the development of cancer. An increased incidence of the following tumors has been associated with human exposure to asbestos:

Tumor	Selected Epidemiologic Evidence
Lung Cancer	(Doll, 1955; Knox, 1968; Selikoff, 1973)
Mesothelioma (Pleural & Peritoneal)	(McEwen, 1970; Bohlig, 1973; Newhouse, 1973)
G.I. Cancer	(Selikoff, 1973)
Laryngeal Cancer	(Stell, 1973; Newhouse and Berry, 1973)

Fibrotic Lung Disease (Asbestosis)--

There is no need for further documentation of asbestosis in humans; such documentation exists in scores of studies. Although the attack rates have varied from study to study (and for type of asbestos fiber), it is clear that inhalation of any form of asbestos will, given sufficient doses, lead inevitably to asbestosis in a significant fraction of the exposed population. The universality of the response can be seen in the table on pages 364-365 of Harington's (1975) review.

Health Effects of Fibrous Glass

The only exposure-specific population studies that have been carried out on the consequences of exposure to mineral fiber other than asbestos have been on fibrous glass. The studies (Wright, 1968; Nasr, 1971; Utidjian, 1970; Gross, 1971) did not address the question of malignancy. They concluded from pulmonary function (Utidjian), radiographic (Wright and Nasr), and post-mortem (Gross) studies that there were no significant effects from occupational exposure to fibrous glass. A discussion of these studies was presented in an article by Dement (1975). A study by Enterline (1975) examined the mortality experience of a cohort of 416 men who retired during the period 1945-1972 from six fibrous-glass manufacturing plants. Enterline found "no evidence of an excess in respiratory cancer mortality. No mesotheliomas were noted." For 115 of the men, the stated retirement cause was disability. Comparing this with the expected distribution, Enterline found "... no evidence of any unusual health hazards, with the exception of a possible excess in chronic bronchitis".

These and other studies were reviewed in-depth in the preparation of the NIOSH Criteria Document on Fibrous Glass (NIOSH, 1977). Upon consideration of human health studies and animal tests, NIOSH concluded that two categories of fibrous glass could be defined--those fibers larger than 3.5 micrometers (μm) diameter and those less than 3.5 μm. For the former, it was concluded:

> The primary health effects associated with the larger diameter fibers involve skin, eye, and upper respiratory tract irritation, a relatively low incidence of fibrotic (lung) changes, and preliminary indication of a slight excess mortality risk due to non-malignant respiratory diseases. In this regard, NIOSH considers the health hazard potential of fibrous glass to be greater than that of nuisance dust, but less than that of coal dust or quartz.

The Criteria Document goes on to address the potential problems associated with small diameter fibers. The laboratory animal implantation studies of Stanton (1972, 1977) were examined and it was concluded that these results could not be extrapolated directly to conditions of human exposure. The document continued:

> On the basis of currently available information, NIOSH does not consider fibrous glass to be a substance that produces cancers as a result of occupational exposure. However, these smaller fibers can penetrate more deeply into the lungs than larger fibers and until more definitive information is available, the possibility of potentially hazardous effects warrants special consideration.

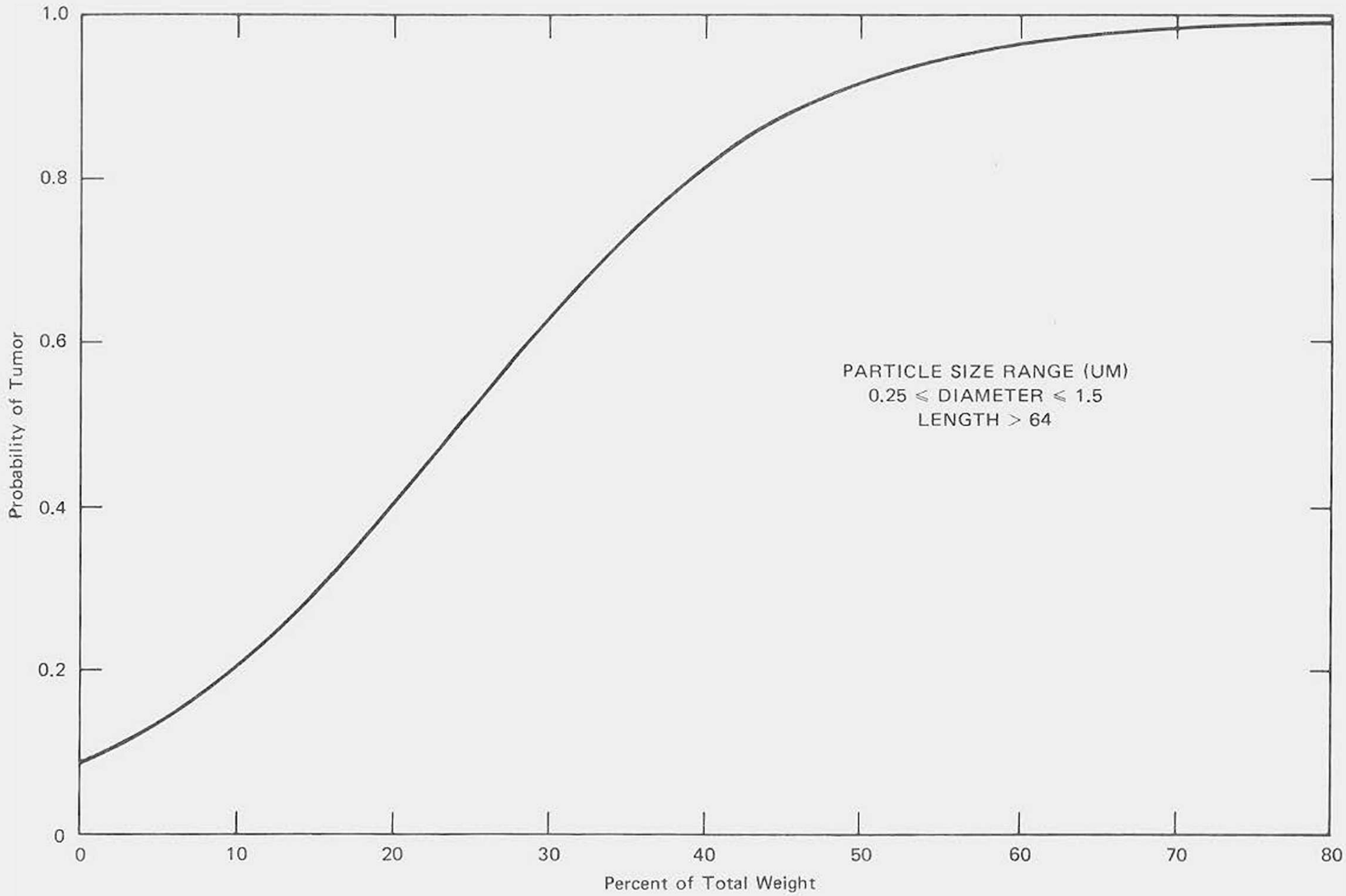
On the basis of these considerations, NIOSH recommended an environmental (workplace air) concentration limit of 3 fibers/cm^3, determined as a time-weighted average concentration for up to a 10-hour work shift in a 40-hour work week. Only those fibers with a diameter less than or equal to 3.5 μm and a length equal to or greater than 10 μm are covered by the recommended limit. Additional recommendations involve medical examinations and record keeping.

Health Effects of Mineral Wool

It has been assumed previously that fibrous glass and rock (or slag) wool could be appropriately grouped together in a discussion of the health effects of mineral fibers. No reported studies of those exposed only to rock wool or slag wool are known, although Enterline is currently carrying out such a study, sponsored by the Thermal Insulation Manufacturers Association (TIMA), as is NIOSH (Ness, 1977). No firm evidence exists from which the health effects of rock wool or slag wool can be predicted. The evidence most clearly indicating potential exposure risks associated with mineral wool is the work of Stanton et al. (1972, 1977), Kuschner and Wright (1976), Pott et al. (1976) and Davis (1972). In these laboratory studies, it has been found that long ($\gtrsim$ 10 μm), thin ($\lesssim$ 1 μm) fibers have greater biological potency (tumorigenicity, fibrogenicity) than shorter or thicker fibers, regardless of the chemical composition of the fibers. This indicates that these long, thin fibers are probably of greatest concern in human exposures to mineral wool. Figure 9 is an adaptation of some of Stanton's data, showing the effect of increasing the fraction of long, thin fibers in implanted fibers on the probability of tumor response in animals (Stanton, 1977).

Comparability of Results for Other Fibers: Extrapolation to Mineral Wool

There is convincing epidemiological and case report evidence that asbestos, upon inhalation, is fibrogenic and carcinogenic in man. Fortunately, no such convincing human evidence exists for other mineral fibers. It is difficult to extrapolate from the results for asbestos to predict human health effects from exposure to mineral wool. The work that has been done with fibrous glass is more directly applicable, but there are still many areas of uncertainty. The NIOSH decision (in regard to the recommended environmental standard for fibrous glass) that "... until more information is available, the recommended standard can also be applied to other man-made mineral fibers..." seems appropriate with respect to mineral wool. The two recent NIOSH publications (1976, 1977) dealing with fibrous glass are recommended as background reading on the health effects of mineral wool, as are the Copenhagen Workshop Proceedings (JEMRB, 1977).



*Adapted from Stanton, 1977.

Figure 9. Probability of tumor versus percent of implanted particles in size range*

METHODS OF STUDY

IDENTIFICATION AND SELECTION OF FACILITIES FOR STUDY

The goal of this task was to select 10 facilities for study, to include five mineral wool producers and five mineral wool users.

The criteria for selection of the 10 facilities were:

- Representativeness of current industry-wide operations.
- Fiber size produced or used.
- Greatest potential for worker exposure to respirable fibers.
- Number of workers exposed.
- Length of history of production or use of slag wool or rock wool fibers.
- Availability of historical work practices and exposure levels and previous industrial hygiene surveys.
- Representativeness of probable future industry-wide operations.
- Potential for future worker exposures to respirable fibers.
- Extremes of environmental control technology applied (e.g., best case and worst case).
- Willingness to cooperate with the survey.

Selection of Producers

Twenty-five major production facilities for rock wool or slag wool in the United States were identified. Each of these was examined for inclusion in the study based upon the criteria above.

Representativeness of Current Industry-Wide Operations--
Three variables were judged to be most important in selecting currently representative plants.

- Production processes
- Raw materials used
- Material produced.

Three major sources of current information were available to aid in the selection (Esmen, 1976; Matthews, 1976; and Schneider, 1975). From these sources, it was concluded that the major differences in production processes were between centrifugation with air or steam attenuation (see Figure 4) and the "dry spinning" process shown in Figure 5. The former is far more widely used than the latter; accordingly, four of the selected plants used the former method of fiberization and only one was selected in which "dry spinning" was used.

Potentially significant differences do exist in the raw materials used, and thus in potential exposures to trace elements. A typical plant uses a mixture of steel mill slag and natural rock. The raw materials identified include:

- Slag:
  - Steel mill
  - Lead smelter
  - Copper smelter
  - Iron smelter
- Phosphate ore
- Clay
- High silica rock
- Lime
- River gravel
- Natural rock

Three of the selected plants use steel mill slag as the basic raw material, with the admixture of a small amount of various rocks and other slags; one uses iron smelter slag and the third uses steel mill slag with the addition of significant amounts of lead smelter slag.

Fiber Size--
We did not identify any facilities that produce "fine fiber" (mean diameter ca. 1.0 μm). The overwhelming majority of current production is of fibers with stated mean diameters around 7 um. The range of fiber sizes is broad, and there is an appreciable proportion of larger and smaller fibers in almost all products, including "respirable" fibers (<3.5 μm diam). Accordingly, this criterion was not specifically applied in selection.

Potential for Worker Exposure to Respirable Fibers--
Although there is a broad range of housekeeping practices in this industry, exposures to airborne fibers appeared to be similar from plant to plant, based upon industry information (Esmen, 1976). Esmen stated that there were no major differences in the proportions (or absolute quantities) of respirable fibers in the production plants.

Number of Workers Exposed--
Facilities with as few as 25 and as many as 150 mineral wool production workers were identified. The plants surveyed ranged from 25-100 production employees. Two of the surveyed plants had 80-100 employees.

Length of History of Production--
All plants ranged in age from 6 to ~50 years; the selected facilities ranged from 7 to ~50 years in age.

Availability of Historical Work Practices and Exposure Levels--
Work practices histories were available from many of those plants contacted. Exposure levels in the past were (and are) essentially unknown, except for the recent Calspan and Corn studies. Plants selected for this study included some

of those studied previously by Calspan for NIOSH and by Corn for TIMA. Three of the five plants produced residential/commercial insulation, which was the most abundant product in the past.

Representativeness of Probable Future Industry-Wide Operations--
As shown in Section 2, the mineral wool industry will probably be more heavily concentrated in industrial insulation than is currently true. Four of the plants produced fibers for use in industrial insulation.

Extremes of Environmental Control Technology Used--
One of the plants surveyed had recently made major investments in engineering measures for occupational exposure control; another was planning such measures in the near future, but had not yet implemented them. Others were operating at varying levels of control effectiveness.

Willingness to Cooperate with the Study--
Approximately one-half of all plants contacted were willing to cooperate with the study. It was concluded that those plants not willing to cooperate did not differ in any substantial way from those that were cooperative, as judged by production processes and products. No consistent bias either in products or in processes was observed.

Selection of Users

Thousands of companies deal with mineral wool in the United States. Many of these purchase fabricated products at wholesale and sell them at retail without repackaging and without substantial opportunity for occupational exposure. Others purchase bulk wool and fabricate consumer products, with substantial opportunity for exposure. Still others produce mineral wool and fabricate it into products, using their entire mineral wool output captively. Other users (e.g., insulation contractors) install mineral wool products (batts, blankets, loose wool, insulating cements, etc.) with potential for exposure.

Representativeness of Current Industry-Wide Operations--
As shown in Table 2, the major uses of mineral wool are in industrial insulation, with the majority of the wool going into ceiling panels. One user selected was a manufacturer of ceiling panels; another was a manufacturer of industrial insulation blankets. A third user installed industrial insulation blankets.

Fiber Size--
No extremes of fiber size usage were found; the production of a relatively modest range of mean diameters is responsible for this.

Greatest Potential for Worker Exposure to Respirable Fibers--
Based upon past experience with asbestos and consideration of basic physical principles, the operations judged most likely to cause high exposures to respirable fibers were those in which the wool was purposely aerosolized. Two contractors "blowing" wool into old and new homes were studied, as was a contractor applying sprayed fire proofing.

Number of Workers Exposed--
This information was not generally available for mineral wool products. Residential insulation products and ceiling tiles are in widespread use by many small contractors. It is thus probable that the greatest numbers of workers are exposed to these products.

Length of History of Use of Mineral Wool--
The oldest uses of mineral wool have been as thermal insulation in structures and in industrial applications. The selected user facilities are all examples of these uses. One of the insulation contractors had been applying mineral wool by essentially similar methods since 1931. The fabricator of industrial insulation had been making similar products for at least 30 years.

Availability of Historical Work Practices and Exposure Levels--
Exposure level information was generally not available prior to the surveys. In particular, exposure level measurement by microscopic fiber-counting methods had not usually been performed in this industry in the past. The work practices involved in the installation of blowing wool and industrial insulation have not changed substantially since the mid-1930s. Consequently, the workers in these two user industries in the past were probably exposed to levels very similar to the present levels.

Representativeness of Probable Future Industry-Wide Operations--
The future of mineral wool usage appears to be principally in industrial insulation and ceiling tiles. Three of the selected users were representative of these uses.

Potential for Future Workers' Exposures to Respirable Fibers--
In the future, as in the past and currently, the greatest potential for respirable fiber exposure will exist where fibers are purposely aerosolized (sprayed or blown). Three examples of these uses were selected for surveys.

Extremes of Environmental Control Technology Used--
The users surveyed included those with fixed "production-line" operations where engineering controls were installed and used and those where field installations in difficult surroundings prohibited use of conventional controls.

Willingness to Cooperate with the Study--
Among the users, as among the mineral wool producers, relatively good cooperation was found. Approximately half of those contacted were willing to permit a survey without protracted negotiations. No consistent biases among those refusing permission were seen. That is, no common factors of size, age, or use could be identified.

Field Studies and Analysis

All surveys were performed in conformity with 42 CFR Part 85a "Occupational Safety and Health Investigations of Places of Employment." The surveys were intended to give the following information:

- A description and documentation of the processes involved in the production or use of mineral wool and the occupational environment at each facility, giving specific attention to worker exposure to airborne mineral wool fibers.

- Eight-hour time-weighted-average (TWA) airborne mineral fiber concentration exposures (in fibers/ml) of all production and maintenance personnel.
- Eight-hour TWA total suspended particulate (TSP) concentration exposures (in mg/m^3) of all production and maintenance personnel.
- Eight-hour TWA respirable airborne particulate concentration exposures (in mg/m^3) of employees in each production process or job category (10% of employees).
- Eight-hour TWA concentration exposures to total airborne concentrations of the elements: cadmium (Cd), chromium (Cr), cobalt (Co), nickel (Ni), manganese (Mn), lead (Pb), zinc (Zn), in $\mu g/m^3$.
- Sizes of fibers to which workers are exposed.
- Fiber size and elemental composition of all mineral fibers and fiber-containing materials produced or used at the facility (including materials produced or used in past years).
- The identification of exposures to other potentially toxic materials in the workplaces surveyed, with sample collection and analysis as required to identify those exposures.
- The survey and evaluation of environmental engineering control measures (such as ventilation systems) and personal protective devices (such as respiratory protection) in use at the facility, including an evaluation of the actual extent of use and effectiveness of those measures or devices.

Field Survey Procedures

Air samples were taken to evaluate worker exposure to airborne mineral fibers, total airborne particulate matter, respirable particulate matter, and trace metals (Cd, Cr, Co, Ni, Mn, Pb, Zn). Bulk samples of raw materials, intermediate products, and final products were also collected for the determination of fiber size and trace element concentrations. The sampling/analysis matrix is shown in Figure 10.

Detector tube samples to determine approximate concentrations of several potentially toxic gases were taken at selected locations. Carbon monoxide measurements were made using an "Ecolyzer" direct reading instrument in some cases. Limited noise surveys were performed, as were limited ventilation surveys and heat stress evaluations.

Survey Equipment--

- Bendix BDX-44, portable battery-powered air sampling pumps.
- MSA Model G, portable battery-operated air sampling pumps.
- Bendix 10 mm (Dorr-Oliver type) nylon cyclone preselectors.
- Millipore type AA (0.8 um mean pore size) 37mm diameter mixed cellulose ester membrane filters.

			SAMPLES			
			BULK MATERIAL	AIR		
				TOTAL SUSPENDED PARTICULATE	RESPIRABLE PARTICULATE	FIBER COUNTS
SAMPLING		MEDIUM		PVC FILTER 37mm. 5.0μm	PVC FILTER 37mm. 5.0μm	MF FILTER 37mm. 0.8μm
		ACCESSORIES			10mm NYLON CYCLONE	
ANALYSIS	OPTICAL MICROSCOPY (Phase Contrast 400X)	FIBER COUNT				X
		FIBER DIAMETER	X			
		LENGTH & DIAMETER				X
	SEM	FIBER COUNT				X
		LENGTH & DIAMETER				X
		MICROPROBE	X			
	X-RAY FLUORESCENCE		X			
	ATOMIC ABSORPTION		X	X		
	WEIGHT			X	X	

Figure 10. Sampling and analytical methods: industrial hygiene surveys

- Gelman type VM-1 (5.0 um mean pore size) 37mm diameter polyvinyl chloride membrane filters.
- Millipore 2-piece and 3-piece polystyrene filter holders.
- 'Ecolyzer' carbon monoxide monitor.
- Alnor "Jr. Velometer."
- Alnor Thermoanemometer.
- MSA and Dräger detector tubes and pumps.
- Botsball.
- Sling psychrometer.
- General Radio 1565-B Sound Level Meter.

Calibration--
The rotameters on each pump were calibrated in Menlo Park before the survey with the use of a "bubble-meter" (timing passage of a soap bubble through a 500 ml burette). The calibration was performed with a Millipore AA filter in line and with a tube of the same length (30") and inside diameter (1/4") as that used for field sampling. No differences in rotameter calibration were found when a polyvinyl chloride (PVC) (Gelman VM-1) filter with significantly lower flow resistance was placed in line, in place of the Millipore AA filter. This calibration was repeated at the survey sites to check for changes resulting from shipping damage and to verify calculated corrections for altitude (Treaftis, 1976). The rotameter scales were marked at 1.5, 1.7, 1.8, 2.0, and 2.2 liters per minute.

The calibration of each pump rotameter was assumed to be accurate until erratic pump behavior (e.g., "jumping" float, marked decrease or increase in indicated flow, etc.) indicated the need for repair or maintenance. The calibration was repeated after each such event, and the rotameter scale remarked to indicate any change in calibration. Use of calibration charts has not been effective with the Bendix pumps because breakdowns are relatively frequent, with consequent frequent changes in calibrations.

The General Radio 1565-B Sound Level Meter was calibrated with a GR 1562-A Sound Level Calibrator. Calibration of the Ecolyzer was done with CO "span gas," at 100 ppm.

Air Sampling--
Personal air samples were taken in the breathing zones of all workers exposed to mineral wool. The sampling effort was intended to characterize peak and time-weighted-average (TWA) exposures to mineral wool fibers, total suspended particulate material (TSP), respirable particulate (RP) material, and the seven listed trace metals, for all job categories. Area (general environment) samples were also taken in some locations. These samples were taken to evaluate the potential exposures of workers not sampled, such as clerical and supervisory workers.

Filters used were 37mm diameter Millipore Type AA (0.8 μm mean pore size, mixed cellulose ester) for fiber counting and 37mm Gelman VM-1 (5.0 μm mean pore size, PVC) for total and respirable particulate matter sampling.

Preparation of the filters and holders is discussed under Analytical Procedures, below. Two pumps and filters were used on each worker. In most cases, one of these was for fiber counting and one for total particulate matter. For approximately 10% of the workers, total and respirable particulate matter samples were taken. Bendix cyclones (10mm Dorr-Oliver nylon type) were used as preselectors before the filter for the respirable samples.

The calibrated pumps were run for 15-20 minutes (without a filter in place) after the battery charger was disconnected to stabilize flow rates before setting the desired flow rates. The filter units (Millipore or Gelman in 3-piece Millipore filter holders or Gelman in 2-piece holder inserted in the cyclone assembly) were attached to the pumps, and the initial flow rate (1.7 liters per minute for respirable; 2.0 liters per minute for all others) was set, with the use of the calibrated pump rotameter scale. The filter was then recapped, and the pump/filter unit taken into the sampling area.

The pair of air sampling filters were clipped to the collar of the worker's shirt or jacket, one on each side, as close as possible to his or her breathing zone, without interfering with work or comfort.

The filter faces were directed generally downward, where possible. In some cases, where there was possible direct contamination of the filters by very large and definitely nonrespirable (>1mm diameter) particles ejected from the process under investigation, the filters were shielded by a shroud over the entire cassette (AIHA-ACGIH, 1975). The approximate inlet velocity for the open faced filters was 7.7 feet per minute (fpm), and the inlet velocity for the TSP samples was 522 fpm. The pair of pumps was clipped to the worker's belt and the pumps started after the removal of the small end plug of the TSP filters and the cover section of the fiber-counting filters. The flow rate was rechecked, and the relevant data (worker, area, place, job, date, time, flow rates, sample numbers) for the pair of samples was recorded on an air sample record sheet.

The flow rates were checked at intervals throughout the sampling period, as were the appearances of the filters. The total sampling periods for each worker were typically 6-7 hours, beginning shortly after the start of a shift and continuing until shortly before the end of the shift. The TSP and RP filter samples were usually left throughout the sampling period to accumulate as heavy loading as possible for the gravimetric and trace metal measurements. The fiber counting filters were usually changed at about midpoint of the shift, or as needed to prevent obscuration of the collected fibers by other particulate material.

The samples being taken were monitored at intervals throughout the sampling period, and air flow rates were adjusted back to the initial values when necessary. The time of each such adjustment was recorded on the air sample record sheet as were the "old" and "new" (adjusted) flow rates. At the end of the sampling period, the filters were recapped and stored for shipment to the laboratory.

Bulk Samples--
In addition to the bulk samples of produced or used material taken at the survey sites, an effort was made to obtain samples of "old" mineral wool products produced in past years. For each sample obtained, the approximate date of production or installation was determined by interviewing the producer or installer and from any evidence at the site of installation, such as an installation record card. In some cases, the date of installation in buildings was determined by interviewing the current owner or tenant.

Analytical Procedures

Air Sample Analysis--

Filter handling--Each Gelman PVC filter was weighed (±0.01 mg) on a Mettler M-5 balance and then placed into a Millipore filter holder. A cellulose band was shrunk onto the holder, and a unique sample identification number and the initial weight of the filter were then recorded on the holder and in a laboratory record book. The numbered filter holder was then stored until field use.

The Millipore filters in holders (for fiber counting) were used as received from Millipore except for the addition of a cellulose band as described above. One filter from each box of 50 was held as a blank and was examined for contamination by using the optical microscopic technique described below. Upon return of the filters to the laboratory, the Gelman PVC filters were reweighed (±0.01 mg) on the same balance used for the initial weighings. This was the sole analysis applied to the respirable particulate samples. After being weighed, the total suspended particulate samples were analyzed by atomic absorption spectrometry; the Millipore filter samples were prepared for microscopic examination without being weighed.

Atomic absorption--The Gelman PVC filter samples were placed in Teflon beakers to which 5 ml of hydrofluoric acid (HF) were added. The beakers were heated to 110°C on a hot plate and intermittently swirled to ensure complete reaction. The samples were taken to dryness, an additional 5 ml of HF added, and the samples were taken to dryness again. Five ml of nitric acid (HNO_3) were added and the solution was evaporated over a 20-minute period. The residue was dissolved in 3 ml of warm nitric acid and transferred to a graduated centrifuge tube. The filter residue remaining in the beaker was rinsed with successive portions of distilled water. These rinses were added to the centrifuge tube. The total volume was then brought to 7.0 ml. Blank samples consisted of unused filters treated in the same manner as above.

The solutions of solubilized mineral wool and the blank samples were analyzed for zinc, lead, manganese, chromium, cobalt, nickel, and cadmium by atomic absorption spectrometry (see Table 3 for operating parameters). Calibration curves were constructed from calibration standards for each of the seven metals. Absorbance measurements corrected for nonatomic absorption and the blank value were then compared to the appropriate calibration curve to obtain the metal concentration in the sample.

Experiments were carried out to establish the validity of the HF-HNO_3 digestion procedure. A filter and a given amount of a previously-analyzed bulk sample, Premium Brand rock wool, were spiked with 50 µg of each of the metals of

Table 3. Atomic absorption operating parameters

Parameter	Zn	Pb	Mn	Cr	Co	Ni	Cd
Wavelength (nm)	213.9	217.0	279.5	357.9	240.7	232.0	228.8
Spectral band pass (nm)	1.0	1.0	0.2	0.2	0.1	1.0	1.0
Standard working range (ppm)	0.1-2.0	0.1-7.0	0.1-3.0	0.2-8	0.1-1	0.2-2.0	0.05-0.5
Gas mixture	Air/acetylene	A/A	A/A	N_2O/acetylene	A/A	N_2O/acetylene	A/A
Flame stoichiometry	Oxidizing	Ox.	Ox.	Reducing	Ox.	Reducing	Ox.
Interferences	*	*	--	--	*	†	*

* Correction was made for nonatomic absorption by using a hydrogen continuum lamp.

† Correction was made for nonatomic absorption by using 231.7 line.

interest. The samples were digested as described above and absorbances of the seven metals determined. The micrograms of each metal found were corrected for background and compared to the amount spiked. The result was a percent recovery factor for each metal (Table 4) that was applied to the concentration results for each of the personal samples.

Table 4. Correction factors from metal recovery experiments

Mn	1.04
Co	0.930
Zn	0.998
Cd	0.970
Pb	1.11
Cr	1.03
Ni	0.949

Fiber counting and sizing by optical microscopy--The general procedures used for mounting the personal filters and for counting and sizing the fibers are described in detail in the NIOSH manual, Sampling and Evaluation of Airborne Asbestos Dust.‡ The samples were mounted in a dust-free hood. Immediately after the cover slip was put in place, it was tapped lightly with tweezers. Any air that remained entrapped was eliminated by pushing on the cover slip with a pencil eraser.

For counting and sizing, a Leitz Ortholux II Pol-BK microscope with 40X, 0.65 NA phase objective, a 10X Periplan GF eyepiece, and Kohler illumination was

‡ This manual, used in NIOSH Course #582, can be obtained from NIOSH, Division of Training and Manpower Development, 4647 Columbia Parkway, Cincinnati, Ohio 45226.

used. A standard Porton reticle (100L = 64 μm) was placed at the focal point of the eyepiece and used as the counting field area ($4.096 \times 10^{-3} mm^2$). Adjustments for Kohler illumination, alignment of phase contrast rings, and the quantitative calibration of the system were checked periodically. All particles having an aspect ratio of 3:1 or greater were counted. The diameter and length of each such fiber were measured and recorded on a tally sheet, as shown in Figure 11.

The initial accumulation of data was made on a 10-key adding machine, with the use of a three-digit code for diameter, length, and presence or absence of "typical" mineral wool morphology. This method permitted substantial savings of microscopist time and the use of research assistants for the transcription of the data. In addition, the microscopists were able to avoid constant refocusing and reaccommodation of their eyes during the counting process, with reduction of "eye-strain" problems.

Scanning electron microscope (SEM) counting and sizing--A small section (10-20%) of the Millipore filter (from which a segment had previously been cut for optical microscopy) was dissolved in a 1:1 mixture of MEK (methyl ethyl ketone) and methanol. The filter (in a plastic petri dish) was photocopied before and after removal of the section. The photocopy images were cut out from the paper, and weighed. The fraction of the filter dissolved was determined by the ratio of the weights of the whole circular image, the intermediate image, and the final image. The MEK/methanol solution with suspended fibers was filtered through an 0.8 μm (25-mm diameter) Nuclepore filter by using aspiration and rinsed three times with filtered water. The Nuclepore filter was not permitted to run dry between rinses and the rinses were added so that the walls of the filter holder were rinsed also. A section of the Nuclepore filter was then cut out and mounted with silver paint on an aluminum SEM stage.

Before use, all solvents were filtered through a 0.4-μm Nuclepore filter. These treated solvents were used to rinse all glassware, and care was taken to prevent dust contamination during filtration.

A drop of dilute suspension of 0.011-μm (±0.005-μm) polystyrene latex spheres (Duke Scientific Corp.) was added to one corner of the Nuclepore filter and allowed to air-dry.

The Nuclepore filter section was then shadowed with gold/palladium with an approximate grain size of 200 Angstrom units (200 Å) and examined at 2,000X and 10,000X in the SEM (Cambridge Mark II) at 30 KV and a tilt of 10°. The polystyrene latex spheres were also examined at 2,000X and 10,000X and the images recorded on videotape as an internal size standard for each filter.

A nominal 100 fields (97-103) were next examined in a random stepwise orthogonal scanning pattern at 2,000X and the field images recorded on the same videotape.

The videotape images were independently examined on a video monitor by the same microscopist who performed the majority of the optical analyses. Particulate images with an aspect ratio of greater than 3:1 were measured directly (±1 mm) and recorded, following measurement of the polystyrene latex sphere images. The monitor image was distorted (vertical suppression); therefore, several independent vertical and horizontal measurements of the spheres were taken.

FIBER COUNTING AND SIZING

SAMPLE NO. ________________ DATE ________________

MICROSCOPIST ________________ 100L = ________________

DIAMETER BY PORTON CATEGORY	LENGTH BY PORTON CATEGORY						
	≤ 4	4 ≤ 6	6 ≤ 8	8 ≤ 10	10 ≤ 13	> 13	TOTAL
≤ 1							
1 ≤ 2							
2 ≤ 3							
3 ≤ 4							
4 ≤ 5							
5 ≤ 6							
> 6							
TOTAL							

TOTAL FIBERS COUNTED ____________

TOTAL FIELDS COUNTED ____________

COMMENTS:

Figure 11. Fiber measurement tally sheet

A typical vertical measurement was 3.5 mm/μm; a typical horizontal measurement was 4.4 mm/μm.

To maximize the area examined, the total monitor screen area was used as the counting field; this was 26.8 cm by 20.7 cm. The typical filter area covered in each counting field was thus:

$$26.8 \text{ cm} \times \frac{1 \ \mu\text{m}}{0.44 \text{ cm}} \times 20.7 \text{ cm} \times \frac{1 \ \mu\text{m}}{0.35 \text{ cm}} = 3602 \ \mu\text{m}^2 \quad .$$

Using the total screen area presented one potentially serious problem: determining the length of those fibers that protruded into the counting area, but whose entire length could not be seen. It was assumed that the length of such a fiber was 1.5 times its visible length. This assumption was based upon examination of those protruding fibers that were scanned over their total length while moving from one field to the next. That total length averaged approximately 1.5 times the visible length in the field.

Bulk Sample Analysis--
The bulk samples were divided into three portions, for atomic absorption, x-ray fluorescence, and SEM microprobe analyses.

Atomic absorption--With the use of fired ceramic balls, 0.1 g of the bulk material was ball-milled in a plastic container until a homogeneous powder was formed. Digestion and instrumental analysis of the milled powder followed the procedures given above for the analysis of the total suspended particulate air samples on PVC filters.

X-ray fluorescence analysis--With the use of fired ceramic balls, bulk samples were ball-milled overnight in a plastic container. The finely ground powder was sieved through a 200-mesh nylon net and dusted on mylar adhesive tape. The tape (of known surface area) was weighed before and after the sample was placed upon it. The deposit, which was visually uniform, was typically 1 mg/cm^2 (±50%). The tape was then placed in the x-ray spectrometer and irradiated with a G.E. Tungsten Target tube with a molybdenum filter at 40 KV and 30 mA. The secondary x-rays were detected with a Kevex Lithium-drifted silicon detector and were accumulated (for 10 minutes) in a Nuclear Data Multichannel Analyzer.

Scanning electron microscope microprobe analysis--A small (~0.1 g) representative sample of the bulk material was placed in a test tube with ~50 ml distilled water. The test tube was placed in a "sonicator" for 10 minutes, until the solid material was evenly dispersed. The water dispersion was filtered (with aspiration) through a 0.4-μm pore size Nuclepore filter. The filter was air-dried in a dust-free hood, and a section was cut out and attached with silver paint to an aluminum SEM specimen stage.

Analysis was by the EDAX 505 energy-dispersive x-ray probe attached to the Cambridge Mark II scanning electron microscope at 30 KV. An initial SEM scan of the sample was made, and "typical" representatives of the following particle classes were selected:

- Small fibers ($\sim\leq 1$-μm diameter)
- Medium fibers ($\sim$4-5-μm diameter)
- Large fibers ($\sim\geq 10$-μm diameter)
- Shot (nearly spherical particles formed during slag fiberization)
- Variable particles (angular particles typical of the general background particulate contamination in the sample).

CALCULATION AND REPORTING OF RESULTS

Air Sampling Volumetric Flows

Total flows for each of the air samples were calculated from the Air Sample Record Sheets. The sample starting time and starting flows and the intermediate and ending flow/time points were used as known points, and it was assumed that flow rates decreased (or increased) linearly from point to point. The average of the flow rates at each consecutive point was taken as a point estimate of the flow over the interval of time between these two points. As an example, one might take a hypothetical sample that was started at 0800 at 2.0 liters per minute (l pm), was checked at 1000 (and found to be still sampling at 2.0 l pm), had decreased to 1.9 l pm by 1200 (and was readjusted to 2.0 l pm), and fell to 1.8 l pm by 1400, at which time the sampling period ended.

Time	Flow (liters/minute) Old	New	Assumed average flow	Intermediate sampling volume since last point (liters)	Cumulative sampling volume (liters)
0800		2.0		0	0
1000	2.0	2.0	2.0	240	240
1200	1.9	2.0	1.95	234	474
1400	1.8		1.9	228	702

Thus, the total volume sampled for this hypothetical case was 702 liters (0.702 m^3).

Gravimetric Samples

For both the total suspended particulate material and the respirable particulate material air sample, the change in weight of the filter (mg) was divided by the total air flow through the filter in cubic meters (m^3) to give a gravimetric value (mg/m^3) for that sample.

Elemental Concentrations

For the seven trace elements considered in this survey, the total quantity (μg) of the specific elements in each sample was divided by the total air flow (m^3) to yield a value in μg/m^3 for each element/sample point (seven per sample).

Fiber Concentrations by Optical Microscopy

The number of fibers counted for each sample and the number of microscopic fields in which those fibers were counted were used (with the sample air volume) to calculate the concentration of fibers per milliliter of air (per cubic centimeter of air).

The basic formula for this determination is:

$$\text{Fiber concentration (f/cc)} = \frac{\text{Fibers} \times R}{\text{Fields} \times \text{volume}}$$

where:

Fibers = total number of fibers counted (- blank count if > 0)

Fields = total numbers of fields counted (100 if fibers < 100)

$$R = \frac{\text{Effective filter area}}{\text{Area of counting field}} = \frac{855 \text{ mm}^2}{4.096 \times 10^{-3} \text{mm}^2} = 2.09 \times 10^5$$

Volume = (liters) $\times 10^3$ = total sample air volume (ml) = cc.

Fiber Concentrations by Scanning Electron Microscopy

The fiber count in fibers/cc is equal to:

$$\text{Fibers/cc} = \frac{\text{Fibers} \times R}{\text{Fields} \times \text{volume} \times F}$$

where:

Fibers = total number of fibers counted (- blank count if > 0)

Fields = total number of SEM fields

Volume = air sample volume (ml)

$$R = \frac{\text{Effective Nuclepore filter area}}{\text{Area of counting field}}$$

$$= \frac{(8)^2 \pi \text{ mm}^2}{2.3 \times 10^{-3} \text{mm}^2} = \frac{201}{2.3 \times 10^{-3}} = 8.7 \times 10^4$$

F = Fraction of Millipore filter taken for analysis $\simeq$ 0.1-0.2.

Time-Weighted Averages (TWA)

Time-weighted averages were calculated as "flow-weighted averages" because the variability in flow rates of the Bendix pumps was sufficient to make control over this variable more important than direct control over the total time of sampling. The averages were calculated by the usual formula:

$$\text{TWA} = \sum_{i=1}^{n} X_i f_i \Big/ \sum f_i$$

where:

x_i = the concentration ($\mu g/m^3$; f/cc) found for the ith sample

f_i = the total volumetric air flow (liters) for the ith sample

n = the total number of air samples.

Linear Regression

Linear regression calculations were performed in the program ST1-08 for the Texas Instruments SR-52 programmable calculator. This program was modified to calculate regression of the logarithms of the independent and dependent variables.

Geometric Mean (GM) and Geometric Standard Deviation (GSD) of Fiber Size (for individual samples)

The basic method was adapted from that of Mercer (1973, p. 96) in which:

$$GM = \exp\left\{\frac{\sum_{i=1}^{k} n_i \cdot \ln D_i}{\sum_{i=1}^{k} n_i}\right\}$$

$$GSD = \exp\left\{\frac{\sum_{i=1}^{k} n_i \cdot (\ln D_i - \ln GM)^2}{\left[\sum_{i=1}^{k} n_i\right] - 1}\right\}^{1/2}$$

where:

GM = geometric mean fiber diameter or length (μm)

n_i = the number of fibers in the ith size category

ln = natural logarithm (base e)

D_i = an average size for that category

k = the number of size categories.

D_i was taken to be the antilogarithm (base e) of the midpoint of the logarithms of the extremes of each Porton size category. In some cases, these quantities were determined graphically from cumulative frequency distribution plots on log probability paper.

The GM and GSD for concentrations within a defined group are:

$$GM = \exp\left\{\frac{\sum_{i=1}^{N} \ln x_i}{N}\right\}$$

$$GSD = \exp\left\{\frac{\sum_{i=1}^{N} (\ln x_i - \ln GM)^2}{N - 1}\right\}^{1/2}$$

$$= \exp\left\{\frac{\sum_{i=1}^{N} (\ln x_i)^2 - \left(\sum_{i=1}^{N} \frac{\ln x_i}{N}\right)^2}{N - 1}\right\}^{1/2}$$

where:

GM = geometric mean concentration (f/cc; mg/m^3) of air samples within a group.

GSD = geometric standard deviation.

x_i = individual sample value (f/cc, mg/m^3).

N = the number of air samples.

The calculations to determine GM and GSD within each exposure category (across facilities), GM and GSD within each facility (across exposure categories), and total GM and GSD were based upon the relationships: (Dixon and Massey, 1957, p. 129).

$$GM = \exp\left\{\frac{\sum_{i=1}^{K} n_i (\ln GM_i)}{N}\right\}$$

$$GSD = \exp\left\{\frac{\sum_{i=1}^{K} \frac{n_i K}{N} (\ln GM_i - \ln GM)}{K - 1}\right\}^{1/2}$$

where:

GM = geometric mean of group geometric means

GM_i = group geometric mean

GSD = geometric standard deviation of group geometric means

n_i = the number of individual concentration values within a given group

N = the total number of individual values

K = the number of groups.

Confidence Intervals for Means Within Groups

In some cases, the method of Lord, based upon range, was used as outlined by Snedecor and Cochran (1967).

It was assumed that the distributions were log-normal. The efficiency of this procedure (relative to interval estimates based upon t) is above 95% for samples up to n = 20.

The confidence interval is calculated by the formula:

$$\overline{X} - t_w W \leq \mu \leq \overline{X} + t_w W$$

where:

$\overline{X}$ = the mean of the logarithms of the measurements in the group

W = the range of the logarithms

μ = the true mean of the logarithms of the population of samples from which the group is drawn

t_w = a value equivalent to Student's t, based upon the acceptable confidence limits (95% in this case) and upon the group size (Table A-7 in Snedecor and Cochran, 1967).

The 95% confidence limits on the true geometric mean concentration are:

$$\exp(\overline{X} \pm t_w W) \quad .$$

In most cases, conventional confidence limits, with the use of the sample geometric mean, geometric standard deviation, and Student's t were calculated:

$$\text{LCL} = \exp\left\{\ln \text{GM} - \frac{\left(t_{.05}\right)(\ln \text{GSD})}{N^{\frac{1}{2}}}\right\}$$

$$\text{UCL} = \exp\left\{\ln \text{GM} + \frac{\left(t_{.05}\right)(\ln \text{GSD})}{N^{\frac{1}{2}}}\right\}$$

where:

LCL = lower 95% confidence limit (two-sided) on GM

UCL = upper 95% confidence limit

$t_{.05}$ = an approximation to Student's t value, chosen from the following table:

(N-1)	$t_{.05}$
1	12.7
2	4.3
3	3.2
4	2.8
5	2.6
6-7	2.4
8-9	2.3
10-13	2.2
14-27	2.1
≥28	2.0

Confidence limits on means across groups are:

$$CLs = \exp\left\{ \ln GM \pm \left[\frac{\left(t_{.05}\right)(\ln GSD)}{K^{\frac{1}{2}}} \right] \right\}$$

where:

$t_{.05}$ = the same approximation of t as in the previous example, but with the degrees of freedom determined by K-1 rather than N-1.

Other Statistical Procedures

Standard statistics texts, such as Snedecor and Cochran (1967), Dixon and Massey (1957), Natrella (1963), and Bowker and Lieberman (1959) were used as necessary. The works of Mercer (1973), Liedel et al. (1977, 1975a, 1975b), and Bar-Shalom (1975) were particularly helpful in selection of appropriate procedures.

DESCRIPTIONS OF FACILITIES SURVEYED

PRODUCTION FACILITIES

Table 5 is a summary of the mineral wool production facilities surveyed during this project. Detailed descriptions of the workplaces, products, processes, worker populations and control measures applied at each of these sites are given in Appendix A. The facilities are coded to preserve their anonymity.

USER FACILITIES

Table 6 is a summary of the mineral wool user facilities surveyed during this project. Detailed descriptions of the workplaces surveyed are given in Appendix B. As with the producers, the facilities surveyed were assigned codes to preserve anonymity.

Table 5. Mineral wool production plants surveyed

	Plants				
	A	B	C	D	E
Raw materials	Steel mill slag, lead smelter slag Coke, oil, PF resin, asphalt	Steel mill slag, iron ore, "phos-phate" slag, coke, PF resin, oil, asphalt	Steel mill slag rock coke maleic acid, oil	Iron smelter slag, dolomite, quartzite, coke, oil	Steel mill slag, dolomite, PF resin, coke, oil
Years of production	28	29	6	20	50
Fiber-forming process	Centrifugal spinner with steam attenuation	Centrifugal spinner with steam attenuation	Dry spinner (Powell process)	Centrifugal spinner with steam attenuation	Centrifugal spinner with air attenuation
Fiber description	Slag wool	Slag wool	Slag wool	Slag wool	Slag wool
Products produced	Batts, blowing wool, and pouring wool	Batts, blowing wool, pouring wool, baled wool	Blowing wool, Baled wool	Ceiling tile	Industrial insulation blocks, blankets, pipe covering
Worker population (Fiber production and maintenance)	100	80	45	15	30
Potential exposures	Fibers, lead fume, H_2S, PF resin, noise	Fibers, combustion products, H_2S, CO, PF resin, noise	Fibers, combustion products, metal fume, maleic acid, noise	Fibers, CO, combustion products noise, general dust	Fibers, noise

Table 6. Mineral wool user facilities surveyed

Facility	F	G	H	I	J	K
Product used	Blowing wool (Slag wool)	Blowing wool (Slag wool)	Industrial blankets (Slag wool)	Bulk (slag wool) wool	Fireproofing	Industrial blankets
Application	New house insulation	Addition to existing insulation	Fabrication for shipment	Production of ceiling tiles	Spray application of fibrous fireproofing to structural steel.	Boiler insulation
Processes	Blowing	Blowing	Facing with wire mesh, packing	Mixing wool with slurry, baking, cutting, sanding, painting, packing tiles.	Pneumatic blowing of dry fibrous mix, wetted with spray nozzle as applied.	Facing with wire mesh, application of cement.
Worker population	4-10	4-10	20	60	2	3
Years of use	15	45	50	20	10	15
Potential exposures	Fibers, heat, CO	Fibers, heat, CO, settled house dust.	Fibers	Fibers, clay, paint, noise.	Fibers, dust	Fibers, dust, noise

RESULTS OF SURVEYS

OVERALL DESCRIPTION OF THE INDUSTRY AND COMMON FACTORS

Producers

The mineral wool production facilities studied were found to have many common factors and some differences. There was relative uniformity of fiber size produced and of raw materials and fiberization processes used. The production facilities investigated were in various states of repair and cleanliness, but worker exposures to airborne toxic materials were generally less than was expected from inspection of the facilities. In some plants, visible airborne dust existed, but exposures to fibers, total dust, and respirable dust were relatively low.

The degree of technical sophistication in this industry is (generally) not great. Control over cupola operating conditions, for instance, was sometimes exercised by the cupola operator who would base his judgement of optimum conditions on the color and flow characteristics of the molten slag. A considerable amount of experience was required of the cupola operators under these conditions.

Equipment breakdowns were fairly frequent in all of the plants surveyed. These breakdowns contributed to the housekeeping and waste disposal problems in the plants because the breakdowns usually occurred in the processing and fabrication equipment. The wool fibers would continue to be produced at the cupola and would then require disposal to waste or recycling. During the disposal or recycling operation, the waste fiber would often be piled upon the floors.

Mineral wool is a relatively abrasive product, and ducts for air conveyance of the product, as well as shrouds for screw belt and skip hoist conveyors, were often worn with holes permitting the escape of fiber. These were repaired, as were other items of process machinery, on site by plant maintenance personnel. Major items of process machinery were often almost completely rebuilt, with little remaining of the original equipment.

The cupolas were a constant source of difficulty with some of the plants. The major environmental problem of concern to the plant managers was emission of combustion products to the outside air. (These emissions were not evaluated for this project.) It was found that several plants initially considered for evaluation in this project had recently been closed; the stated reason for closure was given as inability to comply with local, state, or federal air pollution control regulations. All of the plants surveyed were either in the planning, design, or implementation phases of extensive engineering modifications to their air pollution control equipment. In some cases, there was intermittent recirculation of cupola emissions back into the workplace, with intermittent exposures of the personnel around the cupolas to fly ash, smoke, metal fumes, and combustion gases.

The cupolas and fiberization processes were also sources of noise. Three usual sources of this noise were identified. They were the tuyere (combustion) air, the rotating fiberization apparatus, and the air or steam for fiber attenuation.

For those facilities where phenol-formaldehyde (or occasionally urea-formaldehyde) resins were applied, the curing ovens were sources of smoke and partially cured resin fumes. This was again principally an air pollution problem, with occasional occupational exposures.

Users

Common factors were generally absent among the user facilities surveyed. The only factor in common was the use of mineral wool in products being produced, fabricated, installed, or applied by the workers surveyed. The construction trades surveyed (plasterers and industrial and residential insulation installers) were alike in that they shared exposures to general safety hazards and potentially severe risks of traumatic injury.

UTILIZATION OF ENGINEERING CONTROL AND PERSONAL PROTECTION

Producers

The major applications of engineering controls (specifically for the reduction of occupational exposures) among the producers were in the cupola areas. These were only partially successful. In some cases, the workers in the cupola areas were exposed to unacceptable levels of airborne contaminants despite recent improvements in engineering controls. In general, however, engineering controls were not used in all applicable areas, and those used were often less effective than other designs available.

Personal protective devices were widely used in these plants. The most common were safety helmets and disposable respirators. Cupola operators often used face shields, earmuffs, and protective clothing against molten slag and metal ejected from the cupolas. The use of steel-toed shoes, occasionally with metatarsal guards, was also common, especially among cupola operators. The use of these items of protective equipment was sometimes not required, but most plants had reasonably well-enforced programs of administrative control over personal protective equipment use, usually as part of an active safety program.

The workers in these plants made no particular effort to avoid exposure to airborne fibers through work practices. Indeed, on occasion, cleanup workers were observed carrying armloads of waste mineral wool, with the waste material inches from their faces. Baggers in Facility A occasionally used new bags, which they had slit up one side, as hoods to cover their head and neck area when "fallout" from overhead conveyors was especially noticeable. The cupola operators would attempt to minimize their exposures to combustion gases and molten slag by standing in positions that from experience they had learned were least exposed.

Users

Engineering controls are difficult to apply to many of the workplace environments in which mineral wool is used. Only in the two facilities (H and I), where mineral wool was used in a fixed "production line" operation, had engineering controls been extensively applied. In one of these facilities, control usage was less effective than optimum because of lack of consistent application.

The major method of control of worker exposures in the user facilities was the use of personal protective devices. This usually consisted of the use of disposable respirators. In the case of the sprayed fireproofing contractor, even this minimal protection was not used (although clearly indicated) because of difficulty of usage. The wet cement-bound fibrous material rebounding from the site of application, quickly wetted and plugged the respirator, making it very difficult to breath through, and resulting in limited worker acceptance.

EXPOSURES OF WORKERS IN MINERAL WOOL PRODUCTION AND USER FACILITIES

Production Workers

The following sections present general tables of data. It may be helpful to examine the assumptions made in the presentation and analyses of the data. First, log-normal distributions of data points (individual sample results) were assumed. This assumption was tested several times throughout the course of the study, and no basis for rejection, that is, excessive skewness or kurtosis, (Snedecor and Cochran, 1967) was found for the fiber count, fiber size, suspended particulate material, respirable particulate material, or elemental concentration data. Second, it was assumed that the greatest use of the data will be in making "cross-industry" comparisons.

Thus, groupings of similar job titles within general exposure categories have been made, and individual air sample results have been so grouped in an attempt to give a meaningful picture of this industry and to identify those major exposure categories of interest. An examination has also been made of the similarities and differences between the facilities surveyed.

It was usually assumed in these analyses that each exposure category/facility cell was an intact sample, and that the exposure categories within each facility were internally consistant and mutually distinct (see pp. 34-35 for calculation methods). Accordingly, the results have been presented to display (within each cell) the sample geometric means, geometric standard deviations and 95% confidence limits on the means, calculated from the individual sample results. These have been calculated without "weighting" by sample volume because the sample volumes did not differ appreciably from exposure category to exposure category. Thus, they are effectively time-weighted averages.

Tables 7-11 show the exposures of mineral wool production workers in the five facilities surveyed to concentrations of airborne fibers, total airborne particulate material, total respirable particulate material, and seven trace elements. Exposures to the trace elements are presented only as maximum values and averages (geometric means) because the data were sparse and generally low. The individual sample values by facility, job title, and exposure category are given in Appendix C.

In addition to the exposures to mineral wool fibers, total airborne particulate material, respirable particulate material, and airborne trace elements, mineral wool production workers are potentially at risk of exposure to several other toxic or hazardous chemical and physical agents. The cupola combustion process is inherently relatively inefficient; incomplete combustion, with generation of carbon monoxide (CO), is a possibility when a new batch of coke is charged into the cupola. No excess exposures to CO were found in these production facilities, nor were excessive concentrations of H_2S or SO_2 (possible from use of sulfur-contaminated coke or slag) measured. However, H_2S was present in concentrations above the odor threshold of approximately 0.05 parts per million (ppm) in one plant, probably as a result of the recirculation of stack gases during unfavorable wind conditions.

Noise exposure was a potentially severe problem in the cupola areas of all of these plants. Although the cupola operators usually wore plant-provided hearing protective devices (plugs and/or muffs), noise levels were measured at 120 dB(A), which is near the limit of utility of such devices.

The results shown in Tables 7-11 are discussed in pages 63 to 90 of this report.

Table 7. Mineral wool production facilities--fiber concentrations determined by optical microscopy

Job category	A					B					C				
	N(K)*	GM† (f/cc)	GSD‡	LCL§ (f/cc)	UCL§ (f/cc)	N	GM (f/cc)	GSD	LCL (f/cc)	UCL (f/cc)	N	GM (f/cc)	GSD	LCL (f/cc)	UCL (f/cc)
Cupola operator	5	0.028	3.76	0.005	0.149	16	0.404	2.72	0.239	0.683	14	0.110	1.78	0.079	0.155
Cupola charger	4	0.068	1.69	0.029	0.157	5	0.048	11.8	0.002	1.05	4	0.095	2.02	0.031	0.292
Baler operator	--	--	--	--	--	--	--	--	--	--	4	0.097	1.61	0.045	0.207
Bagger	21	0.074	2.05	0.053	0.103	13	0.052	2.18	0.032	0.083	8	0.109	2.13	0.058	0.208
Warehouse and loader	12	0.126	1.55	0.096	0.166	15	0.116	1.95	0.081	0.167	14	0.210	2.09	0.136	0.324
Batt mach. operator	13	0.096	4.46	0.038	0.238	7	0.193	3.61	0.060	0.617	--	--	--	--	--
Foreman	7	0.114	1.75	0.068	0.189	--	--	--	--	--	--	--	--	--	--
Maintenance	9	0.103	1.88	0.063	0.167	16	0.090	2.93	0.051	0.159	4	0.043	1.44	0.024	0.077
Takeoff	11	0.211	1.79	0.143	0.310	5	0.208	1.90	0.093	0.465	--	--	--	--	--
Clerical	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Labor (cleanup)	20	0.156	1.68	0.122	0.199	10	0.130	2.00	0.080	0.211	--	--	--	--	--
Boiler operator	2	0.044	2.20	<.001	50.8	9	0.108	1.75	0.071	0.167	--	--	--	--	--
Laboratory and QC	1	2.13	--	--	--	5	0.077	2.86	0.021	0.287	--	--	--	--	--
Means and totals by facility	105(11)	0.108	1.19	0.096	0.121	101(10)	0.123	1.24	0.106	0.143	48(6)	0.120	1.220	0.097	0.148

Table 7 (concluded). Mineral wool production facilities--fiber concentrations determined by optical microscopy

Job category	D					E					Means and totals by exposure categories				
	N	GM (f/cc)	GSD	LCL (f/cc)	UCL (f/cc)	N	GM (f/cc)	GSD	LCL (f/cc)	UCL (f/cc)	N(K)	GM[**] (f/cc)	GSD[††]	LCL[‡‡] (f/cc)	UCL[‡‡] (f/cc)
Cupola operator	3	0.331	1.17	0.223	0.491	8	0.146	1.92	0.084	0.254	46(5)	0.168	1.52	0.099	0.285
Cupola charger	3	0.197	2.07	0.032	1.21	7	0.304	1.48	0.213	0.434	23(5)	0.121	1.45	0.076	0.192
Baler operator						--	--	--	--	--	4(1)	0.097	--	--	--
Bagger						--	--	--	--	--	42(3)	0.071	1.20	0.046	0.112
Warehouse and loader						14	0.124	2.1	0.080	0.192	55(4)	0.140	1.15	0.112	0.174
Batt mach. operator						--	--	--	--	--	20(2)	0.123	1.40	0.006	2.441
Foreman						8	0.075	4.44	0.021	0.266	15(2)	0.091	1.23	0.014	0.595
Maintenance	15	0.224	1.85	0.161	0.313	20	0.096	3.38	0.054	0.170	64(5)	0.111	1.24	0.084	0.145
Takeoff						23	0.119	3,84	0.066	0.214	39(3)	0.150	1.22	0.092	0.245
Clerical						3	0.154	2.54	0.015	1.56	3(1)	0.154	--	--	--
Labor (cleanup)	2	0.822	3.60	<0.001	$>10^4$						32(3)	0.163	1.35	0.078	0.345
Boiler operator											11(2)	0.092	1.41	0.004	2.057
Laboratory and QC	3	0.401	1.44	0.163	0.983	1	0.220	--	--	--	10(4)	0.196	1.86	0.072	0.526
Means and totals by facility	26(5)	0.273	1.21	0.214	0.348	84(8)	0.122	1.14	0.110	0.136					
Means (facilities)											364(5)	0.125	1.12	0.108	0.144
Means (j. cat.)											364(13)	0.125	1.08	0.119	0.131
Grand (mean)											364(40)	0.125	1.09	0.121	0.128

*N = Number of individual air samples, (K) = number of exposure categories or facilities.

†GM = Geometric mean concentration for the N samples.

‡GSD = Geometric standard deviation of the N samples.

§= Two-sided lower (LCL) and upper (UCL) 95% confidence limits on geometric mean for the N samples.

**GM = Geometric mean for the K exposure categories or facilities

††GSD = GSD of the (K) facilities or categories.

‡‡Two-sided 95% confidence limits on the geometric means for the K exposure categories or facilities.

Table 8.

	A				
Exposure	N* (K)	GM† Diameter (μm)	LCL‡ UCL (μm)	GM† Length (μm)	LCL‡ UCL (μm)
Cupola operator	55	2.0		16	
Cupola charger	67	1.4		6.7	
Baler operator					
Bagger	375	2.0		16.0	
Warehouse and loader	374	2.0		14.5	
Batt mach. operator	346	1.7		13.5	
Foreman	115	1.9		14	
Maintenance	175	1.4		10.7	
Takeoff	432	1.5		12.5	
Clerical					
Labor (cleanup)	743	1.9		15.1	
Boiler operator					
Laboratory and Q. C.	165	1.2		7.5	
Means and totals by facility	2,847(10)	1.74	1.68 1.80	13.4	12.7 14.0

Mineral wool production facilities--
airborne fiber sizes

B					C				
N(K)	GM Diameter (μm)	LCL UCL (μm)	Length (μm)	LCL UCL (μm)	N(K)	GM Diameter (μm)	LCL UCL (μm)	Length (μm)	LCL UCL (μm)
981	1.2		12.8		350	1.8		18.5	
113	1.3		11.7		66	2.4		19.1	
37	1.9		19.5		87	2.8		25.4	
122	1.8		16.0		206	1.7		15.9	
308	2.2		18.8		750	2.6		23.2	
241	1.8		23.7						
344	1.9		18.5		37	2.0		28.2	
205	1.8		16.0						
229	1.9		22.4						
154	1.4		8.9						
68	1.3		10.8						
2,802(11)	1.56	1.49 1.64	15.5	14.6 16.4	1,496(6)	2.24	2.04 2.45	20.9	19.4 22.5

Table 8 (concluded). Mineral wool production facilities--airborne fiber sizes

Exposure	D: N	D: GM Diameter (µm)	D: LCL UCL (µm)	D: Length (µm)	D: LCL UCL (µm)	E: N	E: GM Diameter (µm)	E: LCL UCL (µm)	E: Length (µm)	E: LCL UCL (µm)	Means and totals by category: N(K)	Diameter: GM (µm)	Diameter: UCL LCL (µm)	Length: GM (µm)	Length: UCL LCL (µm)
Cupola operator	163	1.7		11.4		203	1.8		10.4		1,752(5)	1.43	1.26 1.62	13.4	12.0 15.0
Cupola charger	126	1.8		10.4		258	1.7		9.1		630(5)	1.66	1.49 1.85	10.2	8.7 12.1
Baler operator						--	--		--		124(2)	2.49	0.51 12.3	23.5	7.9 69.5
Bagger						--	--		--		703(3)	1.87	1.65 2.13	16.0	15.9 16.1
Warehouse and loader						342	2.2		18.5		1,774(4)	2.31	2.10 2.55	19.4	16.4 22.9
Batt mach. operator						--	--		--		587(2)	1.74	1.35 2.24	17.0	1.4 204.4
Foreman						217	2.1		21.1		332(2)	2.03	1.32 3.11	18.3	3.2 106
Maintenance	857	2.1		18.8		475	2.0		15.3		1,888(5)	1.96	1.83 2.10	17.0	15.2 19.1
Takeoff						429	2.3		18.6		1,066(3)	1.85	1.32 2.59	15.4	11.2 21.1
Clerical						168	2.0		15.3		168(1)	2.0	-- --	15.3	-- --
Labor (cleanup)	245	1.6		23.7		--	--		--		1,217(3)	1.84	1.63 2.07	17.8	12.4 25.6
Boiler operator						--	--		--		154(1)	1.4	-- --	8.9	-- --
Laboratory and Q. C.	268	1.9		16.2		--	--		--		501(3)	1.55	1.06 2.28	11.9	6.4 22.0
Means and totals by facility	1,659(5)	1.92	1.80 2.05	17.3	14.9 20.0	2,092(7)	2.04	1.97 2.11	15.3	13.9 16.9					
Facility means											10,896(5)	1.83	1.70 1.98	15.8	14.5 17.2
Category mean											10,896(13)	1.83	1.78 1.88	15.8	15.2 16.3
Grand mean											10,896(39)	1.83	1.81 1.85	15.8	15.5 16.0

*N = Number of fibers sized; (K) = number of exposure categories or facilities.

†GM = Geometric mean fiber diameter or length for the N fibers or (K) categories or facilities.

‡LCL and UCL = Lower (LCL) and upper (UCL) 95% confidence limits on fiber diameter or length for the (K) categories or facilities.

Table 9. Mineral wool production facilities--total suspended particulate material concentrations

Exposure Category	A					B					C				
	N*(K)	GM† (mg/m^3)	GSD‡	LCL§ (mg/m^3)	UCL§ (mg/m^3)	N(K)	GM (mg/m^3)	GSD	LCL (mg/m^3)	UCL (mg/m^3)	N(K)	GM (mg/m^3)	GSD	LCL (mg/m^3)	UCL (mg/m^3)
Cupola operator	7	1.005	2.44	0.448	2.256	10	0.753	10.69	0.145	3.912	8	0.624	1.29	0.503	0.774
Cupola charger	4	1.199	1.15	0.988	1.455	2	1.502	1.45	0.054	42.042					
Baler operator	--	--	--	--	--	3	0.081	45.48	<0.001	>10^3	3	0.256	2.08	0.041	1.588
Bagger	12	0.283	1.59	0.210	0.380	6	0.027	15.42	0.001	0.486	5	0.357	1.76	0.176	0.725
Warehouse and loader	9	0.457	2.96	0.199	1.050	9	0.488	2.26	0.261	0.911	8	0.859	1.85	0.510	1.445
Batt mach. operator	7	0.450	1.71	0.276	0.734	6	0.247	18.18	0.011	5.363	--	--	--	--	--
Foreman	4	0.489	1.15	0.404	0.593	--	--	--	--	--	1	0.097	--	--	--
Maintenance	5	0.664	2.19	0.267	1.649	13	0.945	2.20	0.583	1.53	3	0.622	3.82	0.022	17.35
Takeoff	7	1.193	2.56	0.509	2.794	6	1.140	2.83	0.377	3.442					
Clerical	--	--	--	--	--	--	--	--	--	--					
Labor (cleanup)	17	1.149	1.58	0.910	1.452	4	0.355	2.34	0.091	1.387					
Boiler operator	1	0.470	--	--	--	5	0.699	1.72	0.353	1.382					
Laboratory and Q. C.	1	1.148	--	--	--	3	0.058	34.05	<0.001	>100					
Outside crew	3	1.279				3	0.286	2.35	0.034	2.393	2	0.569	1.32	0.047	6.888
Means and totals by facility	77(12)	0.693	1.18	0.624	0.770	70(12)	0.399	1.41	0.321	0.496	30(7)	0.529	1.23	0.440	0.636

Table 9 (concluded). Mineral wool production facilities--total suspended particulate material concentrations

Exposure category	D N(K)	D GM (mg/m³)	D GSD	D LCL (mg/m³)	D UCL (mg/m³)	E N(K)	E GM (mg/m³)	E GSD	E LCL (mg/m³)	E UCL (mg/m³)	Total N(K)	Total GM** (mg/m³)	Total GSD††	Total LCL‡‡ (mg/m³)	Total UCL‡‡ (mg/m³)
Cupola operator	3	0.674	2.33	0.083	5.484	3	1.272	1.09	1.031	1.569	31(5)	0.797	1.12	0.690	0.920
Cupola charger	3	4.056	1.81	0.934	17.6	3	4.100	1.25	2.365	7.108	12(4)	2.296	1.40	1.344	3.921
Baler operator											6(2)	0.144	1.78	<0.001	25.3
Bagger											23(3)	0.161	2.12	0.025	1.047
Warehouse and loader						7	0.591	2.52	0.256	1.365	33(4)	0.573	1.15	0.456	0.719
Batt Mach. operator						5	0.410	2.16	0.156	1.075	18(3)	0.359	1.21	0.225	0.574
Foreman											5(2)	0.354	1.91	0.001	>100
Maintenance	9	0.957	1.95	0.573	1.599	10	0.802	1.62	0.573	1.124	40(5)	0.843	1.08	0.768	0.927
Takeoff						13	0.556	1.86	0.381	0.813	26(3)	0.806	1.30	0.420	1.547
Clerical						2	0.616	1.86	0.002	>100	2(1)	0.616	--	--	--
Labor (cleanup)	3	5.644	2.00	1.014	31.41						24(3)	1.153	1.69	0.315	4.221
Boiler operator											6(2)	0.654	1.16	0.173	2.47
Laboratory and Q. C.	2	3.781	4.06	<0.001	>10³	1	0.384	--	--	--	7(4)	0.384	2.81	0.074	2.00
Outside crew						1	2.397	--	--	--	9(4)	0.695	1.54	0.347	1.393
Means and totals by facility	20(5)	1.688	1.51	1.011	2.819	45(9)	0.731	1.22	0.626	0.854					
										Fac. means	242(5)	0.621	1.21	0.487	0.792
										Job cat. means	242(14)	0.621	1.20	0.559	0.690
										Grand means	242(45)	0.621	1.14	0.596	0.646

*N = Number of air samples; (K) = number of facilities or categories.

†GM = Geometric mean.

‡GSD = Geometric standard deviation of the N samples.

§LCL, UCL = Lower and upper two-sided 95% confidence limits on the geometric means.

**GM = Geometric mean of the (K) facilities or categories.

††GSD = Geometric standard deviations of the (K) facilities or categories.

‡‡LCL, UCL = Confidence limits on the geometric means of the (K) facilities or categories.

Table 10. Mineral wool production facilities--respirable airborne particulate material concentrations

Job category	A					B					C				
	N^*(K)	GM† (mg/m^3)	GSD‡	LCL§ (mg/m^3)	UCL§ (mg/m^3)	N(K)	GM (mg/m^3)	GSD	LCL (mg/m^3)	UCL (mg/m^3)	N(K)	GM (mg/m)	GSD	LCL (mg/m)	UCL (mg/m)
Cupola operator	2	0.161	4.45	--	--	3	0.632	1.72	0.164	2.43	1	0.228			
Cupola charger	2	0.092	1.16	0.023	0.364	1	0.400								
Baler operator						3	0.158	1.48	0.060	0.415	1	0.039			
Bagger	1	0.09	--	--	--						1	0.040			
Warehouse and loader	3	0.032	20.03	--	--	1	0.114				1	0.101			
Batt mach. operator	1	0.427				1	0.140								
Foreman															
Maintenance	1	0.125				2	0.121	2.96	--	--	1	0.733			
Takeoff	1	0.104				1	0.180								
Clerical															
Labor (cleanup)	5	0.041	8.38	0.003	0.591										
Boiler operator															
Laboratory and Q. C.															
Outside crew	1	0.295				1	0.130								
Means and totals by facility	17(9)	0.077	1.32	0.062	0.096	13(8)	0.216	1.28	0.174	0.267	5(5)	0.121	1.74	0.060	0.243

Table 10 (concluded). Mineral wool production facilities--respirable airborne particulate material concentrations

Job category	D N(K)	D GM (mg/m³)	D GSD	D LCL (mg/m³)	D UCL (mg/m³)	E N(K)	E GM (mg/m³)	E GSD	E LCL (mg/m³)	E UCL (mg/m³)	Totals N(K)	Totals GM** (mg/m³)	Totals GSD††	Totals LCL‡‡ (mg/m³)	Totals UCL‡‡ (mg/m³)
Cupola operator	1	0.490				1	0.233				8(5)	0.338	1.34	0.235	0.486
Cupola charger	1	1.661				1	0.496				5(4)	0.308	1.89	0.112	0.852
Baler operator											4(2)	0.111	1.83	<0.001	25.7
Bagger											2(2)	0.06	1.50	0.002	2.29
Warehouse and loader											5(3)	0.052	1.52	0.018	0.147
Batt mach. operator						1	0.108				3(3)	0.186	1.52	0.065	0.530
Foreman											--	--	--	--	--
Maintenance						1	0.091				5(4)	0.167	1.57	0.081	0.344
Takeoff						2	0.123	1.91			4(3)	0.130	1.15	0.091	0.185
Clerical											--	--	--	--	--
Labor (cleanup)	1	0.515				1	0.515				6(2)	0.063	2.57	<0.001	>1.00
Boiler operator											--	--	--	--	--
Laboratory and Q. C.	1	0.356				1	0.356				1(1)	0.356			
Outside crew						1	0.272	--	--	--	3(3)	0.218	1.30	0.114	0.417
Means and totals by facility	4(4)	0.622	1.40	0.362	1.067	7(6)	0.173	1.29	0.132	0.227					
										Facility mean	46(5)	0.147	1.36	0.100	0.217
										Category mean	46(11)	0.147	1.24	0.128	0.170
										Grand mean	46(32)	0.147	1.19	0.138	0.156

*N = Number of air samples; (K) = number of facilities or categories.

†GM = geometric mean of the N air samples.

‡GSD = Geometric standard deviation of the N air samples.

§LCL, UCL = Lower and upper two-sided 95% confidence limits on the geometric means of the N samples.

**GM = Geometric mean of the (K) facilities or categories.

††GSD = Geometric standard deviation of the (K) facilities or categories.

‡‡LCL, UCL = Confidence limits on the geometric means of the (K) facilities or categories.

Table 11. Mineral wool production facilities--
maximum and geometric mean trace
metal concentrations

Facility	Exposure Category	Zinc Max.	Zinc GM	Lead Max.	Lead GM	Manganese Max.	Manganese GM	Chromium MAX.	Chromium GM	Cobalt Max.	Cobalt GM	Nickel Max.	Nickel GM	Cadmium Max.	Cadmium GM
		Trace Metal Concentration (ug/m³)													
A	Cupola operator	713	53	290	41	3	1.5	*	*	*	*	*	*	*	*
	Cupola charger	69	33	30	19	8	6.1								
	Bagger	20	3.3	2	0.4	2	0.3								
	Warehouse and loader	63	14	21	8.4	10	1.9								
	Batt mach. operator	29	4.2	14	3.4	6	0.9								
	Foreman	38	19	31	7.6	2	1.4								
	Maintenance	81	22	58	11	6	2.2								
	Takeoff	78	25	11	3.1	92	13								
	Labor (cleanup)	291	21	348	7.7	28	5.7								
	Boiler operator	18	†	13	†	1	†								
	Laboratory and Q. C.	30	†	†	12.0	12	†								
	Outside crew	42	8.8	19	5.3	6	3.9								
B	Cupola operator	21.0	1.5	*	*	*	*	*	*	*	*	*	*	*	*
	Cupola charger	8.0	2.7			2.0	1.5								
	Baler operator	4.6	--			1.1	--								
	Bagger	4.6	0.5			0.7	--	1.4	--	1.2	--	3.7	--	0.8	--
	Warehouse and loader	11.4	2.9			11.5	--	*	*	1.3	--	*	*	*	*
	Batt mach. operator	5.4	--			8.3	--			*	*				
	Maintenance	26.0	5.6			28.0	--								
	Takeoff	4.4	1.7			9.0	1.1								
	Labor (cleanup)	5.4	--			0.8	--			3.4	--				
	Boiler operator	<2.9	--			*	*			*	*				
	Laboratory and Q. C.	12.0	2.5			1.1	--								
	Outside crew	<2.8	1.4			*	*								
C	Cupola operator	5.4	1.3	*	*	4.0	1.9	*	*	*	*	*	*	*	*
	Baler operator	0.5	0.3			0.9	0.2								
	Bagger	4.1	--			0.6	--								
	Warehouse and loader	1.6	0.6			2.0	--								
	Foreman	0.7	+			*	*								
	Maintenance	2.0	0.9			2.2	*								
	Outside crew	*	*			0.8	*								
D	Cupola operator	1.9	1.2	--	--	0.8	--	*	*	*	*	*	*	*	*
	Cupola charger	4.1	1.9	--	--	12.0	2.3								
	Maintenance	7.3	1.6	3.8	--	1.5									
	Labor (cleanup)	10.7	3.9	--	--	15	5.2								
	Laboratory and Q. C.	0.8	0.8	--	--	2	--								
E	Cupola operator	67	30	*	*	104	9	*	*	*	*	*	*	*	*
	Cupola charger	74	50			29	2.7								
	Warehouse and loader	67	8.9			49	10.1								
	Batt mach. operator	50	5.4			53	0.6								
	Maintenance	241	17.9			81	15.2								
	Takeoff	50	1.9			74	13.8								
	Clerical	15	0.4			30	14.5								
	Laboratory and Q. C.	10	10†			4†	4†								
	Outside crew	96	96†			94†	94†								

*Below detection limits (0.2-4 ug/m³, depending on element, matrix, air volume, etc.).

†Only one sample.

User Facility Workers

Tables 12-17 are representations of the exposures of the workers in the mineral wool user facilities surveyed during this study. As with the production facility results, the presentation aims at showing the cross-industry comparisons of importance. Appendix D contains the individual sample results from each facility.

In addition to exposures to airborne particulate (fibrous and nonfibrous) material in these facilities, other exposures were evident throughout the study. The workers installing blown insulation fiber were potentially subject to heat stress and CO exposures. Potential exposure to heat stress was documented for facility F, in Table 12.

Table 12. Heat stress measurements--Facility F (°F)

	Temperature		
	Outside	Inside truck	Inside attic
Dry bulb	60	>110	
Wet bulb	55	74	
Botsball	64	78	72

Exposures to CO were measured inside the houses being insulated and inside the trucks from which the mineral wool was being blown. Measurements were made on several occasions and with the use of detector tubes. The highest single measurement recorded was 90 ppm, inside the truck for Facility G. On all other occasions, the measurements were between 10 ppm and 30 ppm, and the single excessive measurement could not be duplicated.

Scanning Electron Microscopic Analyses of Air Samples

To evaluate the potential for exposure to sub(optical) microscopic fibers, selected filters were examined by scanning electron microscopy (SEM). Comparative fiber concentrations obtained by SEM and optical microscopic examinations of the selected samples are shown in Tables 18 and 19.

BULK MATERIALS ANALYSES

The bulk materials samples collected during the surveys were subjected to several analyses:

- X-ray fluorescence determination of elemental content
- Atomic absorption determination of elemental content
- X-ray microprobe determination of elemental content for individual fibers and particles
- Optical microscopic determinations of fiber diameter.

Several points were of interest in these examinations:

- The elemental concentrations in the fibers and shot
- The diameters of the fibers
- The differences that may exist between currently used (and produced) fibers, and those that may have been produced in the past.
- The results of these examinations (grouped by survey facility) are given in Appendix E. The fiber size determinations are shown in Table 20.

Table 13. Mineral wool user facilities--fiber concentrations

Exposure Category	Facility	N(K)‡	GM§ (f/cc)	GSD**	LCL†† (f/cc)	UCL†† (f/cc)
Blowing wool inst.*†	F	6	0.518	2.90	0.167	1.60
	G	2	0.139	7.03	--	--
Industrial insul. fab.	H	20	0.208	2.34	0.140	0.310
Tile wet mix	I	20	0.577	2.38	0.385	0.866
Tile boards	I	18	1.210	2.40	0.784	1.867
Tile cleanup	I	12	0.614	2.23	0.368	1.022
Tile cutting	I	--	--	--	--	--
Tile painting	I	2	0.972	1.12	0.354	2.673
Tile packing	I	9	0.632	1.58	0.444	0.899
Tile lab. and Q.C.	I	1	0.518	--	--	--
Tile warehouse*	I	3	0.250	4.05	0.008	8.045
Spray fireproofing	J	3	0.496	1.29	0.263	0.932
Insulation install.	K	5	0.071	1.64	0.038	0.132
Means and totals by facility		101 (12)	0.460	1.25	0.399	0.531

*Includes some area samples.

†The values for all 8 samples were: GM = 0.373 f/cc; GSD = 3.72; LCL = 0.122 f/cc; UCL = 1.137 f/cc.

‡N = number of samples; (K) = number of categories.

§GM = geometric mean of the N samples.

**GSD = geometric standard deviation of the N samples.

††LCL and UCL = 95% (two-sided) confidence limits on the geometric means of the N samples.

Table 14. Mineral wool user facilities--airborne fiber sizes

Exposure Category	Facility	N(K)*	Geometric Mean Diameter (μm)	Geometric Mean Length (μm)	Facility I Totals N(K)	Facility I Totals Geometric Mean Diameter (μm)	Facility I Totals Geometric Mean Length (μm)
Blowing wool inst.	F	181	1.6	12.0			
	G	9	--	--			
Industrial insul. fab.	H	727	2.3	18.8			
Tile wet mix	I	1,989	1.8	17.6			
Tile boards	I	3,361	1.4	6.1			
Tile cleanup	I	1,454	1.9	15.2			
Tile cutting	I	--	--	--	8,617	1.68	10.6
Tile painting	I	303	2.0	12.9	(7)		
Tile packing	I	1,164	2.0	12.5			
Tile lab. and Q.C.	I	124	1.7	11.4			
Tile warehouse	I	222	2.0	15.0			
Spray fireproofing	J	218	2.4	35.3			
Insulation install.	K	75	1.9	11.8			
Total		9,818 (11)	1.73	11.4	8,617 (7)	1.68	10.6
LCL†			1.67	10.3		1.59	9.0
UCL†			1.80	12.6		1.78	12.6

*N = number of fibers sized; (K) = number of categories.

†LCL and UCL = lower and upper 95% confidence limits on geometric mean fiber size for (K) categories.

Table 15. Mineral wool user facilities--total airborne particulate material concentrations (mg/m^3)

Exposure Category	Facility	N(K)*	GM†	GSD‡	LCL§	UCL§
Blowing wool inst.	F	2	2.657	4.89	--	--
	G	2	0.202	>10^3	--	--
Industrial insul. fab.	H	17	1.006	1.73	0.761	1.330
Tile wet mix	I	12	0.768	9.48	0.184	3.203
Tile boards	I	9	0.805	1.96	0.482	1.347
Tile cleanup	I	7	0.582	20.3	0.038	8.93
Tile cutting	I	2	4.930	2.83	--	--
Tile painting	I	1	4.077	--	--	--
Tile packing	I	6	1.879	1.85	0.980	3.60
Tile lab. and Q.C.	I	1	1.785	--	--	--
Tile warehouse	I	3	0.513	3.26	0.027	9.67
Spray fireproofing	J	4	7.461	2.46	<10^{-3}	>10^3
Issulation install.	K	7	1.853	2.11	0.940	3.653
Means and totals by facility		73* (13)	1.135**	1.24††	0.998‡‡	1.291‡‡

*N = number of air samples; (K) = number of exposure categories.

†GM = geometric mean (mg/m^3) of the N samples.

‡GSD = geometric standard deviation of the N samples.

§LCL and UCL = lower and upper 95% confidence limits on the mean of the N samples.

**GM = geometric mean (mg/m^3) of the (K) categories.

††GSD = geometric standard deviation of the means for the (K) categories.

‡‡LCL and UCL = confidence limits on the mean of the (K) categories.

Table 16. Mineral wool user facilities--respirable particulate material concentrations

Exposure Category	Facility	N(K)*	GM* (mg/m³)	GSD*	LCL* (mg/m³)	UCL* (mg/m³)
Blowing wool inst.	F	1	2.565			
Industrial insul. fab.	H	1	0.373			
Tile wet mix	I	2	0.141			
Tile cleanup	I	1	0.126			
Tile cutting	I	2	0.455			
Tile packing	I	1	0.223			
Tile lab. and Q.C.	I	1	0.367			
Tile warehousing	I	1	0.119			
Spray fireproofing	J	2	0.370			
Insulation install.	K	3	0.762			
Total		15 (10)	0.368	1.31	0.301	0.447

Note: Insufficient samples to determine GSD, LCL, or UCL for individual categories.

*Refer to footnotes on Table 15.

Table 17. Mineral wool user facilities--maximum trace metal concentrations ($\mu g/m^3$)

Exposure Category	Facility	Zinc	Lead	Manganese	Chromium	Cobalt	Nickel	Cadmium
Blowing wool inst.	F	119.5	11.5	124.3	*	*	*	*
	G	1,070†	90†	50†	*	25†	*	3†
Industrial insul. fab.	H	81	*	66	*	*	*	*
Tile wet mix	I	1.6	*	2.1	*	*	*	*
Tile boards	I	2.3	*	*	*	*	*	*
Tile cleanup	I	1.7	*	5.6	*	*	*	*
Tile cutting	I	1.3	*	2.1	*	*	*	*
Tile painting	I	0.8	*	3.0	*	*	*	*
Tile packing	I	1.6	1.7	1.9	*	*	*	*
Tile lab. and Q.C.	I	1.0	*	*	*	*	1.4	*
Tile warehouse	I	3.0	*	*	*	*	*	*
Spray fireproofing	J	6.8	*	16.0	3.4	*	*	*
Insulation install.	K	*	*	*	*	*	*	*

*Below detectable limits (all samples).

†Based on 30-liter air sample.

Table 18. Mineral wool production facilities--comparisons of fiber concentrations by scanning electron microscopy (SEM) and optical microscopy (OM) (f/cc)

Exposure Category	A		B		C		D		E		Total Geometric Mean		LCL		UCL	
	SEM	OM	SEM	OM	SEM	OM	SEM	OM	SEM	OM	SEM	OM	SEM	OM	SEM	OM
Cupola operator	0.083 0.056	0.054 0.087	0.270 0.287	1.015 1.250	0.635	0.060			0.221	0.245	0.192	0.211	0.092	0.065	0.404	0.684
Cupola charger			0.150	0.279					0.196	0.312	0.171	0.295	0.052	0.179	0.570	0.488
Baler operator					0.140	0.071					0.140	0.071	--	--	--	--
Bagger	0.042 0.064	0.069 0.069	0.100	0.152	0.826	0.077					0.122	0.086	0.017	0.048	0.897	0.154
Warehouse and loader	0.037	0.076	0.093	0.129	0.725 0.488	0.494 0.231			0.193	0.074	0.188	0.153	0.070	0.081	0.508	0.286
Batt. mach. operator	0.12	0.21									0.120	0.210	--	--	--	--
Foreman	0.11	0.21							0.156	0.315	0.131	0.257	0.027	0.042	0.630	1.59
Maintenance	0.076	0.061	0.143 0.038	0.352 0.084	0.111	0.071	0.360	0.140	0.172	0.157	0.119	0.119	0.083	0.091	0.171	0.155
Takeoff	0.44 0.17	0.41 0.32							0.069 0.041	0.096 0.067	0.121	0.170	--	--	--	--
Labor (cleanup)	0.11 0.020	0.083 0.18	0.112 0.109 0.109 0.137	0.128 0.034 0.132 0.084			1.44	2.035			0.179	0.147	0.040	0.022	0.806	0.988
Boiler operator													--	--	--	--
Laboratory and Q.C.			0.086	0.098			0.264	0.264	0.108	0.220	0.135	0.179	0.058	0.084	0.315	0.380
Outside crew					0.743	0.125					0.743	0.125	--	--	--	--
Geometric mean	0.098	0.120	0.120	0.160	0.416	0.119	0.515	0.422	0.127	0.158	0.156	0.150				
N	12		12		7		3		8		42(5)	42(5)				
GSD	2.01	2.02	1.16	2.92	1.37	1.34	1.68	2.24	1.23	1.25	1.35	1.17				
LCL	0.063	0.077	0.109	0.083	0.311	0.091	0.141	0.057	0.106	0.131	0.108	0.123				
UCL	0.152	0.187	0.133	0.307	0.555	0.155	1.88	3.13	0.152	0.191	0.227	0.183				

Table 19. Mineral wool user facilities--comparisons of fiber concentrations by scanning electron microscopy (SEM) and optical microscopy (OM) (f/cc)

Exposure Category	Facility	SEM	OM	Geometric Mean SEM	Geometric Mean OM	LCL SEM	LCL OM	UCL SEM	UCL OM
Blowing wool inst.	F	5.48	0.723	3.09	0.240	1.240	0.080	7.67	0.718
		0.570	0.238						
	G	6.48	0.552						
		4.50	0.035						
Industrial insul. fab.	H	0.565	0.325	0.367	0.245	--	--	--	--
		0.239	0.185						
Tile wet mix	I	3.12	0.320	0.987	0.455	0.484	0.211	2.01	0.980
Tile cleanup	I	1.36	1.80						
Tile painting	I	2.40	0.898						
Tile packing	I	0.720	0.739						
Tile warehouse	I	0.128	0.051						
Spray fireproofing	J	0.217	0.384	0.217	0.384	--	--	--	--
Total for all samples									
Geometric mean		1.08	0.327						
GSD		1.48	1.39						
LCL		0.843	0.265						
UCL		1.38	0.403						

Table 20. Fiber size determinations in bulk samples

Sample Number	Date	N	GM (μm)	GSD	LCL (μm)	UCL (μm)
A-4	1976	539	3.7	1.9	3.5	3.9
5	1966	158	4.1	1.8	3.7	4.5
6	1976	164	4.8	1.7	4.4	5.2
7	1976	163	3.7	1.9	3.3	4.1
Total		1,024	3.9	1.8	3.8	4.0
B-1	1976	117	3.1	2.0	2.7	3.5
2	1976	514	4.0	2.1	3.7	4.3
3	1976	129	2.8	2.2	2.4	3.2
4	1976	101	3.8	2.4	3.2	4.5
5	1976	142	3.6	2.3	3.1	4.1
6	1976	107	4.8	2.1	4.2	5.5
7	1976	109	3.2	2.1	2.8	3.7
8	1976	108	3.0	2.3	2.6	3.5
9	1976	182	3.4	2.2	3.0	3.8
Total		1,509	3.7	2.0	3.6	3.8
C-1	1976	109	4.3	2.3	3.7	5.0
2	1976	111	3.1	3.0	2.6	3.9
3	1976	107	3.4	2.5	2.8	4.0
4	1976	510	3.2	2.6	3.0	3.5
Total		837	3.4	2.7	3.2	3.6
D-1	1957	110	5.1	2.1	4.4	5.9
2	1962	525	3.2	1.9	3.0	3.4
3	1967	107	3.7	2.3	3.2	4.3
4	1973	119	3.6	1.9	3.2	4.0
5	1976	111	3.6	2.3	3.1	4.2
6	1976	113	4.1	2.3	3.5	4.8
7	1976	101	3.5	2.6	2.9	4.2
8	1976	111	3.1	2.5	2.6	3.7
9	1976	108	2.9	2.3	2.5	3.4
10	1976	161	4.0	1.9	3.6	4.4
Total*		705	3.6	2.3	3.4	3.8
E-1	1977	556	2.0	2.1	1.9	2.1
2	1977	160	2.1	2.0	1.9	2.3
3	1977	126	3.2	2.0	2.8	3.6
Total		842	2.2	2.1	2.1	2.3
F-1	1976	163	3.7	1.9	3.3	4.1
2	1976	164	4.8	1.7	4.4	5.2
G-1	1943	187	2.4	1.6	2.2	2.6
2	1943	101	3.3	1.7	3.0	3.7
3	1946	103	3.4	2.5	2.8	4.1
4	1946	118	0.08	300.0	0.028	0.23
5	1977	527	3.2	2.7	2.9	3.5
6	1943	250	2.1	1.7	1.9	2.2
7	1972	101	1.9	4.5	1.4	2.5
8	1976	122	1.7	4.0	1.3	2.2
9	1937	121	1.5	4.6	1.2	2.0
J-1	1977	522	2.1	2.2	2.0	2.2
2	1977	149	3.1	1.9	2.8	3.4
K-1	1977	161	3.4	2.0	3.1	3.8

*Refers to samples D-5 to D-10

ANALYSIS OF RESULTS

Figures 12 through 17 display pictorial representations of the data on exposures in the production facilities. It should be noted that the confidence limits portrayed in those figures are confidence limits on the means of the several variables considered; no implication is made that exposures of all workers in the facilities/exposure groups considered will be within those limits. Indeed, this question is addressed later, and the distributions of individual air sample results (individual exposures) will be similarly displayed for some of these facilities.

Perhaps the most striking result is seen in Figures 12, 15, and 17. Facility D, the producer of mineral wool for captive use in ceiling tile production, is clearly higher than the other facilities in all three types of measurements of exposures. Fiber exposures, total suspended particulate material exposures, and respirable particulate material exposures are all higher. As these figures were obtained by simple compilation of the means of the individual air sample results, it is clear that the workers in Facility D have higher mean exposures to airborne particulate material (of all kinds) than do the workers in the other production facilities surveyed.

Another interesting result is seen from examination of the exposure data for the baggers and the takeoff exposure categories (Figures 13 and 16). Neither of these were remarkably different in mean exposures from other exposure categories, in spite of the commonly expressed opinion that these two categories had the greatest exposure to fibers.

Figure 18 is a display of the confidence limits on the geometric mean fiber concentration exposures of the user exposure categories, taken from Table 13. As can be seen from examination of Tables 14 through 17, the relatively small number of samples has led to broad confidence intervals for the other variables measured, and display of those results would add little. It is interesting to note that the installation of industrial insulation is apparently associated with relatively low fiber exposures, when compared to the other user exposure categories considered.

Figure 19 is a display of comparisons of the geometric mean airborne fiber exposures for production and user facility workers for the samples evaluated by both scanning electron microscopy and optical microscopy. The marked difference shown in Figure 19 is principally the result of the differences demonstrated for the workers blowing mineral wool insulation (see Table 19).

It is instructive to compare the exposures of user and producer facility workers to all of the variables measured, and Figure 20 presents such a comparison. As can be seen, the workers in the user facilities evaluated are more highly

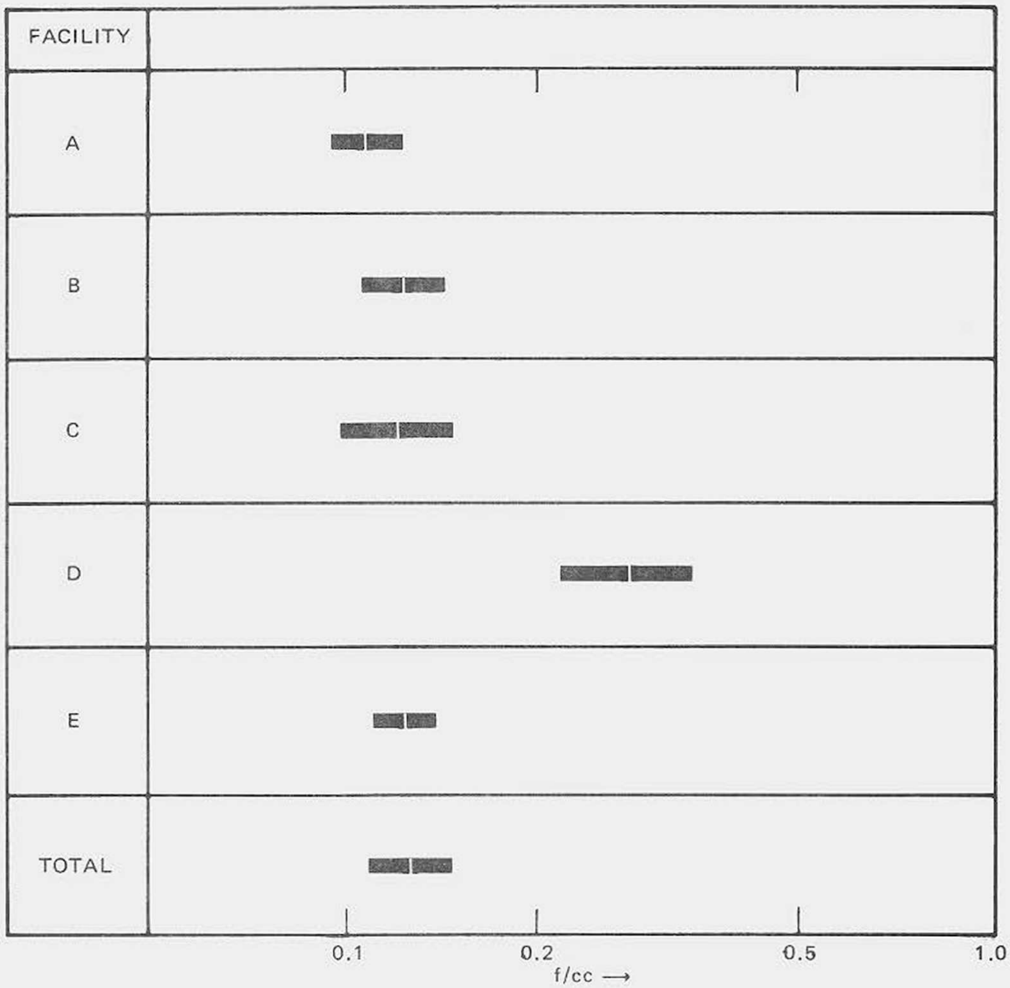


Figure 12. Mineral wool production facilities: 95% confidence limits on geometric mean fiber concentration exposures

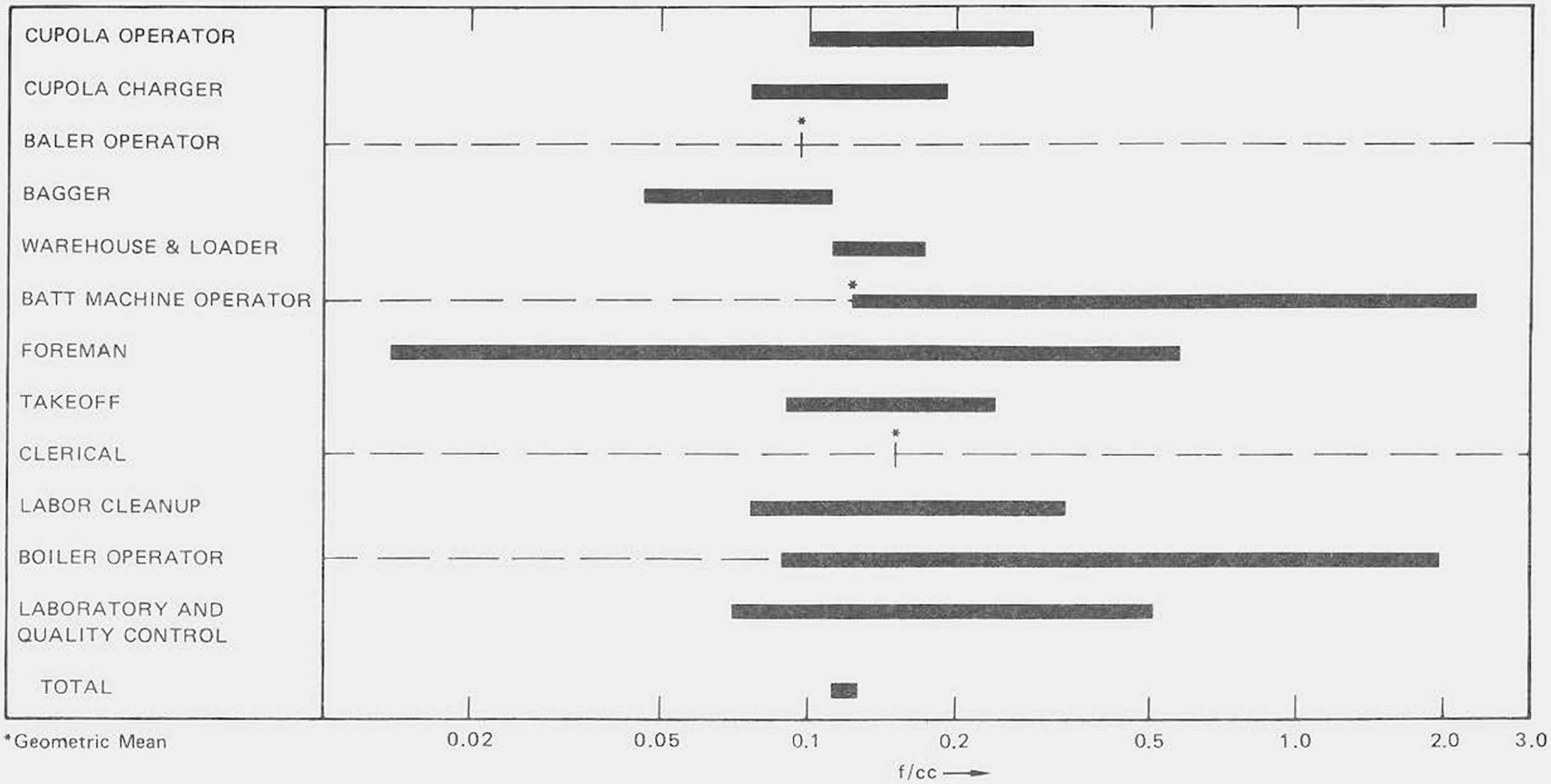


Figure 13. Mineral wool production worker exposure categories: 95% confidence limits on geometric mean fiber concentration exposures

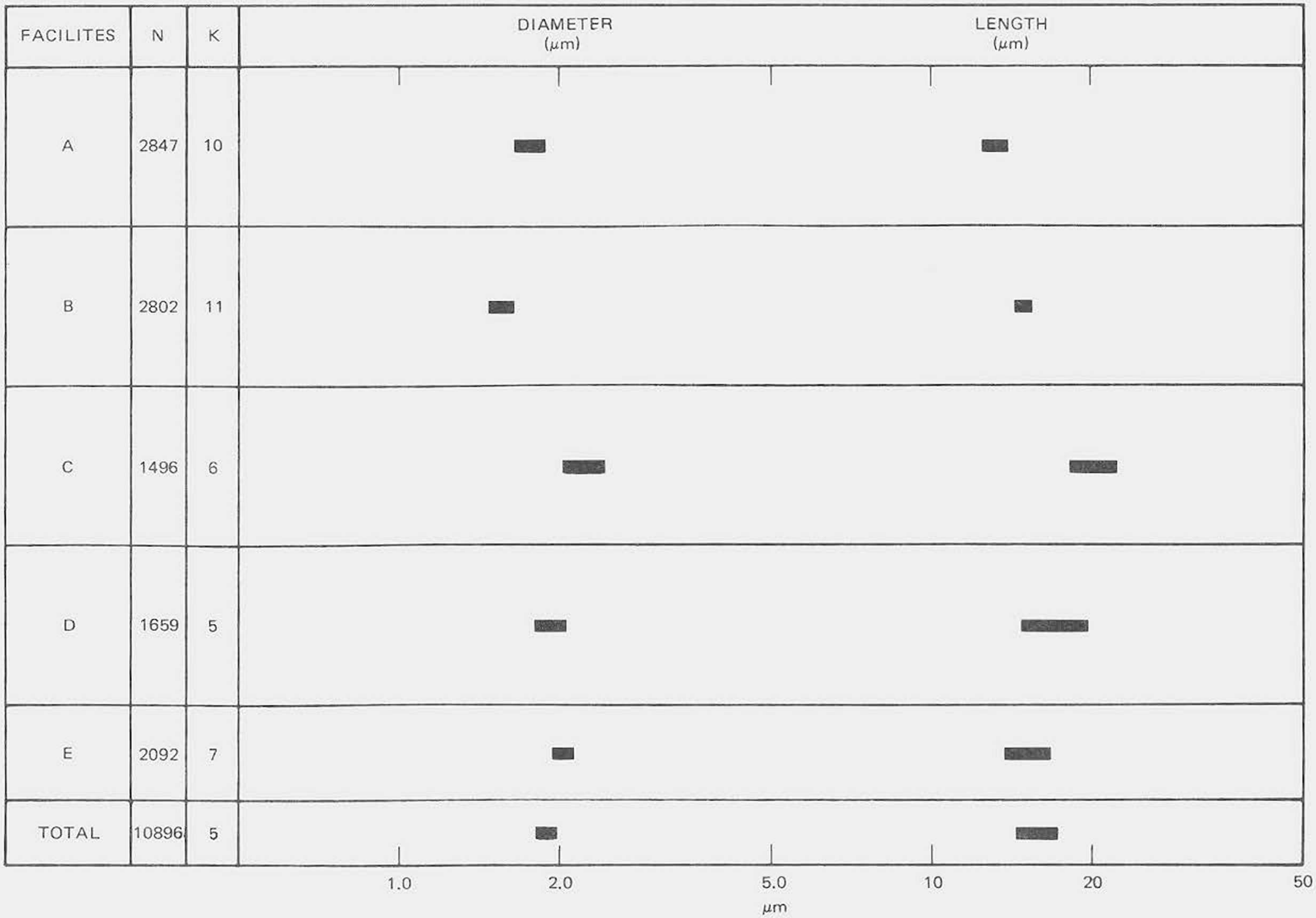


Figure 14. Mineral wood production facilities: 95% confidence limits on mean airborne fiber sizes

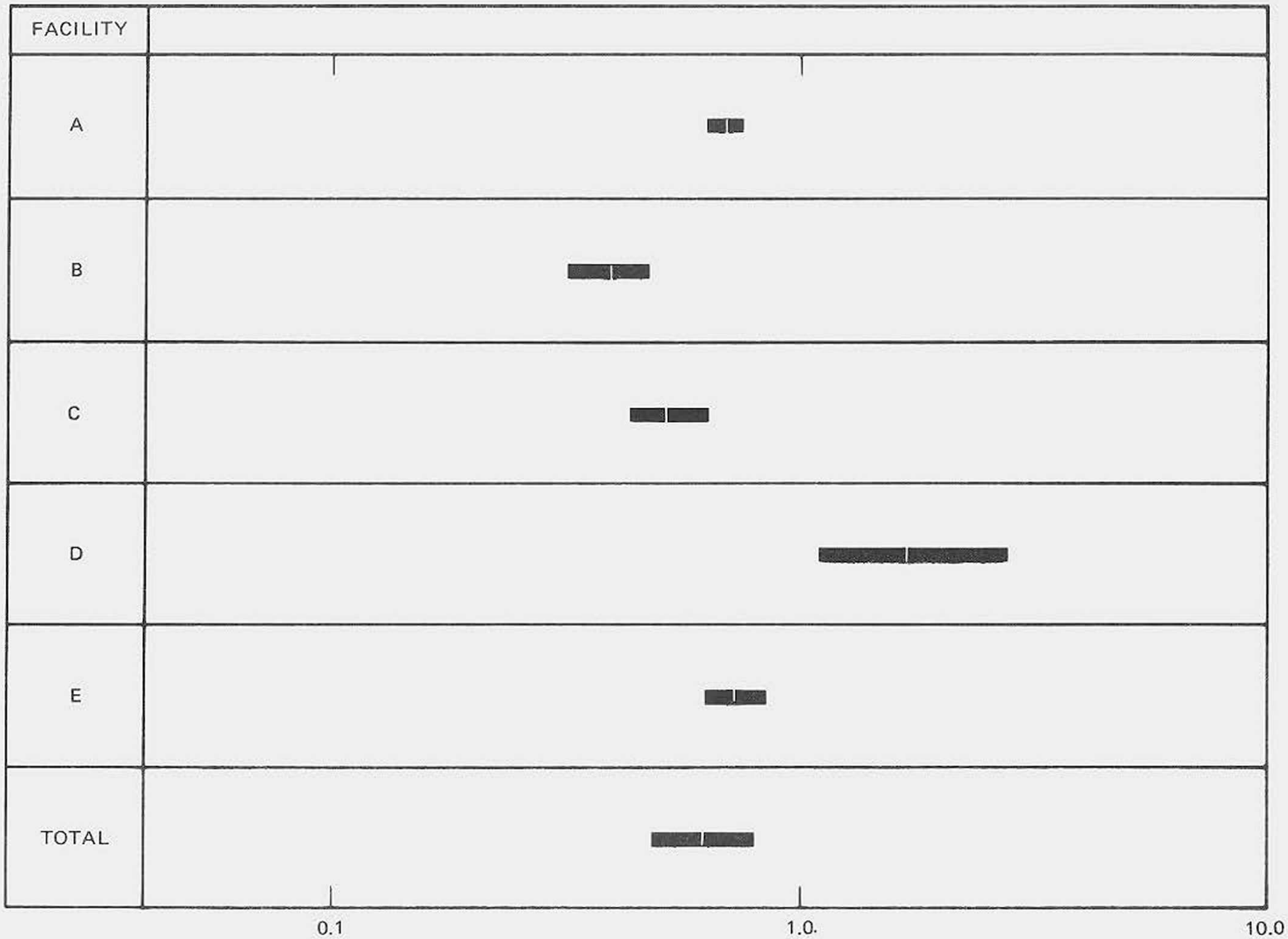


Figure 15. Total suspended particulate material: 95% confidence limits on geometric mean exposures of mineral wood production workers, by facility

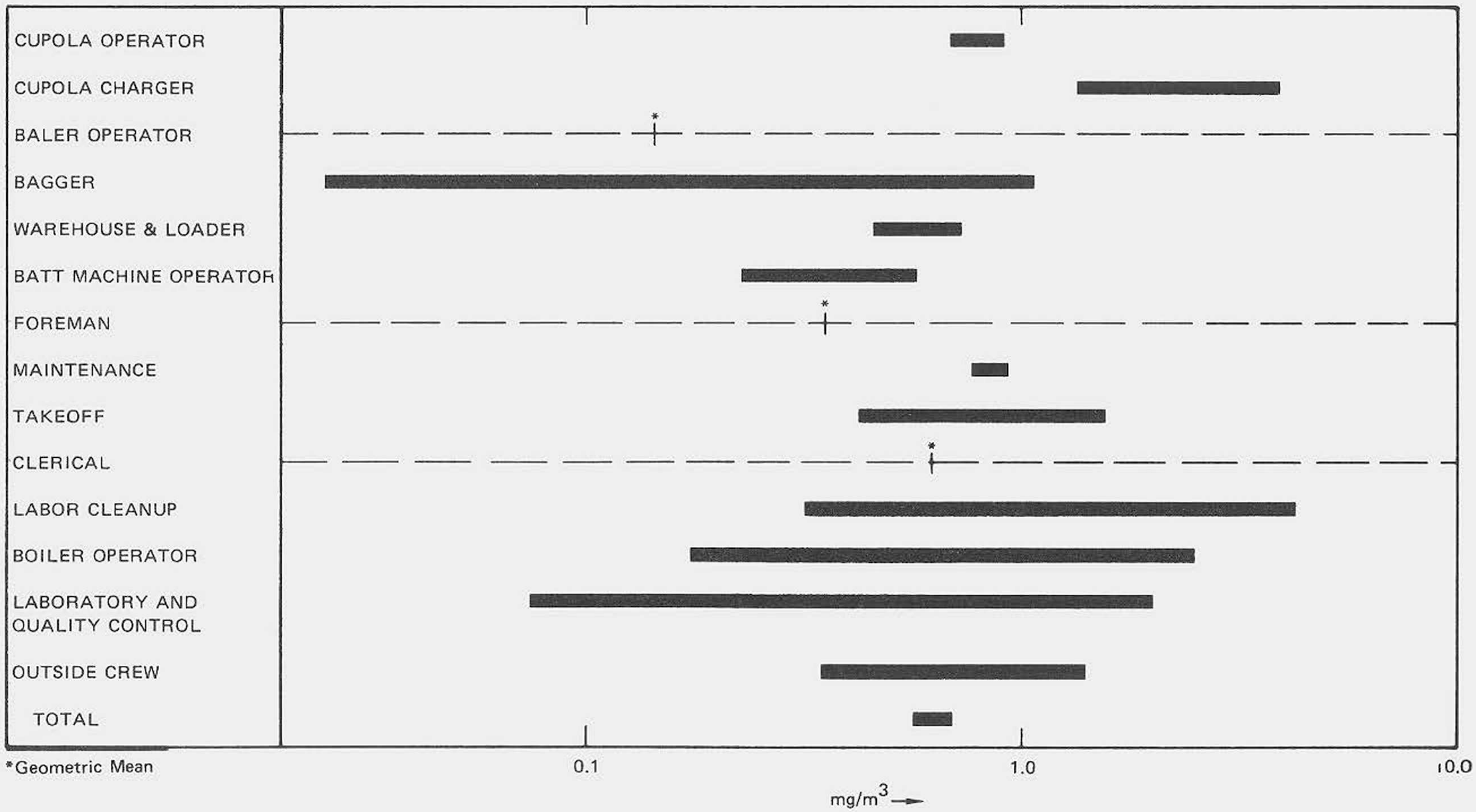


Figure 16. Mineral wool production worker exposure categories: limits on geometric mean total suspended particulate exposures.

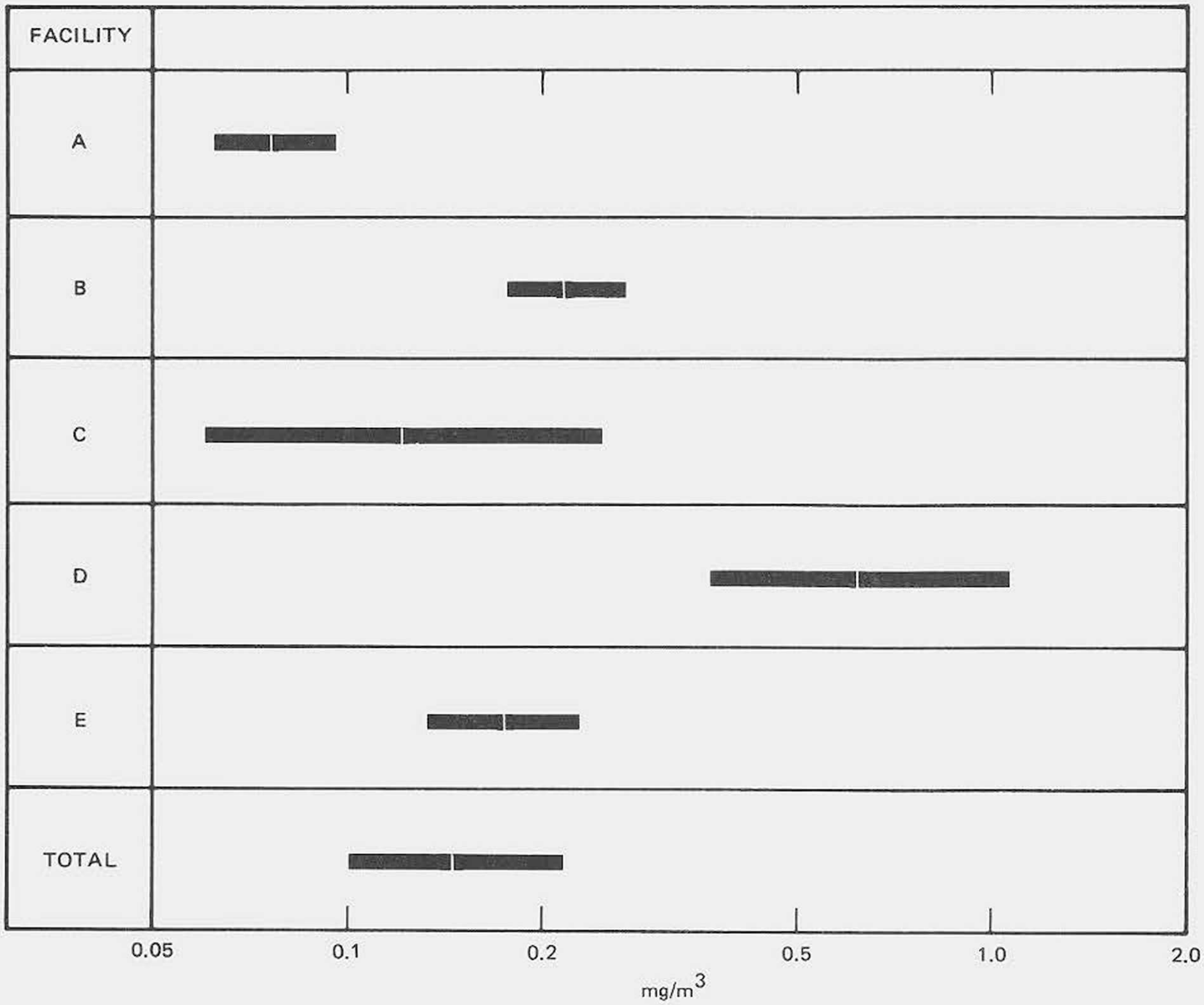


Figure 17. Mineral wool production facilities: 95% confidence limits on geometric mean respirable particulate material exposures

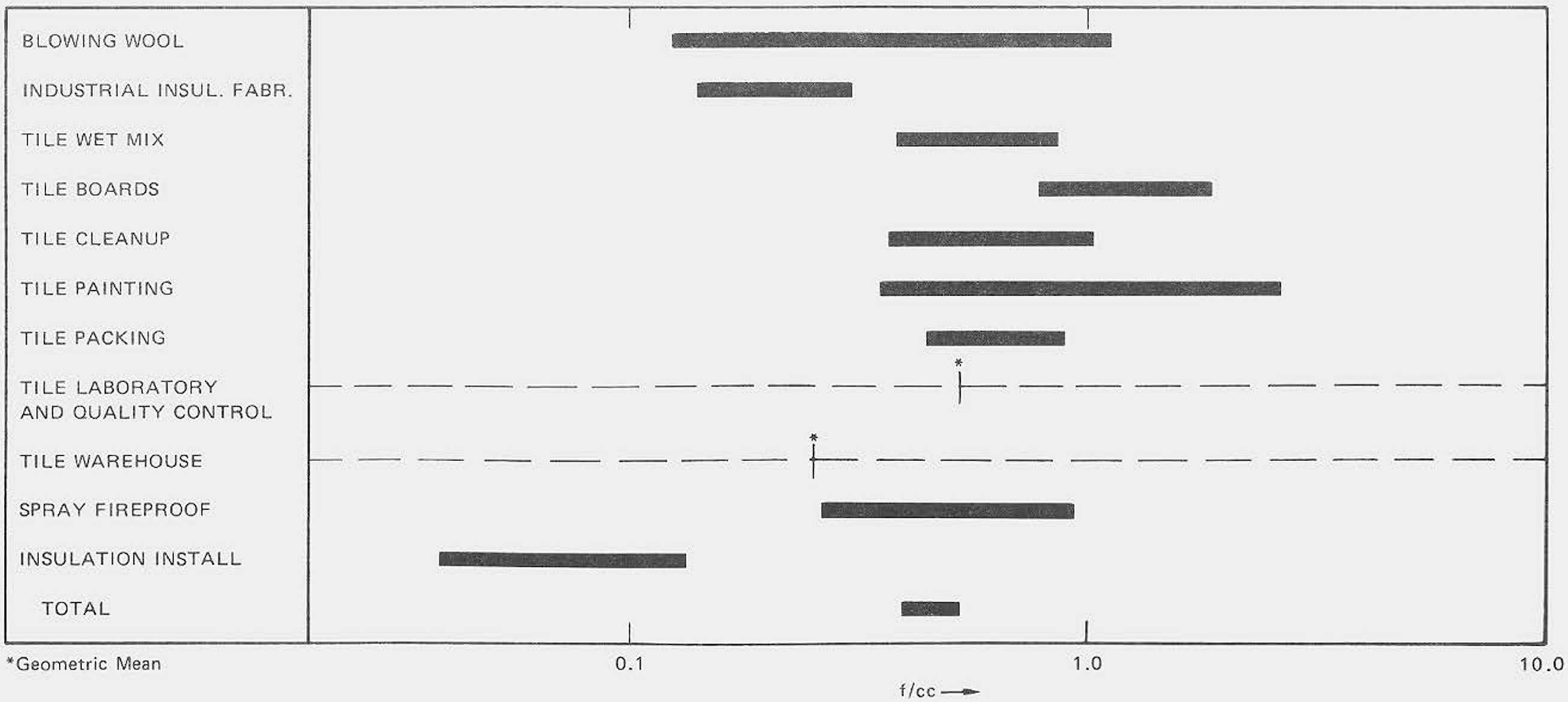


Figure 18. Mineral wool user facility exposure categories: 95% confidence limits on geometric mean fiber concentrations

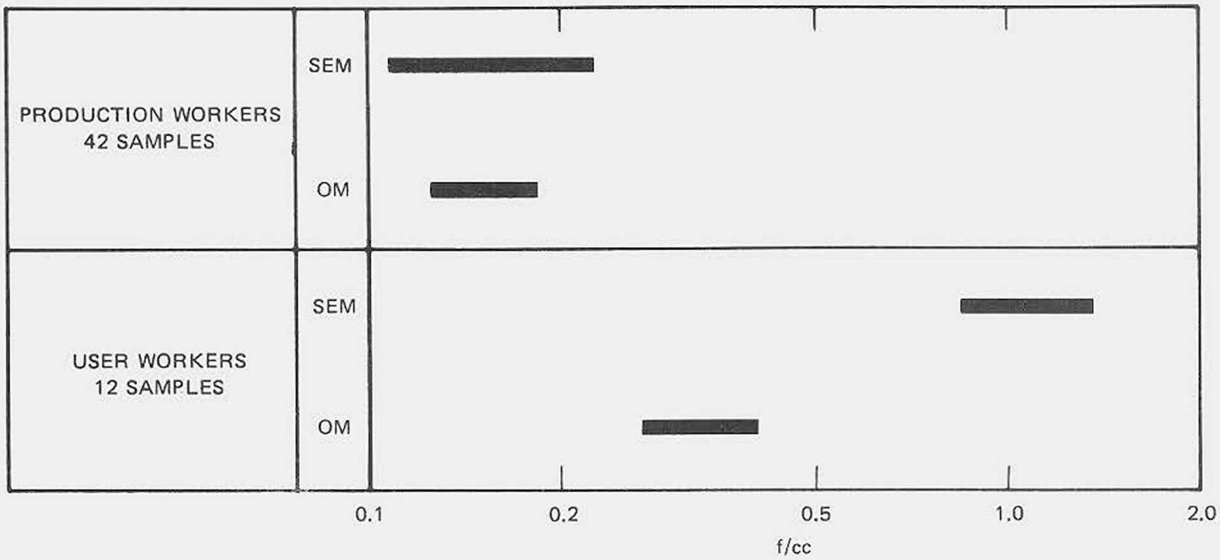


Figure 19. Comparison of confidence limits on geometric mean fiber concentrations for samples examined by scanning electron microscopy (SEM) and optical microscopy (OM)

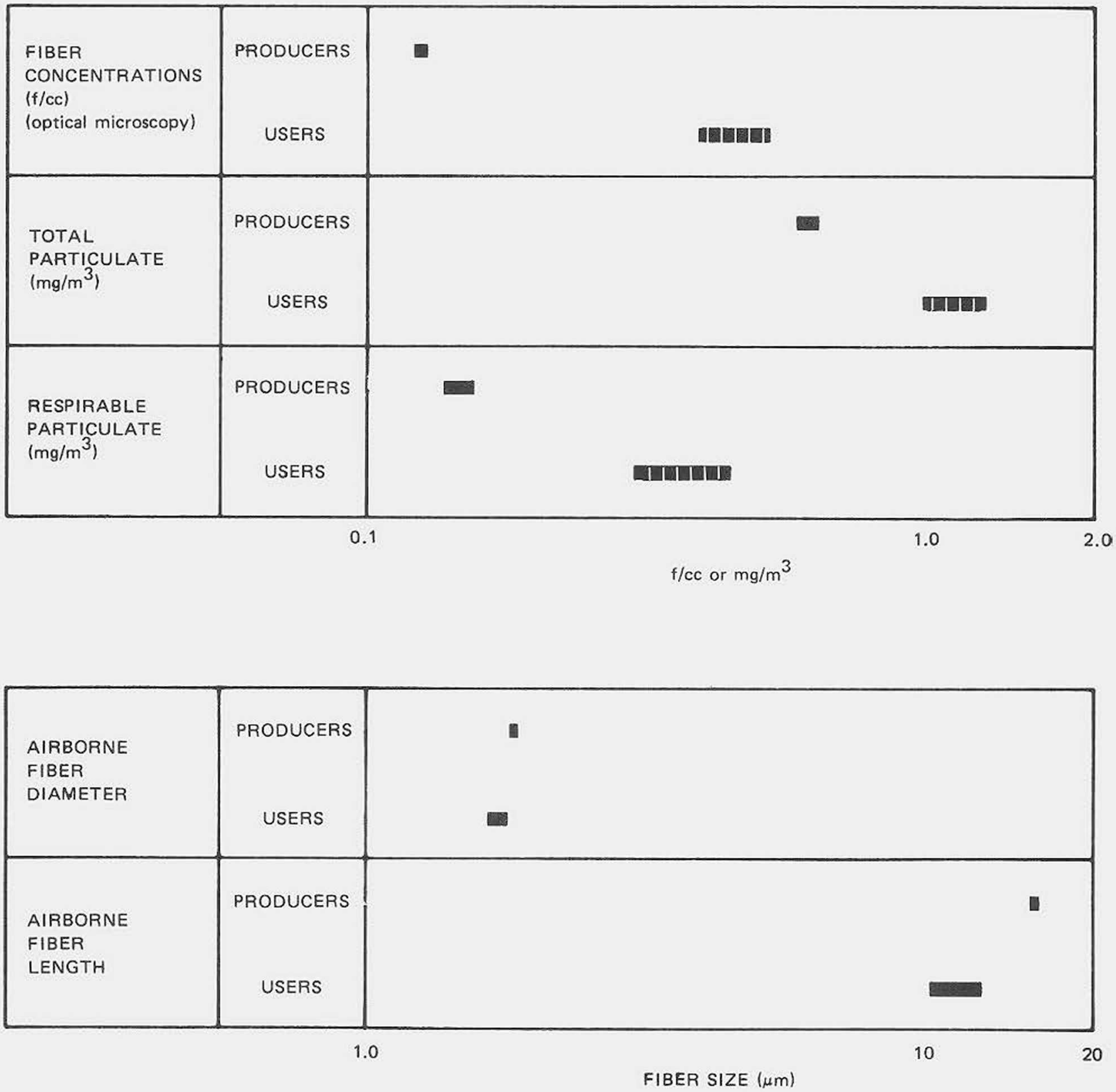


Figure 20. Comparison of exposures of production and user facility workers

exposed than are the production workers. In addition, the fibers to which the user facility workers are exposed are smaller in both length and diameter.

The chemical analyses of bulk material samples by X-ray fluorescence (XRF) and atomic absorption (AA) and the analyses of the individual fibers and particles by X-ray microprobe, reported in Appendix E, were intended to answer several questions about the chemical characteristics of mineral wool.

- Are there differences in elemental composition between the fiber and the shot in the same product?
- Is there an effect of fiber size on elemental composition (or vice versa)?

The data in Appendix E have been tested by conventional statistical procedures during the course of the project to answer these questions. These techniques (chi-square, paired sample t-test) have not indicated any consistent trend for either of these questions. The differences among the fibers were at least as large as the differences between the fibers and the shot, and no size dependence of the elemental composition of the fibers could be defined.

Perhaps more interesting was the variability in overall elemental composition seen on a day-to-day basis within a single plant and the marked differences in chemical composition between plants. Table 21 illustrates the differences that may be found between batches of raw material and product in the same plant. The series of samples taken at Facility G are probably most representative of the relatively great differences in elemental composition that may be seen in a single region. Those results are shown in Table E-28. The concentration ratios are diagnostic of the probable major sources of the raw material used in making the fibers: a high concentration of iron (for instance) indicates that steel mill or iron smelter slag was probably used, and a high concentration of calcium indicates that natural rock was a major raw material. The efficiency of removal of waste metal in the cupola will also affect these ratios. The samples from Facility A, where lead smelter slag was used, exhibit higher concentrations of lead than do the other samples analyzed during this project. It is tempting to suggest that an XRF scan of a mineral wool fiber sample may provide a "fingerprint" with sufficient information to identify the probable source of the sample. The day-to-day variability in the composition of the raw material used within those plants surveyed precludes such a statement at this time.

It has been suggested (Pundsack, 1976) that mineral wool production workers in past years may have been exposed to substantial numbers of small fibers because of the relatively poor control of the fiber sizes produced by the older fiberization processes. Figure 21 is a display of the frequency of occurrence of fibers of specified sizes (by optical microscopy) in the samples from Facility G.

The hypothesis that larger fractions of small fibers were produced in past years is only partially substantiated. Sample G-4, installed in 1946 is the most marked example. Of the fibers detected by optical microscopy, 68% are less than 0.91 micrometers in diameter, and the size distribution is markedly bimodal. As shown in Table 20, the graphically determined geometric standard

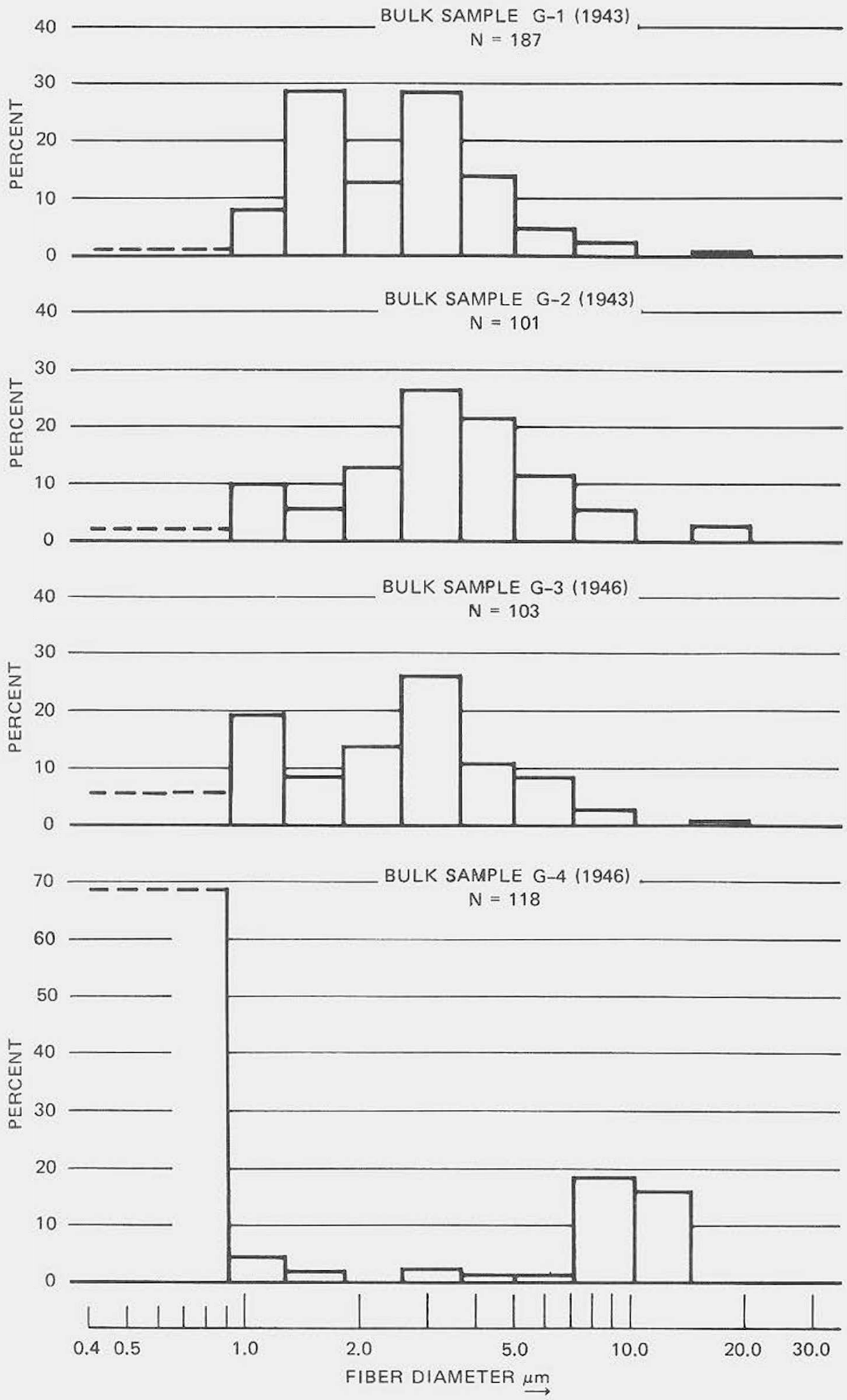


Figure 21. Frequency of occurrence of fibers of specified diameter in samples from Facility G

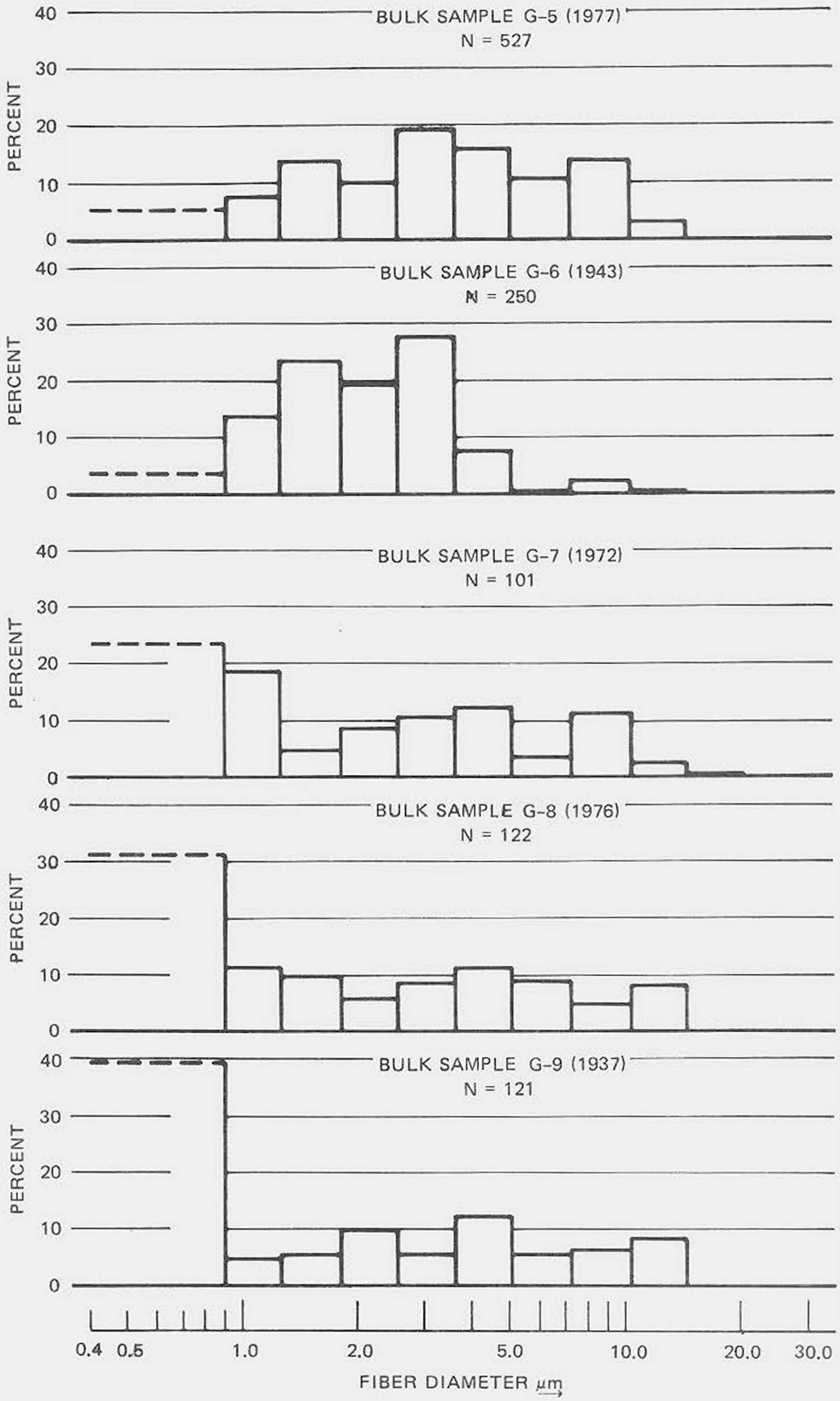


Figure 21. Frequency of occurrence of fibers of specified diameter in samples from Facility G (Concluded)

Table 21. Past chemical analysis of slag and wool--Plant C (percent)

	Slag (1969)	Slag (4/5/71)	Wool (1/30/71)	Wool (3/18/71)
Ignition loss	--	1.35	None	None
Silica	35.8	38.90	40.92	41.37
Alumina	9.3	9.74	11.56	10.86
Ferric oxide	0.8	1.76	1.24	1.44
Calcium oxide	34.7	36.17	37.23	35.56
Magnesium oxide	9.8	8.33	7.02	9.42
Sulfur trioxide	--	1.85	0.68	0.48

deviation of fiber diameter for this sample was extremely large. However, samples G-1, G-2, and G-6 (installed in 1943) exhibit reasonably well-behaved lognormal distributions, without substantial numbers of small fibers. On the other hand, sample G-7 (purchased in 1972) and G-8 (1976) exhibit characteristics similar to G-4, although not so marked as does sample G-9, installed in 1937.

Another aspect of bulk material characteristics is the dependence of airborne fiber size upon the sizes of the bulk material fibers. This dependence is examined in Figure 22 for the five production plants surveyed. The confidence limits on the geometric mean fiber diameters are displayed, and no readily apparent relationship is evident.

Another aspect of fiber size, the range of sizes of airborne fibers available for possible inhalation is also of interest. Figure 23 is a plot, on logarithmic probability paper, of the cumulative frequencies of occurrence of specified sizes of airborne fibers in four of the facilities surveyed. There are two fiber size constraints upon the hygienic significance of exposures to airborne fibers. First, a fiber must be respirable. That is, it must be capable of being inhaled, and reaching the nonciliated portion of the respiratory tract. The general consensus of informed opinion is that a fiber must be both less than 3.5 μm in diameter and less than approximately 50 μm in length to be considered respirable (Dement, 1976). Second, a fiber (once inhaled) must have a biological effect. To prevent biological effects, the NIOSH recommended standard restricts only those fibers less than 3.5 μm in diameter, and greater than 10 μm in length. Accordingly, the lines indicating three restrictions on fiber size have been marked in Figure 23. For the four facilities evaluated there, the fractions within the several size limits are as shown in Table 22.

The interpretation of the columns in Table 22 is conditioned by two important caveats: First, it is important to recognize that length and diameter of individual fibers are highly correlated. In general, the longer the fiber, the thicker it is. Second, it must be recognized that individual samples may vary considerably from the fractions given in Table 22. However, those general fractions assist in determination of the quality of exposure. Column 4 in Table 22 gives the fraction of fibers that would be restricted in the NIOSH-recommended standard (fibers <3.5 μm diameter, and >10 μm length). This fraction varied from 39% in Facilities D and I to 56% in Facility C. Column 5 presents the fraction of fibers that might be considered respirable (<3.5 μm diameter, <50 μm length). This fraction ranged from 63% (Facility C)

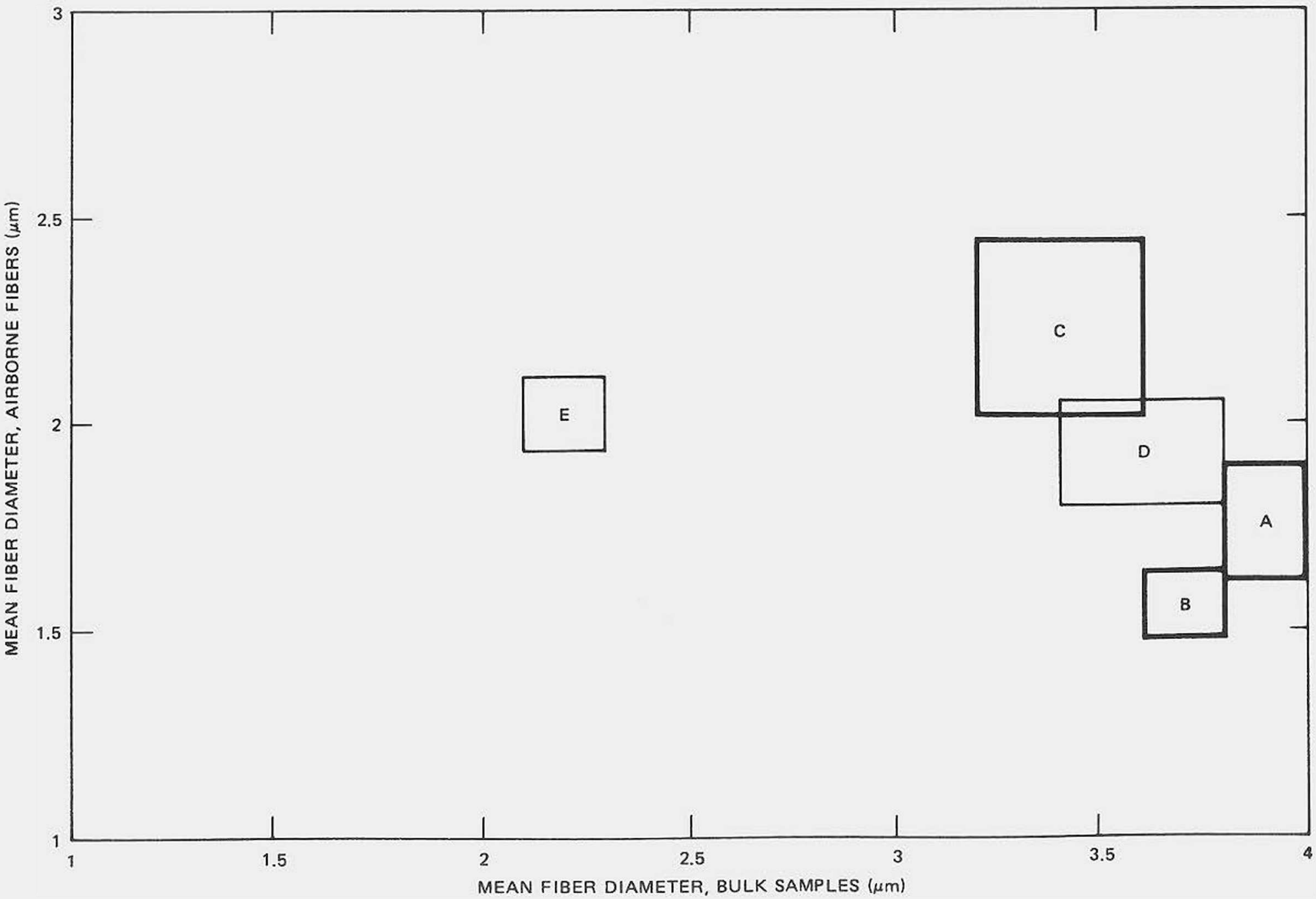
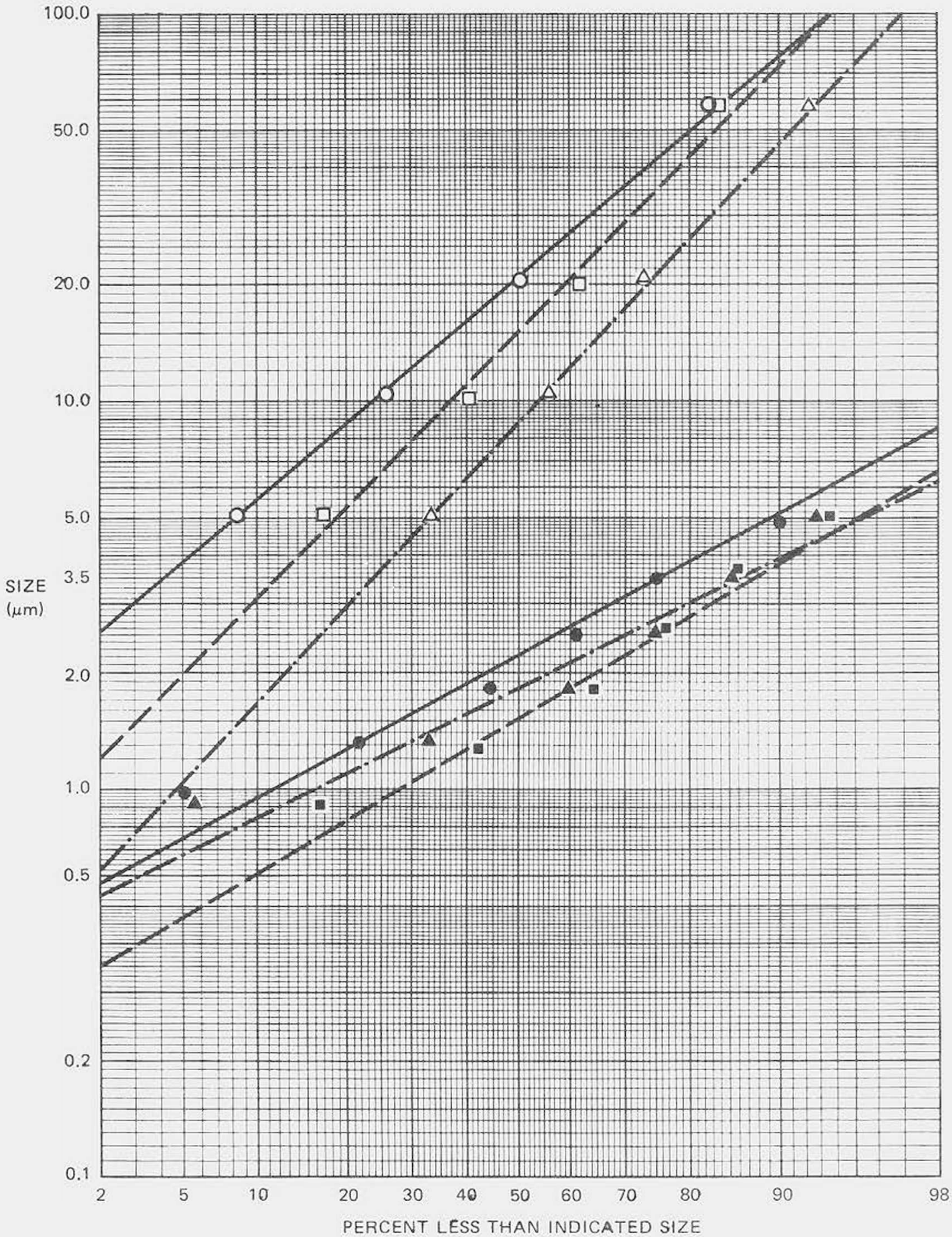


Figure 22. Effect of material mean fiber diameter on mean airborne fiber diameter.



Facility C, N = 1496
- ○——— Fiber Length: G.M. = 21 μm; GSD = 2.8
- ●——— Fiber Diameter: G.M. = 2.2 μm; GSD = 2.0

Facility B, N = 2862
- □- — — Fiber Length: G.M. = 14.5 μm; GSD = 3.3
- ■- — — Fiber Diameter: G.M. = 1.5 μm; GSD = 2.1

Facilities D & I, N = 10357
- △— · — Fiber Length: G.M. = 8.7 μm; GSD = 3.8
- ▲— · — Fiber Diameter: G.M. = 1.8 μm; GSD = 1.8

Figure 23. Cumulative frequency distributions of airborne fiber sizes in four facilities.

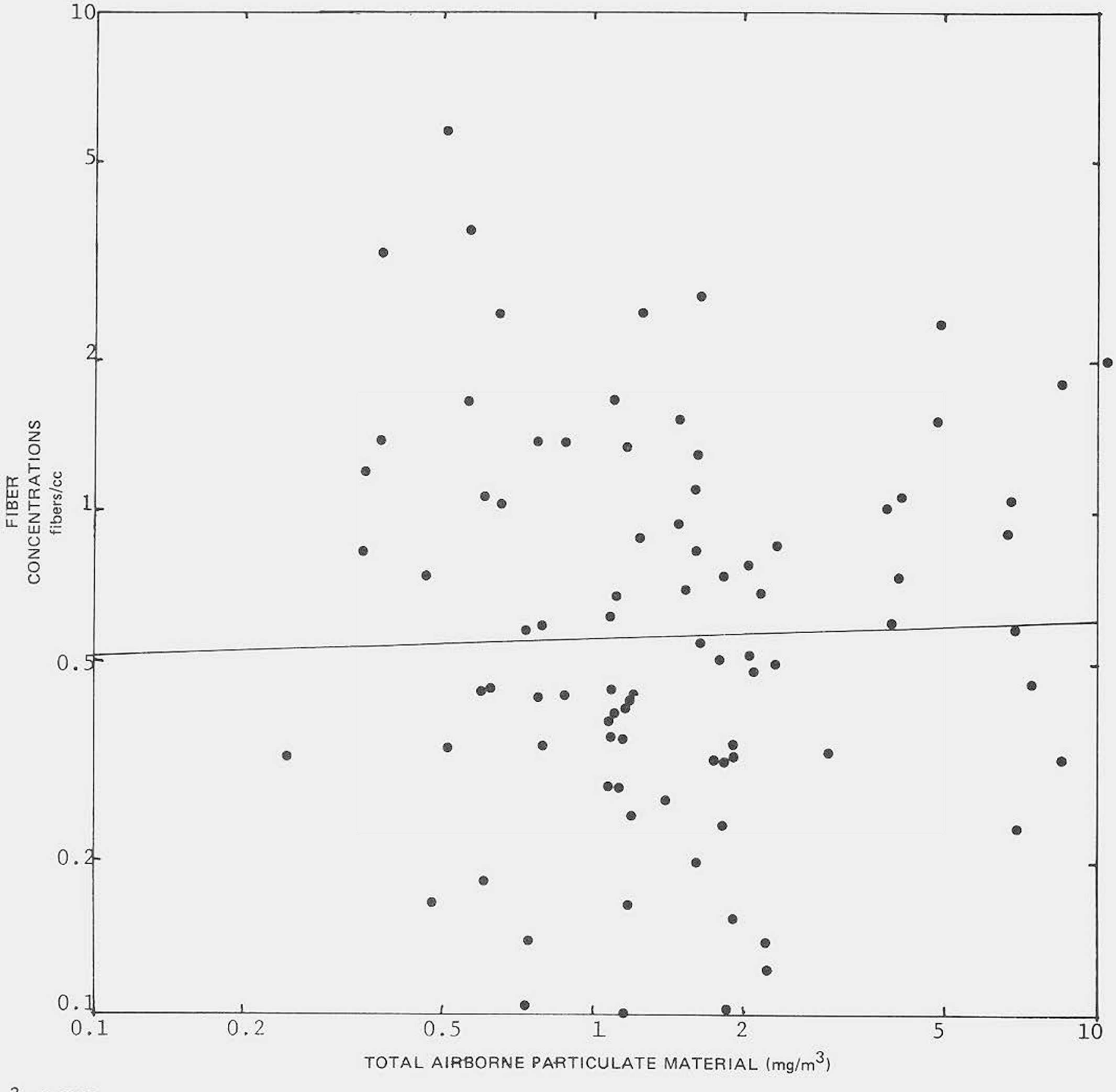
Table 22. Fractions of airborne fibers in specified size ranges for four facilities

Facility	1 <3.5 μm diameter	2 >10 μm length	3 <50 μm length	4 Col. 1 x Col. 2	5 Col. 3 x Col. 1	6 Col. 3 - (1 - Col. 2)	7 Col. 6 x Col. 1
B	0.88	0.62	0.81	0.55	0.71	0.43	0.38
C	0.75	0.75	0.84	0.56	0.63	0.56	0.42
D and I	0.86	0.45	0.92	0.39	0.79	0.37	0.32

to 79% (Facilities D and I). Column 6 presents the fraction of fibers that fell between the two length criteria (>10 μm; <50 μm). Column 7 gives the overall fraction of fibers that might be considered most hazardous. The figures in that column represent the fraction of fibers that are both small enough to be inhaled, and long enough to elicit the biological responses with which the NIOSH recommendation is concerned. These fractions, between 32% for Facilities D and I and 42% for Facility C, are representative of what might be considered to be the biologically effective fraction of the airborne fibers.

The relationship between fiber concentrations and total airborne (suspended) particulate material concentrations was considered. The correlations observed ranged from almost nonexistent (Figure 24) to fairly strong (Figure 25). In general, neither of these measures is a very useful index of the other.

Another set of correlations was performed for the total and respirable particulate material concentrations in each facility. These correlations ranged from weakly negative (Figure 26) to strongly positive (Figure 27). Again, no consistent relationships were found.



$r^2 = 0.0036$

Figure 24. Linear correlation of ℓn fiber concentrations with ℓn total suspended particulate material concentrations: individual air samples—Facilities D and I

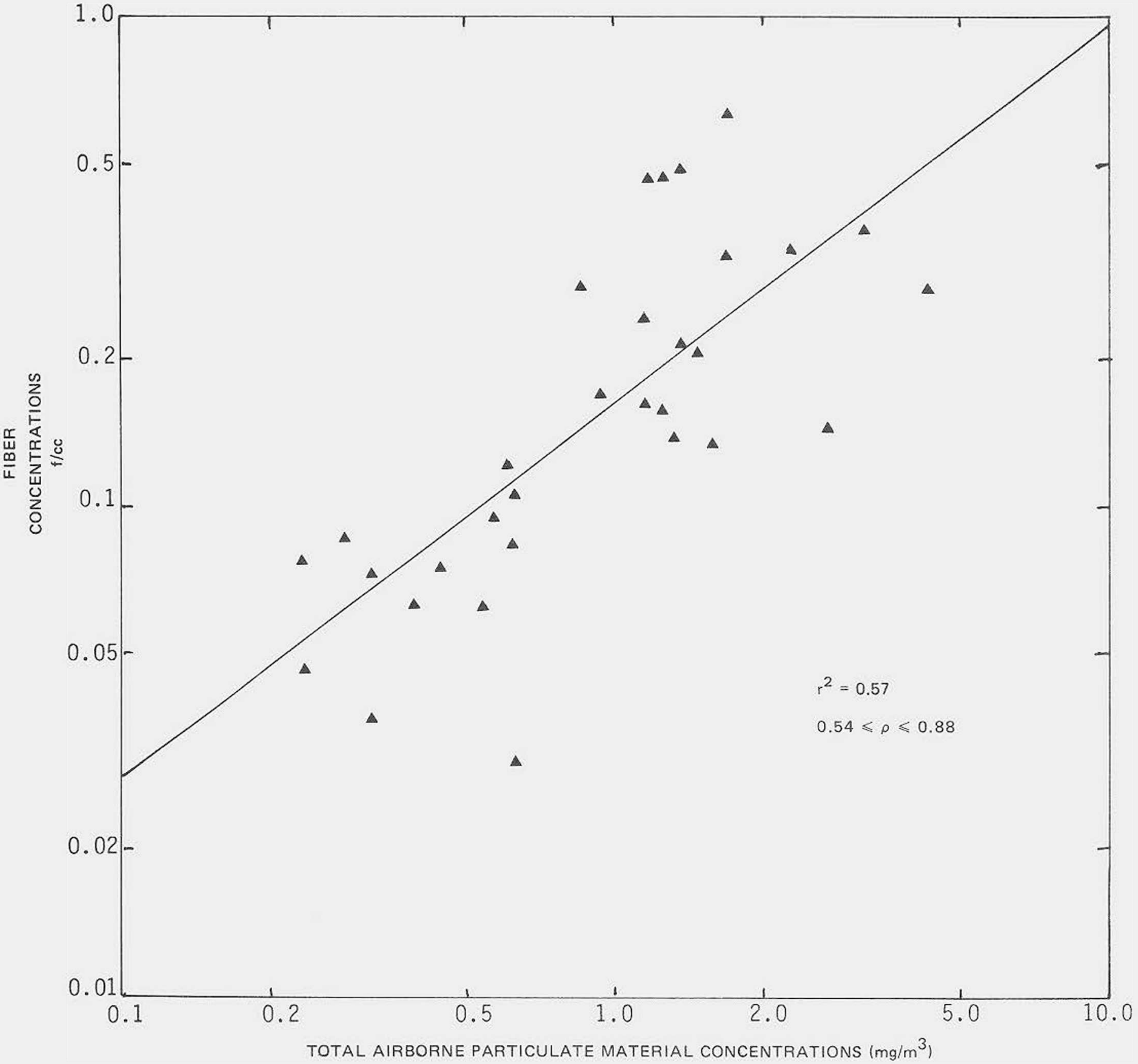


Figure 25. Linear correlation of ℓn fiber concentrations with ℓn total airborne particulate material concentrations for 30 randomly selected sample pairs—Facilities E and H

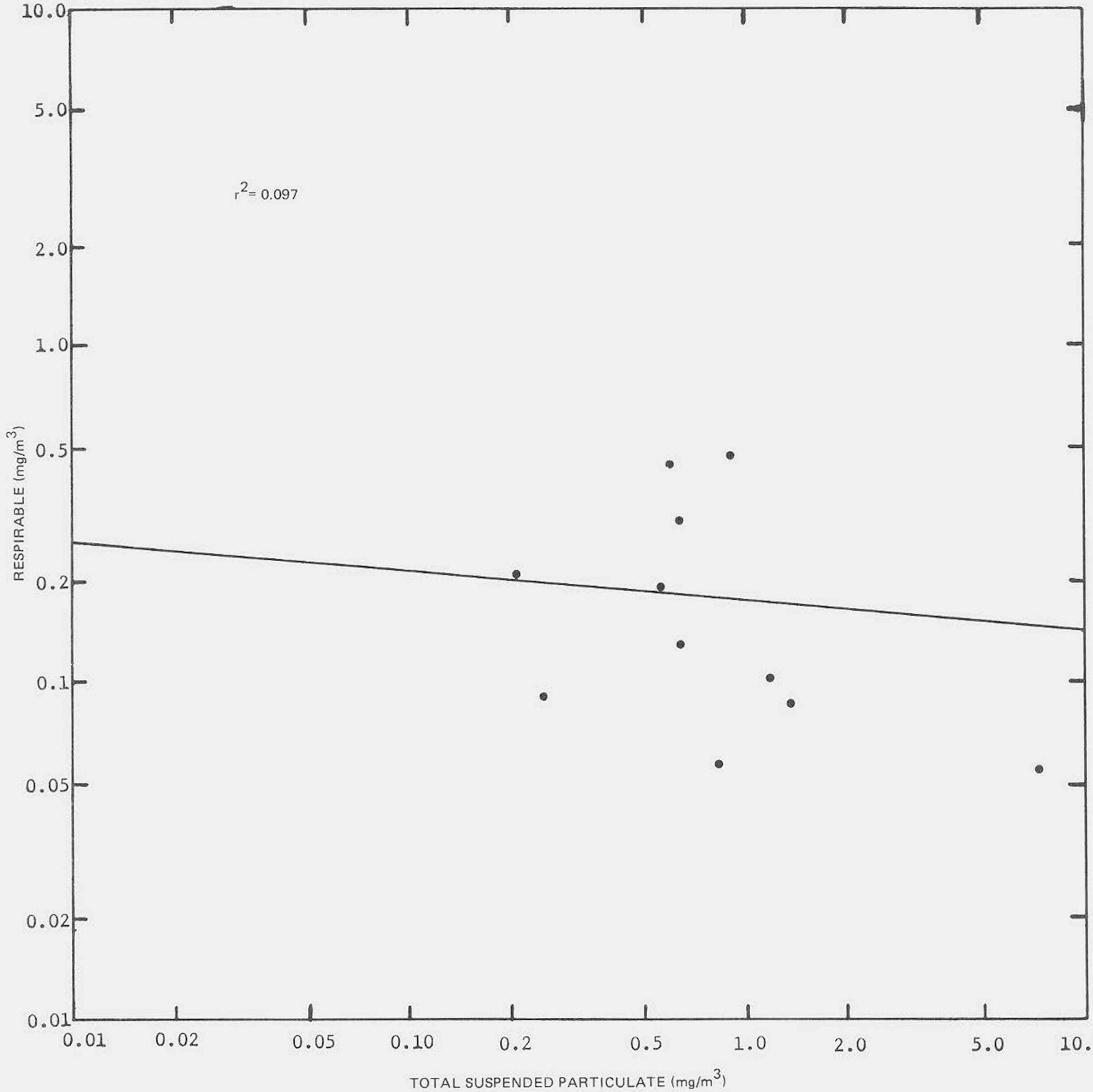


Figure 26. Linear correlation of ℓn respirable particulate material concentrations with ℓn total particulate material concentrations—Facility A

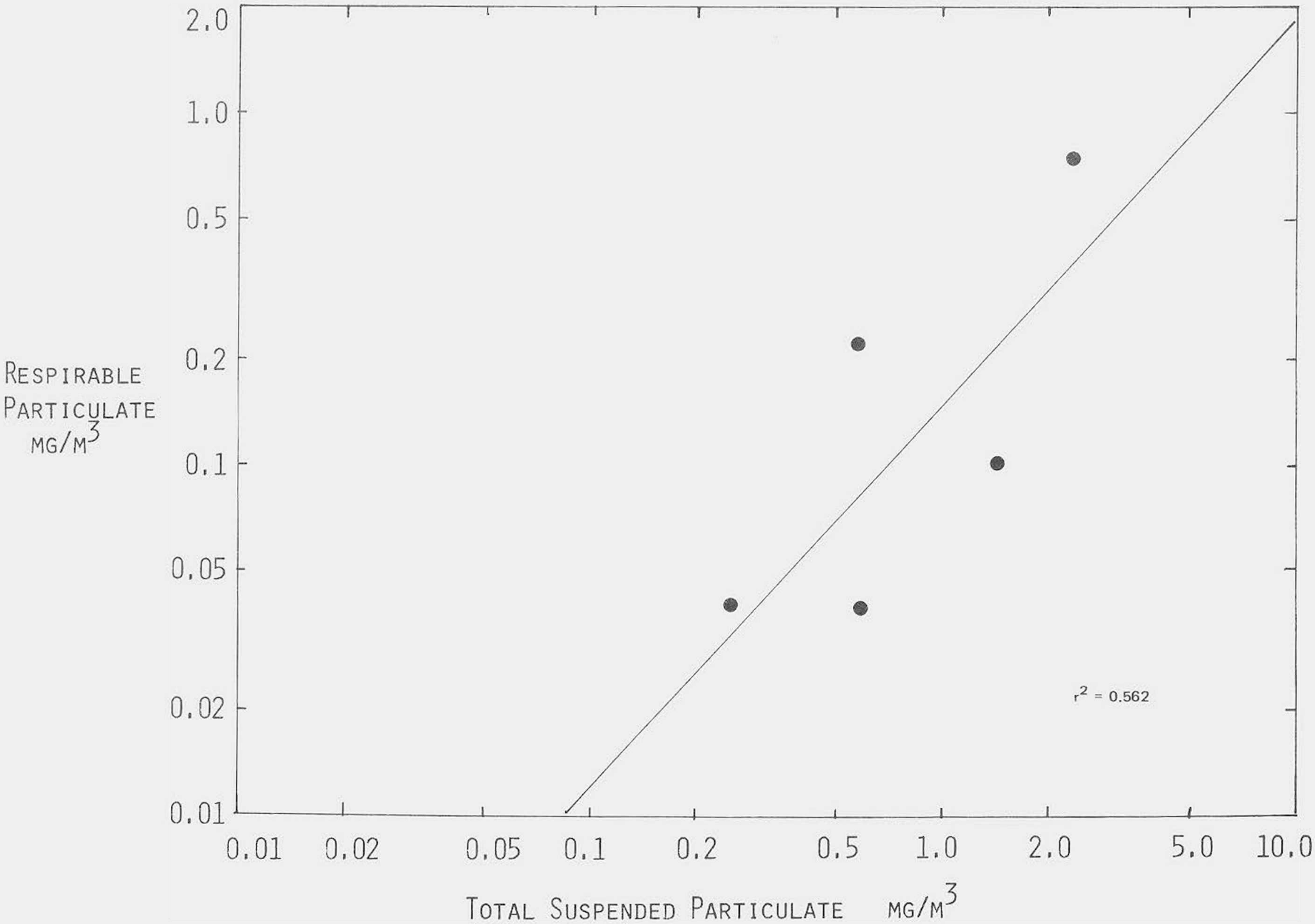


Figure 27. Linear correlation of ℓn respirable particulate material with ℓn total particulate material concentrations—Facility C

OVERALL ANALYSIS

In general, the users of mineral wool are exposed to higher levels of all forms of airborne particulate matter than are the producers (see Figure 20). This is true for fibrous, total, and respirable particulate material. Within the producer exposure categories, there are significant overlaps of the confidence limits on mean exposures. The baggers appear to be least exposed to airborne fibers, although the confidence limits on the geometric mean fiber exposures of several other exposure categories overlap those of the baggers.

The cupola chargers are clearly exposed to the highest concentrations of total suspended particulate material (see Figure 16). Because of the relatively great diversity of exposure levels, and the relatively small sample sizes (number of facilities) it is difficult to determine whether other exposure categories are at particular risk. In general, the laborers (cleanup workers), maintenance workers, and cupola operators appear to be more highly exposed than other exposure categories.

In addition, it is important to remember that on a daily basis there is a great deal of cross exposure in these facilities. That is, laborers may relieve baggers, warehouse workers, or take-off workers, and may do all four jobs in a single day. Thus, the exposures ascribed to a particular exposure category may represent a mixed exposure in several jobs.

Within the user exposure categories, a greater differentiation of job descriptions can be made, although the measured mean exposure confidence limits are broader. The breadth of the confidence intervals is the result of the relatively great diversity of exposures, as well as the relatively small number of samples. As can be seen in Tables 13 through 17 and Figure 18, the installation of industrial insulation is clearly attended by the lowest fiber exposures; the handling of dry boards in preparation for ceiling tile production is equally clearly attended by the highest fiber exposures. The peak exposures of the blowing wool installers are somewhere in the middle, as measured by optical microscopy. When the electron microscopic results are considered, however, the true extent of the total fiber exposures of blowing wool installation workers is evident. Their peak fiber exposures measured by electron microscopy are significantly higher than for any other exposure category and include many fibers with lengths far under 10 μm.

Thus, any interpretation must consider the relative biological significance of exposures to short, thin fibers. This significance is still undetermined, and its determination is far beyond the scope of this report. It is merely noted here that the fiber exposures of these blowing wool installation workers include many fibers below the limit of resolution of the optical microscope used in this study. That limit of resolution is approximately 0.4 μm.

The worker with the highest exposures to total particulate material was the plasterer applying sprayed mineral fiber fireproofing in Facility J. His exposures were in excess of 20 mg/m^3. However, his respirable particulate material exposure was less than 1 mg/m^3, indicating that the preponderance of the particles sampled were very large. Observation of his work confirms this; the major apparent source of his exposure was bounce-back of sprayed material from the surface being coated.

The workers in Facility D were exposed to higher levels of all forms of airborne particulate material than were the workers in any other production facility surveyed.

TOPICS OF SPECIAL INTEREST

Trace Metals

The trace metal exposures measured in this study were nearly all near or below the detection limit by atomic absorption spectrometry. The exposures (with one exception) were far below the relevant hygienic standards (OSHA, NIOSH, or ACGIH). That exception was for the cupola operators and a laborer in Facility A, for whom lead concentrations above the 0.2 mg/m^3 OSHA standard were measured. The cupola operators were exposed to lead fumes resulting from the melting of the lead smelter slag used as a raw material in this facility. The laborer was assigned to removal of collected fly ash from the baghouse, and that collected material had a high lead concentration. The cupola operators usually wore supplied-air respirators during tapping, which reduced their actual inhalation of lead to a small fraction of that measured. The laborer wore a half-mask cartridge respirator, but had limited training in the proper use of the respirator. Its effectiveness was thus seriously compromised, nevertheless it was probably adequate for the reduction of lead inhalation to a level below the OSHA standard.

Noise Exposures

The cupolas in all of the production plants surveyed were sources of noise. The noise came from three sources:

- The combustion air flow.
- The air or steam flow used for secondary fiber attenuation.
- The motors and bearings for the spinning discs and wheels used for primary fiberization.

Overall levels were in the range of 90-120 dB(A), with a bimodal frequency distribution.

The two fluid flow sources were the most potentially harmful; the peak frequency of this noise was usually in the 2000-4000 Hertz (Hz) range. The noise from the spinners was typically a low-pitched "rumble" in the 20-40 Hz range. The Powell process was much less productive of the higher frequency noise, because of the lack of fluid attenuation, and the overall noise levels were lower.

The engineering solution to this excessive exposure problem is not readily apparent. It is probable that major redesign of the entire process would be required. Currently, the main defense is the use of personal hearing protection combined with sound insulation booths to which the cupola operators may retire during slack periods.

Thermal Stress

Although only minimal heat stress conditions were recorded during this study, in the blowing wool insulation installations surveyed, the potential for severe heat stress in conditions of high ambient temperatures is present. The installers work in attics where they are exposed to the solar heating load that the insulation is designed to prevent from affecting the living space below. The insulation traps the heat, and the lack of effective ventilation prevents exchange of the heated air. Inside the trucks, the workers filling the hoppers are exposed to the radiant and convective heat load from the walls and roof of the truck (which usually consist of a single layer of sheet metal), as well as to the heat from the gasoline engine driving the blower. Anecdotes of temperatures as high as 175°F (dry bulb) were related by these workers.

Safety Hazards

The most apparent danger facing the user workers in the construction trades is the risk of accidental injury. For example, one plasterer applying sprayed mineral fiber fireproofing was working from a scaffold with his head above the level of the cross beams he was spraying. The overspray and bounce-back material liberally covered the scaffold and offered the potential for slipping. (If the sprayed material had been cementitious fireproofing, which is applied as a pumped slurry and is significantly more slippery underfoot, the hazard would have been much greater.) While the scaffold was being moved, the plasterer was at risk of head injury. The bounce-back material liberally coated the plasterer's glasses, and the risk of eye injury was present.

The blowing wool installers, both in the attic and in the truck, were also subject to physical hazards. The workers in the attics were perched precariously upon the ceiling joists and worked from an awkward crouching posture. Their heads were near the roofs, through which shingle nails often protruded. Where the attic contained air-conditioning equipment, they were often forced to lie prone and work their way into corners to attain full coverage of the attic floor. The worker in the truck repetitively lifted 40-pound bags of mineral wool almost to his face level to empty them into the hopper.

Fiber Size Distributions

Although the lognormal assumption has been used throughout this report because of its convenience for both exposure level and fiber size comparisons, it may not be the most appropriate distribution to use in the determination of median fiber diameter. Figure 23 displays the idiosyncracies of concern. The diameter distributions shown in that figure display a definite upward concavity. Leidel (1977) has suggested, based upon work by Santner (undated), that this type of variance from a true lognormal distribution may be cause to consider the use of other distributions, such as the Weibull or the log extreme value distributions. This suggestion has merit in that it would be desirable to more closely approximate the true median sizes of these fibers. The suggestion has the distinct disadvantage of requiring more complex calculations where statistical tests are to be applied. The topic requires additional consideration because the determination of compliance with the NIOSH-recommended standard of 3 fibers/cc applies only to those fibers less than 3.5 μm in diameter and larger than 10 μm. This determination will thus require either the counting of only those fibers, or the counting and sizing of all fibers with subsequent determination of those fibers within the relevant size range. If the latter course is chosen then the size distribution assumption is critical.

Comparisons with Previous Work

The reports of Corn et al. (1976) on exposures in two mineral wool production facilities and of Ness (1977) on exposures and mortality experience of workers in a ceiling tile production plant are relevant to this study. The results reported here are not inconsistent with those previous reports. That is, mean fiber concentrations appear to be generally rather low (≤1 f/cc) in the facilities surveyed, and differences between exposure categories are not marked. Interfacility differences are more apparent. Exposures to all forms of airborne particulate material (fibrous, total, and respirable) are higher in the ceiling tile manufacturing facilities studied (Facility D in this report; Plant A in Corn's report) than they are in the other production facilities studied.

Corn's finding that fibers less than 1 μm in diameter represent a small portion of total airborne fiber concentrations is also substantiated by this study. No statistically significant differences were detected in mean fiber concentrations determined by scanning electron microscopy and by optical microscopy in the production facilities.

Corn's conclusion that total suspended particulate material concentrations were unreliable as predictors of airborne fiber concentrations was partially substantiated, although the correlation between these two measures of workplace contamination was fairly strong for Facility E.

Less work has been done on the users of mineral wool, and comparisons must therefore be made with studies in similar trades that use different materials. One such study, of insulation installers working with fibrous glass, was performed by Fowler in 1971. The results reported there may be compared with the results from Facility K in this report. The insulation installers in Facility K were exposed to a geometric mean fiber concentration of 0.071 fibers/cc, with a geometric mean diameter of 1.9 μm.

The installers working with fibrous glass were exposed to an overall geometric mean concentration of 1.3 fibers/cc, with an approximate geometric mean airborne fiber diameter of 3 μm. It must be concluded that the exposures were different, and that the mineral wool installers in Facility K were exposed to lower concentrations of smaller fibers than were the fibrous glass installers.

Reitze et al. (1972) evaluated the exposures of sprayed fireproofing installers to airborne asbestos fibers. The material used was similar to that used in Facility J, except that asbestos was used instead of mineral wool; the method of application was identical. The worker emptying bags into the hopper (hod-carrier) was exposed to concentrations of asbestos fibers ranging from 5-22 fibers/cc (fibers > 5 µm), and the nozzle operator (plasterer) was exposed to concentrations between 30-100 fibers/cc. These concentrations were more than 100 times greater than the exposures to mineral wool fibers measured in Facility J in this report.

No direct comparison should be made between the potential health effects of exposure to asbestos and exposure to mineral wool fibers. However, the substitution of mineral wool for asbestos appears to have been dramatically effective in reducing the exposures of sprayed fireproofing workers to airborne fibers.

Past Exposures

The extrapolation from current levels of exposure to estimated past levels of exposure, without substantial data on past air sampling results, or engineering controls is extraordinarily difficult. In addition, major changes have occurred in materials and processes in the several industries and plants surveyed, and records of those changes are almost nonexistent.

From an epidemiological point of view, the past use of asbestos in many segments of the insulation industry is a major confounding variable in any attempt to relate exposure to mineral wool fibers to morbidity or mortality in the exposed populations of workers. Nearly all of the user workers studied had varying (but significant) histories of exposures to asbestos. The exceptions were the blowing wool installers (home insulation installers in Facilities F and G) for whom no history of asbestos exposure could be elicited. The production workers in Facilities D and E had been exposed to asbestos. In Facility D, the exposure lasted for a few months, but in Facility E, the exposures were probably intense and were certainly prolonged. Asbestos-containing materials were the major products of the plant for many years. As indicated above, for the sprayed fireproofing installers, exposure to asbestos was probably quantitatively higher than current exposure to mineral wool, even without regard to the probable greater biological hazard of asbestos exposure.

Past exposure levels of production workers to mineral wool fibers were probably higher than current exposure levels, with a few exceptions. That judgment is based upon observations of work practices and the recollections of plant personnel in the facilities surveyed.

The area samples taken in Facility D, in the wool room area, are representative of one such past exposure. Inside the enclosed wool rooms of many plants, it was common practice to hand shovel wool. Some of the wool was bagged for sale, some shifted to make room for additional production, and some loaded onto conveyors for transport to other plant areas. The fiber levels in those area samples (≥ 10 fibers/cc) are indicative of the possible past levels of exposure. The exposures in other plant areas were probably significantly less severe, although occasionally higher than current levels. The fiber exposures of the laborers (cleanup workers) in Facility A were somewhat higher than other workers in that facility, but were not extraordinarily high, even though they were observed to perform the following operations during the sampling periods:

- Carrying armloads of waste batts
- Using compressed air and steam lines to clean the floors
- Using pitchforks to empty an enclosed pit under the batt machine.

These operations are characteristic of past activities that might be expected to produce relatively high fiber exposures. Even those exposures, however, were not significantly different from other exposures within the plant.

The major areas in which past fiber exposures in production plants would be expected to be significantly greater than current exposures would be the aforementioned hand shoveling of mineral wool within wool rooms and possibly the exposures of baggers. Gravity-feed bagging and hand tamping and packing of the bagged material were common in past years.

Past exposures to total particulate material were unquestionably higher in most plant areas than they are currently. In particular, exposures of the cupola operators and chargers to smoke, fumes, and combustion gases were probably noticeably higher; the exposures of workers in the main plant area to smoke from the curing ovens (where resins were applied) were also probably higher. Anecdotal statements from both hourly and salaried (management) personnel in all five production facilities surveyed indicated that past exposures were substantially higher than at present. Reductions in exposures have been the result of both occupational environment control measures and measures to reduce emissions to the outside air. Emissions reduction measures have affected the in-plant environment because of the necessity for process enclosure to reduce fugitive emissions and process blow-by emissions.

The quantitative extent of the differences is questionable, but in some circumstances, past exposures were probably as much as ten times greater than present exposures. This was more likely the case for the cupola chargers and cupola operators in several of the plants surveyed. In addition, a significantly greater awareness of the potential for hazardous exposures exists in this industry today than existed in the past. This awareness has led to greater acceptance and use of personal respiratory and hearing protection in appropriate circumstances by many workers in the insulation industry.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The exposures of mineral wool production workers and user workers in 11 facilities to mineral wool fibers, total suspended particulate material, respirable particulate material, and trace metals were evaluated by detailed industrial hygiene surveys. Their exposures to noise and heat were evaluated in several of these surveys.

The production workers surveyed were found to have relatively low exposures to all forms of airborne particulate material, with few exceptions. The user workers had higher, but more variable exposures. It was generally not possible to separate exposure categories on the basis of different exposures; there was significant overlap of the confidence limits on mean exposures across the facilities surveyed.

Past exposures in this industry were probably higher than at present, and asbestos exposure was relatively common.

In addition to exposures to airborne particulate material, exposures to excessive noise levels were universal in the cupola areas of the production plants. Heat stress was a potential problem for the installers of blown mineral wool insulation.

Exposures to small diameter (<1.0 μm) fibers were not common, except in the installation of blowing wool. In those installation situations, electron microscopically visible airborne fibers were present in concentrations up to ten times greater than optically visible fibers.

SRI's recommendations are that:

- The exposures of blowing wool installers to small fibers should be evaluated further.
- The noise exposures of cupola operators should be evaluated, and engineering solutions to this problem should be sought.
- The exposures of sprayed fireproofing workers to total airborne particulate material are excessive, and suitable personal respiratory protection should be sought.
- Engineering measures to ameliorate the working conditions of the blowing wool insulation installers should be sought for both the worker in the attic, and the worker emptying bags into the hopper (in the truck).
- Additional old samples should be sought to clearly identify potential past exposures to small diameter fibers.

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APPENDIX A

PRODUCTION FACILITY DESCRIPTIONS

1. Plant A

Description of the Facility

This plant's history began in approximately 1949, when the production was moved from an original site to its current site. Two supervisors, but none of the current hourly employees of the plant were employed with the company at that time. Production and maintenance workers are all organized under one union, a local of the United Steel Workers Union. There are approximately 100 production and maintenance workers, and 15 salaried workers in the plant, including clerical staff at the main headquarters office, which is removed from the production facility. The only products currently being produced at the plant are building insulation batts, of various widths, lengths and thicknesses, and blowing wool and pouring wool. Production is currently being maintained on a three-shift (four crew) basis, seven days per week.

Medical, Industrial Hygiene and Safety Program

The only medical assistance available within the plant is first aid, administered by supervisors. Pre-employment examinations are given. Periodic examinations are given only where specific indications exist. In the recent past, exposures to lead in the cupola area have required such examinations. All industrial hygiene at the plant is handled at the corporate level, by a consultant environmental engineer.

There is no full-time local safety or industrial hygiene activity at the facility. The safety program consists of periodic meetings on topics of particular interest. All injuries, no matter how slight, are required to be reported to the immediate supervisor. That supervisor makes the determination as to whether further medical treatment should be sought from a local physician. Personal protective equipment presently used includes safety helmets, protective foot gear, hearing protection and face shields in the cupola area, disposable respirators for those production workers who desire them, half mask particulate respirators for the utility workers who remove the collected shot and collected fly ash to the dump and supplied air respirators for the cupola workers. Use of these protective devices, with the exception of the safety helmets, is optional with the employees. The workers in the cupola area, the "notchers" (cupola operators) consistently wore hearing protection, as well as safety face shields. The "notchers" also usually used supplied air respirators during the "tapping" of waste metals from the cupola. For those employees who relieved in that area, however, hearing protection was provided, but not consistently used.

Present Operation

Blowing wool, pouring wool, and batts are produced in this plant from essentially similar slag wool fibers. There are differences in the binder and dust suppression agents added, and in the fluid used for attenuation of the fibers after spinning. The process flow diagrams for this plant are shown in Figure 6 in the main body of the report.

Slag wool is produced by layer charging of locally obtained steel mill (blast furnace) slag, lead smelter slag, and metallurgical coke into cupolas. Following each cupola is a centrifugal spinner, onto which the molten slag runs, and from the edge of which it is thrown as coarse fiber.

On the batt line, additional fiber attenuation is provided by steam injection around the spinner. The fibers are pulled into a "blow chamber" with the addition of atomized oil (#2 fuel oil or 40 weight lubricating oil) and a phenol formaldehyde resin (Reax®, West Virginia Pulp and Paper Co.). A portion of the shot drops out in this process. The fibers are formed into a mat on a metal mesh conveyor belt in the blow chamber, and the fibrous mat goes directly to a curing oven to bake the resin. The conveyor speed is varied as needed to produce batts of 3-1/2 inch or 5-1/2 inch nominal thickness. The mat is then conveyed to a cooling section where air is pulled through it, and then to a series of circular saws where the entire width of the mat is slit into either four or six longitudinal sections to form individual batts. The width of these batts depends upon the desired end product, and was either 15-1/2 or 23-1/2 inches during the survey period. Following the slitting, the mat is usually enclosed in either paper (common brown Kraft) or aluminum foil-backed paper. The paper is usually applied to both the top and bottom of the longitudinally cut batt sections. Asphalt is usually applied to the bottom sheet of paper, as a vapor barrier. The paper-wrapped lengths of wool are now cut transversely by a "guillotine". They move on to a take-off table, where they are removed and stacked into compression bagging machines, from which they are bagged, taped closed and moved to the warehouse for storage or shipment.

The wool line (for production of blowing wool and pouring wool) uses a slightly different process. Following the spinner, attenuation is by compressed air. The fiber is conveyed to the blow chamber with the addition of oil (no resin) as a dust suppression agent. The fibers are collected on a moving chain screen, and then conveyed to a transversely moving conveyor belt where they are broken into clumps by a beater paddle, and transported to an air lift. They are airlifted across to a settling chamber/granulator, and then airlifted again to the top of the packing column for the bagging machine. When the batt machine is broken down, which happens relatively frequently, waste fiber from the batt line will be directed into the wool line. The blowing wool and pouring wool is pressure packed into multi-ply paper bags, then taped closed.

Past Operation

Until the early 1960's lead slag from the local lead smelters was the major raw material. At about the same time, the configuration of the spinner was changed slightly due to a proprietary process suit filed by a competitor. This change was relatively minor and did not, apparently, affect the characteristics of the fiber produced at this plant. The binders, and oil for dust suppression have changed over the years, although not dramatically. According to a local insulation contractor the material, especially blowing wool, presently produced in this plant is somewhat more "dusty" than it was in a period about 10 years ago. A steam attenuated process was used at one time, with a probability that a much wider range of fiber diameters were produced in each product, including small diameter fibers. No samples of this material were obtainable for all size analysis. The same general line of products have been produced in this plant since the 1940's and before. The production processes in the past were somewhat cruder, with gravity feedthrough chutes to the bags, and hand tamping of the bagged fiber.

Job Descriptions and Personnel

The median length of employment (seniority date) was four and one-half years at the time of the survey; the oldest employee (hourly) had worked there since 1953. There is a fairly regular flow of workers between this plant and a local steel plant, and many of the workers have experience at both plants.

The work done may be divided into four general areas:

1. Production
2. Maintenance
3. Warehouse
4. Supervision and Clerical

There are 17 production workers on each shift, plus a foreman and a shift maintenance worker. There is much interchange of jobs within each shift; each worker may fill several slots in relief. In addition, a worker may work overtime in a job category different than his usual category. The foreman and the maintenance man are the exceptions; although the foreman may relieve (for lunch and break) any of the production workers, he is most likely to relieve the "notcher" and the batt machine operator. The shift schedules are 7:00 a.m. - 3:00 p.m., 3:00 p.m. - 11:00 p.m., and 11:00 p.m. - 7:00 a.m., with 2-15 minute breaks and 1-30 minute break within an 8 hour day. The 30 minute break is usually taken in the lunchroom; the 15 minute breaks may be taken either in the lunchroom or on the loading docks.

Specific Job Categories: Payroll Titles (Number of employees on each shift in parentheses)

Charger (1): Using a small "payloader", the charger picks up alternate loads of steel slag, lead slag and coke from the (outdoor) slag pile area, and drops them into the charging door of the cupola. Some time is spent in relief of the "notchers". Exposures to the charger are most likely to be to metal fumes and coke combustion products (smoke). The cupola charging door remains open, and during periods of winds from the west, the charger will be intermittently exposed to significant amounts of fume and smoke.

Notcher (2): The notcher is responsible for maintaining a constant and adequate flow of molten slag to the spinner, where the fiber is produced. He uses steel rods to remove cooled lumps of slag from the slag trough, and occasionally "taps" the bottom of the cupola to remove collected molten metal, using an oxygen lance.

Batt Machine Operator (1): The batt machine operator is second to the foreman in overall direction of the shift work. He spends most of his time on the batt machine, adjusting settings and making sure of a smooth flow of product. His exposures to the wool are dependent upon the number of breakdowns per shift. The least experienced operators were most exposed.

Assistant Batt Machine Operators (1): Assists the machine operator. Most of his time is spent on, under or around the batt machine, and in relief of other workers.

Take-off Table Workers (2): Removes the completed batts from the machine and places them in compression packers for bagging and shipping. These workers were stated to be most exposed to fibers.

Batt Line Bagger (1): This worker (often a woman) operates the compression packers from which the compressed batts are ejected into paper bags for shipment. Although she works near the take-off table, her exposures are at a less intense level because of less intimate exposure to the material, and distance from the take-off table. The bagger may relieve the taper (below).

Batt Line Taper (1): Takes the batt filled bags and closes and tapes them with a label that indicates the product, and the date and shift on which produced. He then stacks the bags on pallets. Exposures appear to be less intense than either the take-off workers or baggers.

Batt Line Loader (Forklift operator) (1): Using a fork-lift truck, the loader picks up the filled pallets and takes them either into the warehouse for storage, or loads them directly into trucks or railroad cars for shipment. Some time is spent in relief of other workers, although this varies for each individual loader. On evening and night shifts, the loader spends significant amounts of time loading rail cars and trucks.

Batt Line Cleanup and Relief (2): These workers are responsible for cleaning up around the batt machine, and for relief of other workers. They use pitchforks, air lines and steam lines, and forklift trucks with "pusher" blades for the cleanup; they were often observed to carry armloads of waste batts during breakdown periods. Another probable major source of exposure was the cleaning operation under the batt machine, particularly under the blow chamber. The cleanup workers entered a small pit, and used a pitchfork to clean out waste wool.

Wool Line Bagger (1): This worker operates the gravity fed compression machine which compresses the "blowing" and "pouring" wool into multiwall paper bags for shipment. The bagger fits the bags onto the bagging machine, and removes the filled bags. The pace of the work is relatively constant, since the wool line is not subject to as many breakdowns as the batt line. Significant visible airborne dust was seen in the area surrounding the bagging machine, and the baggers were occasionally observed using split bags as "hoods" over their heads during particularly dusty periods.

Wool Line Taper (1): The taper tapes, closes and labels the packed bags of wool, and places them on pallets for removal to the warehouse by the loader. He (or she) also relieves the bagger as necessary. The exposures of the taper are apparently less than those of the bagger.

Wool Line Loader (1): The loader, using a forklift, moves the loaded pallets to the warehouse or into trucks or railroad cars, as with the batt line loader. This worker may relieve the batt line loader, or the wool line taper or bagger. Exposures to mineral wool appear to be relatively low.

Wool Line Cleanup (1): The cleanup worker also relieves the taper and the bagger on the wool line. Much of his time is spent sweeping, blowing, and otherwise removing settled wool fiber from the floor area surrounding the wool bagging equipment.

Utility Cleanup (1): This worker assists as needed throughout the plant. Using a payloader, he removes piles of waste from the entrances to the plant to the waste dump. He also collects and disposes of the waste (shot, slag and fiber) from beneath the cupolas, and the collected fly ash from the bag-house.

Maintenance: The maintenance workers are assigned to four major crews.

1. Shift Maintenance (4): One worker is assigned to each production crew to maintain equipment during the production shifts. The extent of their exposures to the production processes varies widely, depending upon the equipment failures reported during each shift.

2. Slag Pile: Workers are assigned (days only) to the slag pile. They receive incoming shipments of slag from gondola cars, screen it to remove fines, move it to working stockpiles for the charger, clean up spilled slag, and engage in other duties as assigned. Their major exposures are to slag and coke dust, with only limited exposure to fibers.

3. Boiler Room: A boiler room operator is assigned to each shift. He is responsible for maintaining the boilers and heaters needed to supply process steam. He makes tests of water quality, and may intermittently come to the production areas, but spends most of his time in the boiler room area, with minimal fiber exposure.

4. General Maintenance: The remainder of the crew is assigned to duties of a general mechanical craft nature. Welding, carpentry, machinery repair and electrical repair are examples. Duties may involve substantial contacts with process equipment, or virtually none.

Others: Quality control, clerical, transportation and supervisory workers are also assigned duties that may involve intermittent contact with the production processes. With the exception of the quality control man, who may experience relatively intense and prolonged exposure, these workers do not ordinarily appear to be exposed to high concentrations of airborne fibers, or other airborne contaminants.

Inspection of the Plant

Potential Exposure

The following possible inhalation exposures to potentially toxic airborne materials were noted during the intial survey of the plant: 1) mineral wool fibers, 2) smoke, metal fumes, hydrogen sulfide, and carbon monoxide in the cupola area, 3) phenol-formaldehyde resin, near the batt line, and 4) collected fly ash from the bag house during disposal.

Physical and General Safety Hazards

The cupola had very high noise levels, as well as potential exposures to molten slag, high temperatures, and infrared radiation, especially during the tapping of metal from the bottom of the cupola, and cleaning the slag trough leading to the spinner. Machine guarding was generally adequate, with the exception of the batt machine, where the two compressing belts used in the final depth sizing of the batt provide an in-running nip point that is open and without adequate protection. Personnel were observed kicking batt material between these two rollers on several occasions, especially during breakdown periods, when the mat was not flowing smoothly. Intermittent high noise levels were also noted during the use of steam and airlines for blowing floors clean.

Housekeeping

Housekeeping in this facility was a continuous problem throughout the time of the survey. A continuing effort was made by plant personnel to keep the floors clean, but with limited success, because of the continuing breakdowns of equipment. On occasion, the aisles beside the batt machine would be waist deep in discarded batts that had been thrown from the batt line. Pitchforks, forklifts, and the above mentioned air and steamlines were used to clean up this material during the time of our visit. A shower is provided for the men, with hot water, although it was reported to us that it is rarely used.

Engineering Controls

There is a continuing effort at this plant to upgrade the engineering controls for control of emissions from the several stages of the process. These include a recent upgrading of the ventilation equipment on the cooling oven; installation of the bag house to meet air pollution control requirements; a planned enclosure and isolation booth in the cupola area, together with enclosure of the spinner, to reduce exposures to lead fume and noise; and general exhaust ventilation in the main part of the plant. General engineering control in the plant was reasonable, although the general ventilation in the main plant area (currently provided by ceiling exhaust fans) could be further improved. Smoke from the curing oven, and from low temperature combustion of settled oil, resin, and dust on top of the curing oven was noted throughout the survey. Some fraction of this smoke may have been due to cupola emissions being blown into the plant. The cupola area was particularly susceptible to local weather conditions. During winds from the west, high potential exposure to smoke and fumes from the cupola was noted in the area where the "notchers" work.

There were also points noted where air velocities and enclosures were insufficient to prevent occasional escape of fibers from process equipment. The first airlift from cupola no. 2, leading to the wool line, was open and escape of free fiber was noted. It appeared that the major source of dust exposure in the plant was the handling and cleanup of the waste batt material from the batt line, and escape of fiber from the various conveying ducts in the wool line. The plant is old, and much of the equipment has been rebuilt many times. The ducts were patched by welding in multiple places, and much of the replacement equipment is fabricated on site by plant personnel.

2. Plant B

Description of the Facility

This plant's history of mineral wool production began in 1948, when it was converted from its former use as a tin smelter (during World War II) to a production site for slag wool. There is presently no active employee organization at the plant. One supervisory and one hourly employee, of the current staff, were employed prior to 1959.

There are approximately 92 employees at this plant. The products currently produced at this plant are building insulation batts and pouring/blowing wool, for the commercial market; and baled granulated wool which is wholly consumed by a subsidiary ceiling tile plant. Production (at the time of the survey) was being maintained at a three shift, five day week level, with batt production only three to four days per week.

Medical, Industrial Hygiene and Safety Program

The plant offers first aid, given by supervisors. All injuries are reported to the foreman, who administers first aid and determines whether the assistance of a physician should be sought. Pre-employment physical examinations are given before initial employment, and before return to work after substantial lay-off periods. Periodic examinations are given every five years for all employees, and yearly for those employees over 60. A retirement and disability insurance program are provided. The medical program is administered locally, by the works manager, with direction from corporate headquarters.

The industrial hygiene and environmental control programs are technically and administratively directed from corporate headquarters.

There is no full-time local safety or industrial hygiene program manager at this plant. The Works Manager, and the Personnel Superintendent, are both active in the promotion of safe practices. Principal operational responsibility rests upon the Personnel Superintendent. Periodic safety meetings are held to discuss topics of current interest, with attendance required for all employees.

Personnel protective equipment currently used includes safety helmets, protective footgear and clothing in the cupola area, side shield safety glasses, personal hearing protection (E.A.R. formable plugs) and disposable respirators. Enforcement is principally directed toward appropriate use of safety glasses, helmets and hearing protection; with that enforcement appearing to be consistent.

Present Operation

Three cupolas are in operation. One of these is dedicated to the batt (blanket) forming line, when it is in operation. The other two may be used for granulated wool; i.e., either for pouring/blowing wool production, or for production of baled wool for ceiling tile production but not for batt production. The product flow from the batt line cupola may be diverted from its usual course, and to the granulator wool lines, when demand/production of batt material forces closure of the batt line. These flows can be seen on Figure A-1 which is the process flow diagram for plant B.

Raw materials are:

Coke
Steel mill (blast furnace) slag
"Phosphate" slag (from production of phosphate fertilizers)
Iron ore

The coke is obtained locally from varying sources, as is the steel mill slag and iron ore. The phosphate slag is obtained from phosphate fertilizer operation in Tennessee. This material is carried from stock piles to a pit by the front loader operator, and then is carried by worm drive to the "unloader" station. It is then taken up into siloes by a skip hoist for storage. Gravity flow brings the material to weight hoppers, from which it is taken by a "transfer car" (small

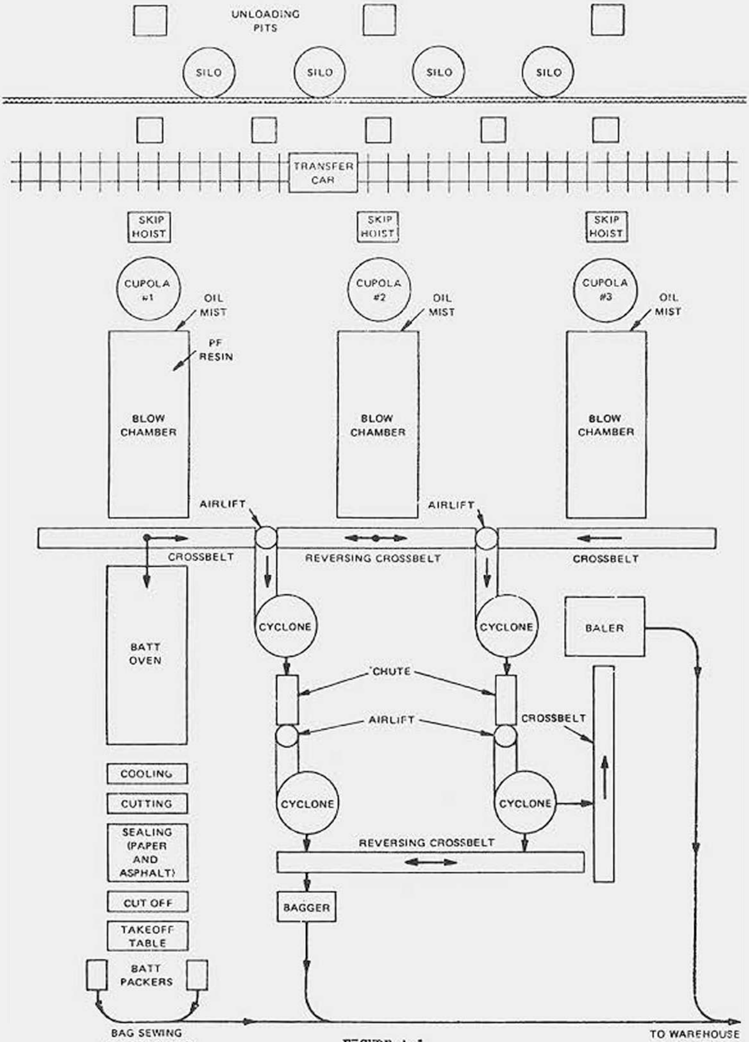


FIGURE A-1

PLANT B - PROCESS FLOW DIAGRAM (Not to Scale) rail shuttle) operated by the "charger" and offloaded into a skip hoist which delivers it to the cupola. The raw materials are later charged into the cupolas, and the molten slag flows to centrifugal spinners (spinning in vertical plane). The slag flows to the edge of the spinner, and the partially fiberized slag is additionally fiberized and attenuated by steam jets. The fiberized material is carried to a blow chamber, with the addition of oil/water aerosol mist, as a lubricant. In the #1 blow chamber, phenol-formaldehyde resin is added as a binder, when the product is to be formed into batts. The large shot is dropped out prior to entrance to the blow chamber. The fibrous mat formed in the blow chamber goes directly to the "batt machine" curing oven for curing of the resin. This is followed by cooling, slitting the mat longitudinally, application of asphalt coated Kraft paper to the lengths of batt material, cut-off to desired length, and packing. The batts are packed by a hydraulic compression packer into paper bags and then sewn shut.

The production process for pouring/blowing wool and baled wool are essentially similar, differing only in the final "packaging" of the product. The wool from the blow chamber is broken in large clumps by beaters; transported by crossbelt to an air-lift, and lifted to a cyclone. The wool is collected by the cyclone, and discharged down a chute to another air-lift/cyclone sequence. Thence it is delivered to a cross-belt, and taken to either the bagging machine, or the baler. The baler produces tightly packed bales approximately 1 x 1 x 1m, weighing about 700 lbs. each, by repetitive hydraulic ramming of collected wool. The bales are faced on two sides with heavy corrugated paper and bound with wire. The bagging machine produces 30 lb. bags of wool by a single hydraulic ejection of collected wool into a Kraft bag. The bag is then sewn shut. From this point, the product (batts, bags, or bales) may be either taken to the warehouse for storage or loaded into rail cars or trucks for delivery to customers.

Past Operations

This plant has apparently not changed significantly in its mode of operations since 1959, and has been essentially similar since the mid-1950's, according to the memory of the only current supervisory employee employed by the predecessor company. The period from 1948 to 1955 is less certain, although it was stated by the older hourly employee that the plant was much "better" now than previously. It was stated that there were formerly much higher dust and noise levels in the plant; and that the emissions control devices substantially reduced secondary exposures to re-entrained fly-ash smoke and vapors from discharge points outside the plant and that the discharge into the plant of smoke and fumes from the cupolas is less than was formerly the case.

Inspection of the Plant

The following possible exposures to potentially toxic airborne materials were noted during the initial survey:

- Mineral wool fibers.
- Smoke, metal fumes, hydrogen sulfide, carbon monoxide and fly-ash in the cupola and boiler areas.
- Hydrogen sulfide and phenolic vapors and gases from the curing oven and stack gas discharge scrubber, recirculated into the plant during unfavorable winds.
- Combustion products (blue grey smoke) of unknown origin -- apparently arising from the curing oven and blow chamber.

Physical Agents and General Safety Hazards

The cupola area had very high noise levels, as well as exposures to molten slag, high temperatures, and infrared radiation. Machine guarding was generally adequate, although it was noted that the guards were occasionally removed during operating periods, especially by maintenance personnel. Welding was carried out in open areas without adequate shielding around the site in one case. The aisles were poorly marked (markings were worn down to be poorly visible in areas with frequent forklift traffic); one set of stairs had poorly fastened hand rails; product (especially bales) was occasionally left in passageways, with less than two feet of passage space on either side.

Housekeeping

Housekeeping was a continuous problem in this facility throughout the survey. Waste batts were (during the operation of the batt machine) often thrown into the aisles on either side of the machine, to be cleaned up and disposed of when time was available. The horizontal surfaces of the area surrounding the baler and bagging machines were festooned with loose wool during all periods observed.

Engineering Controls

It was stated that a $2 million investment was to be made in this plant (in 1977) with one of the main aims to improve the environmental control measures. The equipment, especially the batt machine, is old and requires constant attention if it is to function. The duct work and chute and conveyor covers are worn and patched, and covers over transfer points are often left open, with consequent spillage of product.

During southerly winds, the smoke and fumes from the cupolas and curing oven are blown into the main production area of the plant; during easterly winds, fibers from the blow chambers (especially #1) are blown back into the area of the cupola operators.

Job Descriptions and Personnel

The median length of employment for hourly personnel at the time of the survey was approximately four years; approximately 50% had been hired in the period from late 1972 to January 1973. The official payroll titles of all plant personnel are recorded on the following, as received from the Personnel Superintendent.

There is much interchange of jobs within each shift, particularly within the Factory Labor and Factory Utility A groups. They often relieve each other, and the more skilled workers for lunch and coffee breaks. In addition, there is cross-shift relief, with e.g., cupola operators working as baggers (Factory Labor or Utility) for overtime pay.

Breaks (1-30 minute; 2-15 minute) were usually taken in the lunchroom, at the time of the survey. Smoking habits of the workers did not appear remarkable.

The Plant consists of Production, Quality, Engineering, Personnel and Office departments. All work on a fixed shift basis with the exception of the Production Department which follows a rotating schedule as follows:

1st shift 7:00 A.M. - 3:00 P.M.
2nd shift 3:00 P.M. - 11:00 P.M.
3rd shift 11:00 P.M. - 7:00 A.M.

Specific Plant job categories by department are as follows:

PRODUCTION DEPARTMENT

Job Title	# Employees	Shift
Front End Leader	3	1 on each shift
Cupola Leader	3	1 on each shift
Cupola Operator	9	3 on each shift
Cupola Charger	3	1 on each shift
Machine Tender	3	1 on each shift
Baler Operator	3	1 on each shift
Loader	3	1 on each shift
Unloader	2	1 on 1st, 1 on 2nd
Mobile Equipment Operator	1	1st shift
Loading Leader	1	1st shift
Warehouse Worker	1	1st shift
Fact. Utility A (Batt Line Take off)	5	1st shift
Factory Utility A	7	All shifts
Factory Labor	12	All shifts
TOTAL	56	

ENGINEERING DEPARTMENT

Job Title	# Employees	Shift
Mechanic Leader	3	1st
Mechanic A	9	1st
Mechanic B	1	1st
Maintenance Helper D	1	1st
Boiler Operator A	3	1 on each shift
TOTAL	17	

QUALITY DEPARTMENT

Job Title	# Employees	Shift
Tester A	1	3rd shift
Tester B	2	1st and 2nd shift
TOTAL	3	

Specific Job Category Descriptions

Front End Leader

This worker is responsible for the operation and output of the batt machine, baler and bagger. His station is near the batt machine, and he roves throughout the production area.

Machine Tender

His principal responsibility is to the batt machine, when it is operating. He will work in the same general area as the Front End Leader, although with more time spent close to the batt machine, often entering the "pit" under the batt machine to adjust and monitor paper and asphalt flow.

Baler Operator

His work is centered at the operating station of the baler. Assisted by a laborer, he uses control devices to move the bales from the machine to the loading platform (of the baler) where they are picked up by the loader. He fits a heavy, rubber-covered metal backing plate into place for each bale (to serve as a packing barrier) and fits wire around the bales, to be fastened when the bale is complete.

Loader

The loader operates a forklift truck and takes packaged bales, batts and bags (stacked on pallets in the latter two cases) from the production areas to the warehouse and from the warehouse to the loading docks. He also loads products into trucks and rail cars.

Loading Leader

This man is responsible for assuring a smooth flow of product into the warehouse and trucks and cars on the loading docks. He spends portions of his time in the production area, and in the warehouse, as well as a significant fraction (approximate one-fourth) doing paper work in an office in the warehouse.

Warehouse Worker

The warehouse worker is employed consistently in the warehouse and loading dock area, with most of his time spent loading and some spent on cleanup.

Factory Utility A (Batt Line Take Off)

These five workers (all women) work on an as-needed basis, depending upon the customer demand for batts. They typically work three or four days/week. They remove the batts from the take-off table after they are cut off, and pack them into bags with compression packers. They may also relieve other employees who are working in the batt machine area, sewing bags shut, etc.

Factory Labor

These workers perform the bulk of the entry-level jobs in this plant. They may relieve at any of the production stations (except the leadman, machine tender, or cupola or boiler operators jobs). They are often assigned to cleanup duties, and may also be assigned to move packaged products from the batt, bale, or bag lines to the warehouse; to loading duties or to other jobs involving relatively intimate contact with mineral wool fibers.

Factory Utility A (Except Batt Line Take-off)

These workers are at an intermediate level of skill between the Factory Labor group, and the Machine Operators. They may either perform labor duties, or be assigned as relief to the machine operators.

Cupola Leader

The cupola leader's duty station is on the boiler and cupola floor areas. He is responsible for maintaining an adequate temperature and loading in the cupolas and for the fiber production. He supervises the cupola operator and cupola chargers.

Cupola Operator

The cupola operators are responsible for the maintenance of adequate flow and quality of slag to the spinners. They use metal rods to remove "bridges" of hardened slag from the trough leading to the spinners; they use oxygen lances to "tap" the bottom of the cupola to remove collected metals. They may also be assigned to clean the cupolas during downtime and to replace linings.

Cupola Charger

This worker operates the transfer car beneath the silo and weight hopper areas, transferring weighed charging material (coke, slag and ore) to the skip hoists for charging into the cupolas.

Unloader

This worker is responsible for maintaining the flow of material to and from the silos. He is stationed in the silo pit, with occasional climbs to the top of the silos.

Mobile Equipment Operator

This worker operates a front-end loader ("Payloader") and moves raw materials from stock piles into the unloading pit, from where the unloader delivers it to the silos. The mobile equipment operator is also responsible for cleaning out the waste pits under the cupolas, and for taking the waste to the on-site dump area.

3. PLANT C.

Description of the Facility

First commercial production of mineral wool at this plant was in 1970, when the plant was purchased on a "turnkey" basis. There are currently approximately 45 workers employed here, on a four crew, three shift per day, seven day per week basis. Only 30 workers were available for sampling during the survey period, since one crew was in the midst of a 5-day rest period. These workers are organized under a local of the United Steelworkers of America, and have been so organized since initiation of production.

The products currently being produced at this plant are:

- "Tile" wool, produced for sale in bales to producers of ceiling tile.
- "Acid" wool; similar to tile wool, but with a maleic acid additive, for use in concrete products.
- "Blowing" wool, produced by a similar process, but bagged instead of baled for use in thermal insulation.

Medical, Industrial Hygiene and Safety Programs

All of these programs are handled at corporate level by the plant Medical Department and the Environmental Quality Control section. Pre-employment medical examinations and periodic examinations are given, according to schedules determined by the Medical Department. The Environmental Quality Control program includes industrial hygiene and safety as well as emissions control and has a competent professional and support staff, adequate equipment, and an active program of industrial hygiene, and is well-equipped to perform evaluations of the environment at this facility.

Safety programs inlcude utilization of safety committees, with labor and management representation, that take action upon worker complaints or upon observed discrepancies in operating procedures. Violations of standing safety orders are grounds for disciplinary action. Personal protective equipment currently in routine use includes: safety glasses with side shields, safety helmets, safety shoes (with metatarsal guards), hearing protective devices, and dust respirators (for those employees who desire them).

DESCRIPTION OF PLANT PROCESSES

Present Operations

Tile wool and blowing wool are produced in this facility using steel mill slag, metallurgical coke, and silicate rock as raw materials. A process flow diagram is shown in Figure A-2. The slag wool is produced by the "Powell process", (see Figure 5). Unlike conventional mineral wool plants, in this plant, the wool is taken directly by airlift to packaging, without passing into a "blow chamber" or being formed into a mat. The path of the slag wool is shown in vertical profile in Figure A-3.

An oil lubricant/dust suppressant ("Mulrex" oil, Mobil Oil Co.) is usually sprayed onto the wool in the course of its first air lift immediately after fiber formation. For the wool which is to be used in cement production, maleic acid is added as a hydrophilic agent to promote binding of the fiber to the cement.

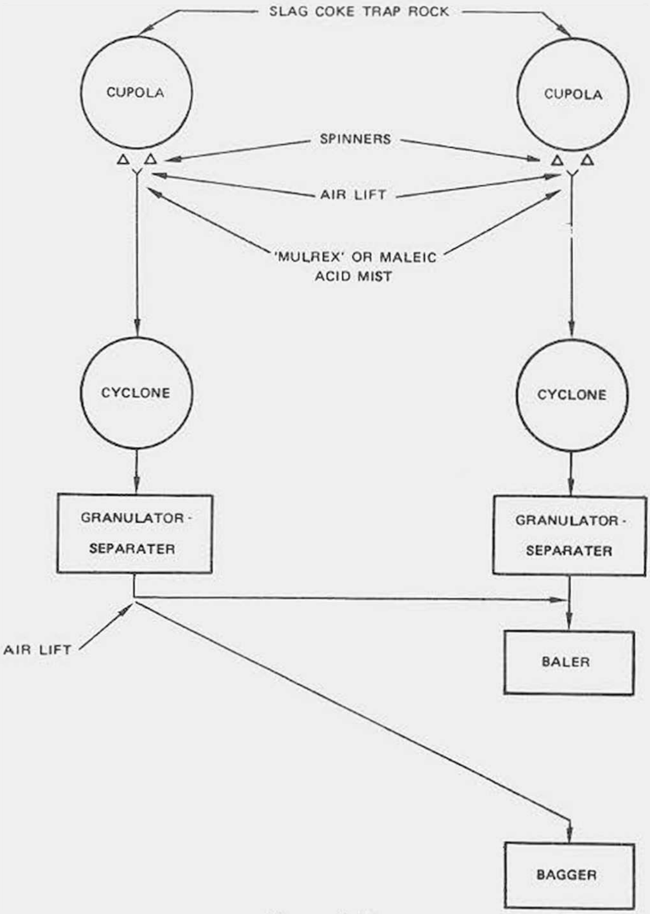


Figure A-2

FIGURE 1. PROCESS FLOW PLANT C

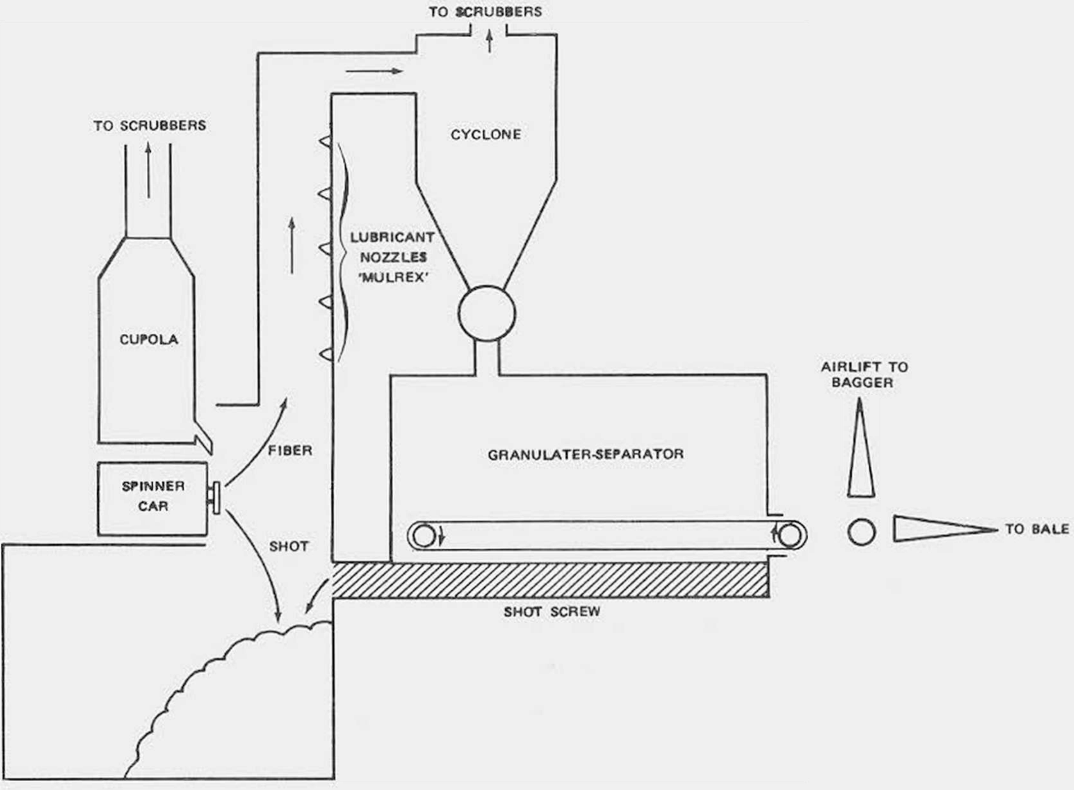


FIGURE A-3

PRODUCTION OF FIBER, PLANT C

The fiber next goes to a cyclone for collection and delivery to a granulator-separator unit where the fiber is granulated, and the shot is separated from the fiber. The shot is carried from this unit to the waste pit while the fiber is carried by conveyor belt either to the baler unit or to a second airlift/cyclone combination, and thence to the bagger. The bagging unit is a comparatively recent addition due to increasing demand for this product as a thermal and sound insulation agent. The fiber-forming process is not designed for production of insulation fiber, but it has been so used in the recent past. The baler unit is a conventional compression packer and bales are weighed and then tipped onto pallets and moved by forklift either to railroad cars, to trucks, or to temporary storage in the small warehouse area. The bags are stacked and are packed on pallets for similar moving.

Past Operations

The operations in this plant have been substantially similar since plant start-up in 1970. Thus, exposures have not changed drastically, with the exception of those associated with the bagging operation. However, it should be noted that the employees of this plant have nearly all been employed in other job categories within the steel industry, many of which may have relatively high exposures to potentially toxic materials. Some of the employees in this operation had been employed (for instance) in job categories associated with the coke ovens, and thus may have had prior exposures of potential health significance before entering the mineral wool industry. The polynuclear aromatic hydrocarbons (PNAs) were probably the most significant of these exposures, insofar as any potential carcinogenic effects are concerned.

Personnel and Job Descriptions

The hourly personnel in this plant are divided into a relatively few categories. There is significant interchange among these categories (with the exception of the millwright category), especially by the laborers who may fill any of the less skilled jobs. Some of the jobs were being filled temporarily by personnel of other corporate divisions who had "bumped" into these positions by virtue of seniority after being displaced from their regular positions.

The following hourly job categories exist in this plant:

Foreman (one per shift) - The foreman roves throughout the plant overseeing the production process. His exposures are limited because of his usual distance from the process equipment and the periods he spends in the office preparing records and schedules.

Front-End Loader (one per shift) - Much of the work shift of these workers is spend outside using a front-end loader ("pay-loader") to:

1) load slag, coke and stone into silos for transfer to the cupolas; and
2) clean out the waste pits under the cupolas and take the waste to the on-site dump (once per shift).

The cab of the "pay-loader" is enclosed and is usually left closed during dusty operations.

Cupola Operator (one per shift) - The cupola operator is responsible for charging and for maintaining adequate temperatures and adequate flows of slag in the cupolas. They are responsible for monitoring and recording the operating parameters of the cupolas and are usually involved in the "tapping" operation (to remove waste metal from the bottom of the cupola) of all cupolas. Their major exposures appeared to be to mineral wool fiber and combustion gases (probably CO, H_2S or SO_2), with significant secondary intermittent exposures to metal fumes during tapping.

These workers sometimes wear respirators during their shifts. In some cases they wore approved disposable respirators throughout their shifts; in other cases they wore respirators only while tapping; while others did not wear respirators at any time.

Assistant Cupola Operators (2 per shift) - The assistant cupola operators exposures are very similar to those of the cupola operator, except that the assistants spend more time in close proximity to the cupolas, and less time in monitoring and recording operating parameters of the cupolas.

Baler Operator (1 per shift) - The baler operator spends most of his shift operating the baling machine. His contact with the wool is limited although his station is under a crossbelt conveyor taking wool to the bagging machine. This location exposes him to a fairly constant "fallout" of wool.

Bagging Machine Operator (1 per shift) - This worker is assigned to the bagging machine when it operates. When demand for the bagged wool is low, the machine is shut down. He may be assigned to various duties in the plant, as a laborer. The bagging machine appeared to be the "dustiest" station in the plant, although the bagging machine operator was less exposed than the laborers assisting him.

Forklift Operator (1 per shift). This worker uses a forklift truck to move bales from the baler to the warehouse, and to trucks or rail cars. His major path is from the baler into the warehouse, with extended periods moving from the warehouse to the loading docks. His contact with the wool was limited, although some visible airborne fiber was generated by movement of the bales, with the amount appearing to depend upon the vigor with which the bale was picked up or dropped.

Shipper (1 only, on day shift). The shipper serves in the same capacity as a loading leader, supervising the packing and shipment of packaged wool. He spends his time between the loading dock and the warehouse, with relatively little direct contact with the product.

Millwright (1 per shift). The millwright performs the usual routine maintenance tasks in the plant. These tasks may involve welding, brazing, soldering; replacement of process equipment; small electrical repairs; and other mechanical craft work. The millwright may spend nearly all of his shift in the plant, or in the shop, which is separated from the plant. It is estimated that approximately 1/3 of his time is spent in the plant over the course of a year, and approximately 2/3 in the shop, with relatively slight exposure to mineral wool.

Laborers (3-4 per shift). The laborers may fill any of the several roles:

- Loading

  Taking bags from gravity roller feeds (direct from bagging machine) to pack into trucks and rail cars. Close contact with bagged wool, with significant probable exposure.

- Bagging Machine

  Assisting the bagging machine operator, putting bags over compression packing spout; observing automatic sealing operation, clearing jams, etc.

- Sampler-Tester

  Testing samples of wool for coverage (in laboratory water channel), ignition loss and shot content (after sieving).

- Miscellaneous

  Cleanup and routine maintenance assistance duties, and relief of other workers.

Sample-Tester (1 only). This job was not filled during our survey and so no observation of the duties associated with it was possible. It is assumed that the duties are similar to those described above for the laborer.

INSPECTION OF THE PLANT

Potential Exposures

The following are potential exposures which were noted during the survey:

1. Respiratory exposures to airborne mineral wool fiber, general particulate material, metal fume in the cupola area, and byproducts of coke combustion in the cupola area.

2. Potential skin exposures to the binding and lubricating agents used in the wool.

3. Noise in the cupola area.

Housekeeping

Housekeeping in this facility was generally acceptable during this survey. There were significant levels of settled dust on the horizontal surfaces throughout the plant, but these were usually not excessive. One unacceptable practice noted was the use of a compressed air line by the baler operator to blow off accumulated settled dust and fiber from the baling machine.

Engineering Controls

The major engineering controls applied in this plant are the emissions control devices for the removal of gaseous and particulate contaminants from emissions from the cupolas before discharge to the atmosphere. Visible suspended particulate material was obvious throughout the course of the survey. This appeared to be primarily suspended mineral wool fibers.

One area where control appeared to be inadequate, was in the cupola area during the "tapping" process. Clouds of reddish-brown fume, accompanied by acrid gas, was a usual, but momentary, accompaniment to the tapping process.

Physical Agents and General Safety Hazards

The noise levels in the cupola area were noticeably high (probably above 95 dB) but were predominantly low frequency. This is due to the lack of fluid (steam or air) attenuation of the fiber by high velocity jets. Machinery was well guarded, and no obvious safety hazards were noted. There were points where doors in process equipment were left open, and where carelessness could have led to injury, but these were in areas where only supervision or maintenance personnel would be expected to go. Occasional instances of misuse of lift trucks were noted, but no accidents or near-accidents were observed.

4. PLANT D.

Description of the Facility

This plant was constructed in 1956, and production began in 1957. The principal product (mineral wool fiber based acoustical ceiling tile) has been produced here since 1957, with additional products (discussed under Past Processes) on occasion.

The ceiling tile production aspects of this plant are discussed under User Facility I. There are approximately 80 hourly employees at this plant, which operates on a five day per week, three shift per day basis for wool and board production and on a one shift basis (days only) for tile production, depending on demand. (See Process Descriptions Below).

The only product in production at the time of the survey was ceiling tile. Production workers are organized under a Local of the Oil, Chemical, and Atomic Workers (OCAW).

Medical, Industrial Hygiene and Safety Programs

The only medical assistance available within the plant is first aid, administered by supervisors and trained hourly employees. Pre-employment examinations are given. Periodic examinations, including audiometry, are given at unstated intervals.

Industrial hygiene at the plant is the responsibility of the Employee Relations Supervisor. A recent industrial hygiene survey (approximately four years ago) was done for determination of total dust levels in the plant. No results of this survey were available.

The safety program is the responsibility of the Employee Relations Supervisor, with technical assistance as required (e.g. machine guarding) from the technical staff. Ear plugs and safety glasses are issued routinely to all employees who need them, and intermittent attempts are made to enforce their use in appropriate areas. At the time of the survey, the use of this equipment appeared to be sporadic, with only a few employees consistently wearing the supplied equipment. There is a joint labor/management safety committee that meets regularly to discuss safety matters.

Present Operation

The process flow sheet for this plant is shown in Figure A-4. The raw materials used here are quartzite, dolomite, metallurgical coke, and slag. The slag is obtained by mining an old (approximately one hundred years) local bank of iron furnace slag. As with other typical mineral wool plants, there is layer charging of a single cupola. There is a single centrifugal spinner, with steam attenuation of the partially fiberized material. The steam attenuated fibers are conveyed to the blowing chamber, with addition of oil for lubrication. The fibers then

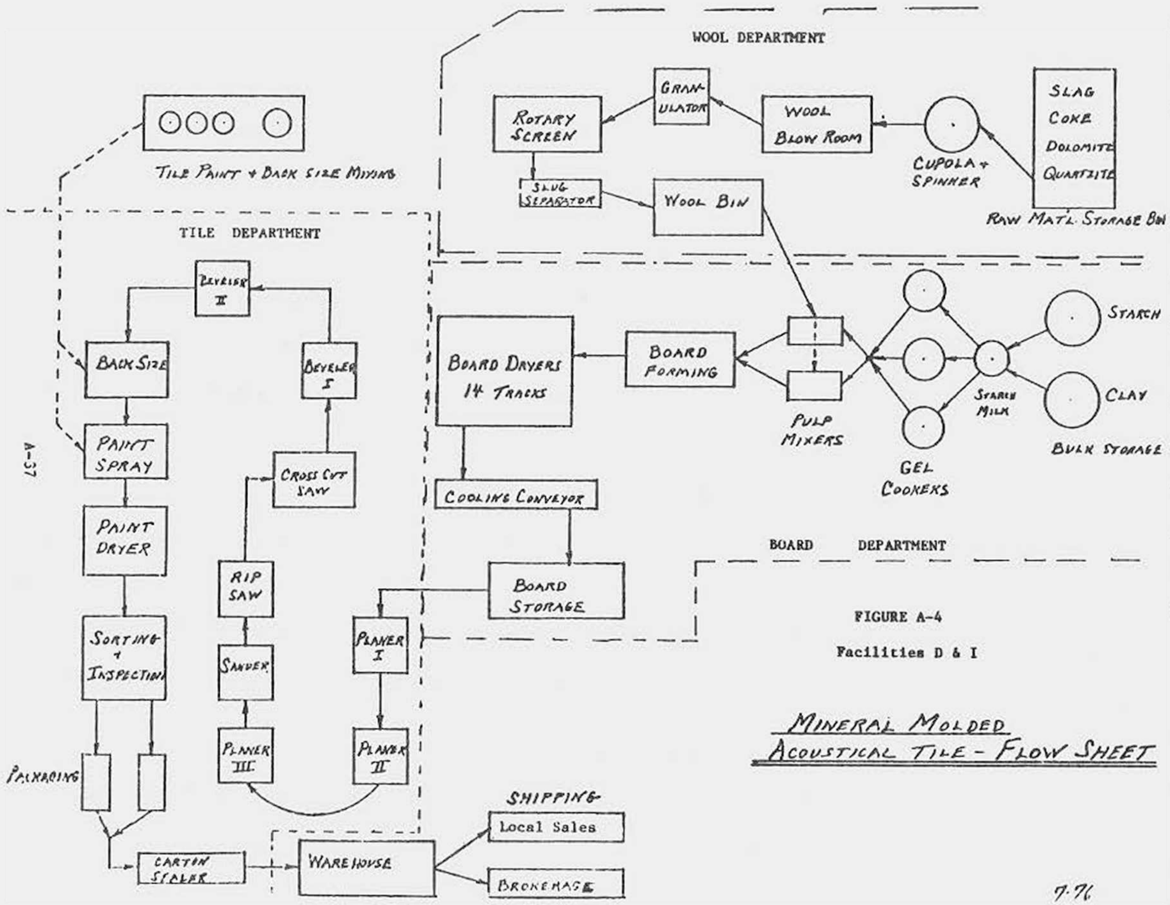


FIGURE A-4

Facilities D & I

by conveyor to a granulator/separator and from here are conveyed into a wool bin for in-plant storage, before addition to the ceiling tile mix. (See Facility I under User Facilities). All of the wool produced here is used internally, with none being sold.

Past Operations

The production of the ceiling tiles has been the same since the plant's start in 1957, but the characteristics of the fibers produced have changed slightly. Until 1961, the fiber diameter was usually slightly more than 7 um, with design specifications of 7-11 um. From 1961 to 1966, the mean fiber diameter was stated to be approximately 6.8 to 6.9 um, while since 1966 the production specifications, and examined records of mean fiber diameter indicate a mean diameter of 6.7 to 6.8 um. These fiber size determinations have been made with a light field microprojector, calibrated with a stage micrometer. The total magnification on the screen of the microprojector appears to be about 1,000.*

A potentially serious exposure occurred in the mid-1960's when it was attempted to add asbestos to the currently produced mineral acoustic tile. The asbestos was injected into the blow chamber, following production of the mineral wool and mixed with the wool at that time. It was stated that this asbestos was a brownish material, and it was probably amosite. No vestiges of this operation currently are evident, and it apparently was carried out only for a very few months.

It was stated by both management and by workers that the past conditions in this plant were significantly dustier than is currently the case.

*The true magnification of the microscopic system used, and its limit of resolution, is unknown.

Specific Job Categories

Cupola Operator - This man is responsible for the operation of the cupola and his specific responsibility is to maintain the production of wool fiber and the smooth operation of the cupola. He cleans the slag trough to permit the continued smooth flow of slag, monitors temperatures and steam flow, taps the cupola on occasion to remove accumulated molten metal, and is generally responsible for monitoring the smooth performance of the cupola. He is exposed to fume and smoke from the cupola, relatively high levels of noise, and occassional heat and infrared radiation.

Wool Utility - This worker relieves both the cupola operator and the charger, and spends most of his time cleaning up in the wool department, especially around the blow chamber and the wool bin. He removes the collected slag and shot below the cupola, and sweeps up the wool room. He has occasional very high exposures to the wool fibers, especially in sweeping (as well as the exposures of the cupola operator and the charger, during his relief periods in those positions).

Charger - The charger works in a separate building from all other workers (about 100 yards away from the main plant). This building is also used as the bulk storage area for the plant. He loads a weighing hopper from the silos holding the individual raw materials, and transfers the contents of the hopper to a conveyor, from which they are delivered to the cupola on demand. He is exposed to dust from the coke, slag, and rock. He is also exposed to intermittent high noise levels (from delivery of the coke, slag and rock into the hopper) and occasional extremes of cold in the winter. The charger may relieve the cupola operator on rare occasions.

Other job categories are discussed under User Facility I, in Appendix B below.

Inspection of the Plant

Physical Agents and General Safety Hazards

High noise levels were noted in the cupola and tile line areas. In addition, the area surrounding the spinner in the cupola was inadequately protected by barriers, leading to occasional spurts of molten slag onto the floor and in the general direction of the cupola operator.

Housekeeping

Housekeeping appeared to be generally adequate in this plant throughout the time of the survey. Piles of waste material were noted around some process points and relatively large amounts of settled dust were seen in the wool room in the area surrounding the blow chamber and the storage bin.

Engineering Controls

The enclosure around the spinner in the cupola area was insufficient to prevent occasional (especially during tapping) ejection of molten slag and metal and emission of fume and smoke into the area of the cupola operator. Additional enclosure and ventilation could be provided here.

Potential Exposures

The following possible inhalation exposures to potentially toxic materials were noted during the initial survey of the plant:

1. Mineral wool fibers.
2. Smoke, metal fume, and combustion gases in the cupola area.

5. PLANT E (See Plant H under Appendix B for description of the fabrication operation at this plant.)

Description of the Facility

The building in which the plant is housed dates in part from the 1880's when a silver and gold smelter occupied this site. Some of the original walls can still be seen. In the 1920's a mineral wool production operation was started on the site, using the slag from the smelter as raw material. In approximately 1950, major equipment purchases were made; and in 1973 the warehouse and fabrication buildings were added.

The last three years have seen major improvements in the occupational and environmental health engineering measures in the plant. These include: A waste recycling and "admix" system which was begun in August 1975 and is scheduled for completion in September 1977; local exhaust ventilation on the fabrication equipment (begun in March 1976 and completed February 1977); and a dust collection system for cutting and slotting saws which is scheduled for completion in October 1977.

There are approximately 100 employees at the plant; 30 of these are administrative, clerical, and sales workers with little contact with the product, and 70 are hourly employees in the production, fabrication, warehouse, maintenance, or other sections who may have direct contact with the mineral wool, either continuously or intermittently during the day. All production and fabrication workers are organized under a local of the Carpenters and Jointers Union. Production was being maintained on a three-shift, five day/week basis at the time of the survey.

Medical, Industrial Hygiene and Safety Program

The medical program in the plant is administered by the plant personnel department. Medical examinations are carried out at a local medical clinic. Preemployment examinations are given to all potential hourly employees. Routine annual physical examinations are given to all salaried (exempt) personnel, including the foremen (Shift Managers). Annual audiometric examinations are given to the Shift Managers, Assistant Shift Managers, Chargers, Cupola Operators, and maintenance workers.

Noise surveys are carried out occasionally by company personnel. Material Safety Data sheets are required of vendors of supplies and equipment, and recommended precautions are implemented by plant supervisory personnel. Some sampling for environmental emissions had been done in the past.

Medical records are not retained at the company. Information on retired or disabled workers is not generally available, as the pension plan is on an annuity basis, with the annuity purchased from "an insurance company". This has led to loss of formal contact with retired employees, although many retirees continue to live in the area, and informal contacts are maintained. There is no union pension plan.

The use of personal protective equipment is limited, although approved disposable respirators are available for those workers who desire them. Safety helmets are not mandatory, except for the cupola operators, who also routinely use faceshields, and are required to wear earmuffs. Disposable earplugs are available for all employees, and are required in some areas. Safety glasses are mandatory in all areas.

Present Production Operations

The products currently produced at this plant include mineral wool blankets and higher density boards, which may or may not be faced with "chicken wire" mesh, and pipe covering materials. The former materials are typically between one and three inches thick, four feet or eight feet long, and two feet wide. The range of densities at the time of the survey was between six pounds and ten pounds per cubic foot (bulk densities).

Formerly, two complete lines were in operation, but at the time of the survey only one cupola and production line were in operation. The materials used in the process include:

- "White Slag" - steel mill (BOF) slag
- Metallurgical (foundry) coke
- Mulrex® 90 lubricating dust suppression and binding oil
- Phenol-formaldehyde resin, mixed on-site with Reax® by plant personnel, or urea resin
- Domomite rock

The fiber production process begins with introduction of the coke, slag and dolomite into the cupola. These materials are stockpiled outside the main plant building, and a working stock is kept in the storage area at the north end of thebuilding. The weighed charge of the materials is batch loaded into the cupola by a conveyor. The cupola temperature is maintained at above 3000°F. The molten material flows down onto a spinning dish rotor, from which it is flung by centrifugal action. The fibers are further attenuated by an annular stream of air around the periphery of the dish. The Mulrex® oil is added (by atomization) as is the phenol formaldehyde binder. The fiber is pulled down onto a traveling wire mesh belt by downdraft air in the "wool room." The granulated waste fiber reclaimed from succeeding process steps is also added at this time. The blanket of fibers on the belt is varied in thickness for production of different density materials by varying the speed of the belt. The blanket is carried to the curing oven (500°F) for curing of the binder. The blanket is then cooled (again by downdraft air), is edge-trimmed, slit longitudinally to the desired width, and cut into the desired lengths by a guillotine. The finished pieces are taken from the end of the line by the take-off crew and either sent on to the fabrication shop for further treatment or are packed into containers for delivery to customers.

The packaging method most commonly used during the survey was "shrink wrapping" with polyethylene wrap. This was done immediately following the take off, and the shrink-wrapped packages were usually loaded directly into railroad cars for shipment.

Past Operations

Past operations included the current range of products now being manufactured at this facility. In addition, some blowing and pouring wool was manufactured as were batts for residential and commercial insulation. A process of potential health significance was the production of insulating block and cements containing asbestos in the years from 1923 (when the company was started) to 1968 and 1970 (respectively) when asbestos was eliminated from the formulations of these products.

It is not known how many of the current employees were exposed to this material, nor what the extent of the exposures to those employees involved with its production were, nor what the asbestos content of the material was.

Statements by management and hourly personnel indicated that, until the beginning of 1977, operations in this plant were under less control than at present. Smoke from the curing ovens was a substantial problem, leading to poor visibility within the plant. The "slotter" and band and circular saws within the fabrication department were also poorly controlled, with substantial emissions of waste fiber into the workroom air.

Job Descriptions and Personnel

The rate of turnover in personnel in this plant depends very much on the general economic climate; in 1976 there was virtually no turnover. Several employees have retired after thirty or forty years with the company. The management staff is relatively new; the technical engineering staff is likewise relatively new to this plant.

Senior hourly and salaried production personnel are titled according to their function, but most of the hourly personnel are called "crew persons" and may work in either the production, fabrication, yard, or warehouse operations, depending on need. In general, the hourly personnel are assigned to a fairly permanent crew, but may be pulled from that crew if need arises. The usual pattern of staffing for the day shift is:

- Production Line - 15 workers

  1 Shift Manager

  1 Asst. Shift Manger

  1 Cupola Operator

1 Charger

1 Warehouse loader

2 Asst. Loaders

5 Take-off Workers

1 Shift Maintenance Worker

1 Carton Worker

1 Stenciler

- Maintenance Shop - 8 workers

  1 Maintenance Foreman

  7 Maintenance Mechanics

- Yard Crew - 5 workers

  1 Equipment Operator

  4 Crewpersons

- Receiving Clerk - 1 worker

- Laboratory - 1 worker

The crews on the night and evening shifts consist of only the 15 production workers, except under unusual circumstances, when a press of orders may cause the fabrication crew to be called in.

Shift Manager

The shift manager is responsible for the production and fabrication operations on his shift, and for the smooth flow of materials through the process. Most of his time is spent around the production line, and particularly at the take-off station, checking the quality of the blankets and blocks as they come off the line. Some of his time is spent in the office doing paperwork. He also does some quality control analysis, taking samples of material from the line and performing ignition loss tests on a hot plate in the production area. When necessary, he may relieve other workers for breaks or lunch. He was observed to work as a take-off person, and as a cupola operator on different shifts. He is also called the foreman.

Assistant Shift Manager (Assistant foreman; leadman)

The assistant foreman assists the foreman, and mainly works around the production line. He frequently goes to the foreman's office to check the production schedule. He is the individual most likely to make the first attempt to correct any malfunction in the production equipment. He supervises the operation of the "poly wrap" machine. His exposure to the fiber is relatively more intense than the foreman, because of his frequent adjustments of the equipment.

Charger

The charger is responsible for the correct loading of the slag and coke into the cupola. He spends much of his time on the ground floor, weighing and measuring the amounts of raw materials; some fraction of that time is spent in a small room constructed to reduce his noise exposure. Significant fractions of his time are spent on the "balcony" at the top of the cupola, observing the charging operation. He is exposed mainly to the dust from the slag and coke, although some fiber may be carried up to the balcony from the wool room.

Cupola Operator

The cupola operator works at the bottom of the cupola, supervising the flow of molten slag from the cupola onto the rotor for fiberization. He removes cooled pieces of slag that may impede the flow, using a long iron rod. Much of his time is spent away from the immediate area of the cupola spinner, but near to it, so that he may monitor the flow as needed. Some time spent in the noise-reduction enclosure near the cupola.

Shift Maintanance Worker

This worker tends to be a "jack-of-all-trades"; he is the individual most likely to make adjustments and minor repairs to the production equipment if the shift manager or assistant shift manager are unable to satisfactorily repair it. He may spend much of his time around the production process, or virtually none. His activities when not working on the production machinery are those of a general mechanical craft nature; he may weld, do electrical repairs, repair other mechanical equipment, or light carpentry.

Maintenance Workers

These workers do work of a general mechanical craft nature. They performed the following tasks during the survey: electrical repairs, welding, metal cutting (with oxy/acetylene torch), operating lathes, repairing railroad tracks (replacing ties and fill), and general housekeeping in the maintenance office and shop. The foreman spent most of his time in the office, making the duty schedule and ordering parts and other duties of a supervisory nature.

Equipment operator (CAT operator) - Yard crew

This worker spends much of his time operating a Payloader, moving raw materials from the stockpiles outside the plant into the storage area in the north end of the plant, from where they are loaded by the charger into the cupola.

Warehouse loaders

The warehouse crew spent nearly all of their time moving stored packaged product from the warehouse into railcars, using a forklift and hand trucks. Some time spent moving received material from the receiving room into the production or warehouse areas.

Receiving Clerk

Spends much of her time in the receiving room, logging in and storing materials. During the period of sampling on this person, she mixed the phenol formaldehyde resin in the area near the charger, taking about one hour for this task. Much time spent walking around the plant, and in the office, obtaining approvals for orders.

Laboratory Technician

This individual spends nearly all of his time in the laboratory, and rarely goes into the production area. He performs more extensive tests on the product than the ignition loss test performed by the Shift Manager, including sieving for determination of shot content.

Crewperson:Production

The main duties of the production crewpeople are as take-off operators; removing the blankets from the end of the production line and stacking them on skids or packaging them for shipment. However, this is a general labor category, and those listed as crew-persons may work in the fabrication shop; they may be assigned to cleanup; they may be assigned to work outside the plant, helping the yard crew. Similarly, the fabrication crew may assist with the production tasks, or in the warehouse, or in loading railcars or trucks.

Inspection of the Plant

The following possible inhalation exposures were noted during the initial survey of the plant:

- Mineral wool fibers
- phenol-formaldehyde resin, near the curing oven
- Dust from slag and coke in the charging area
- Smoke near the curing oven
- Combustion gases near the cupola

Housekeeping

The housekeeping in the plant was generally quite good, in large part due to the waste wool disposal system discussed below, under engineering controls. The older portions of the plant, around the cupola, were less well kept than the newer portions; some of the floors in that older portion dated from the 1880's and they showed the effect of their age. It was difficult for the personnel assigned to cleanup to remove all waste material from the cracked, uneven, and otherwise imperfect floors. Personnel assigned to each shift cleaned up as necessary at the end of the shift, and during the shift when needed.

Sanitary facilities were adequate and clean; hot and cold running water and adequate toilet facilities were provided. The lunchroom was somewhat less clean than is desirable, but it was generally adequate.

Engineering Controls

The plant is in the midst of a continuing effort to upgrade and replace existing controls. The management staff is heavily technically oriented, with extensive experience in the industry. Emission controls for compliance with EPA and state agency regulations on emissions to air are being installed on the curing oven, and have been installed on the cupolas. These controls, because of the need to control fugitive emissions, and blow-by streams, have aided in the control of contaminant levels in the workplace, as well.

One unique arrangement (unique for the mineral wool industry) was the waste disposal and recycling system installed in the production and fabrication areas. The system (which is proprietary) returns waste material to the process stream, with substantial cost savings, as well as substantial apparent benefit to the cleanliness of the plant.

APPENDIX B

USER FACILITY DESCRIPTIONS

1. Facility F - Description of the Facility

The company surveyed is a general commercial and residential insulation contractor, which began business in the mid-1960's. At the time of the survey this company was the largest volume insulation installer in its local area, averaging approximately 400 installations per year. The employees of the firm include the owner and an office clerical employee, and (usually) four to six installers. Although the installers have been organized in the past under the Carpenters Brotherhood, the operation did not have a contract with any labor organization at the time of the survey. The usual work week is five days, eight hours per day, with overtime rare.

Health and Safety Program

No formal health or safety program is currently in operation, although the owner brings to the attention of his employees items of particular interest that relate to safety and health. The major emphasis is on prevention of respiratory irritation due to mineral wool and fibrous glass, and on measures to reduce effects of heat stress. The former is accomplished by issuing and encouraging the use of disposable respirators during blowing operations; the latter is provided for by opportunities for rest breaks during installations in particularly hot environments.

Present Operations

There are two major operations performed by this company. First (usually in new construction), batts of insulation material may be installed in the walls and ceilings for thermal insulation ("batting"). Second, bagged insulation material may be blown into the attic or wall spaces by a pneumatic blower. The materials used by this company are predominantly (>90%) slag wool supplied by a local plant, and approximately one-half of the jobs performed are "blowing" applications. In a small fraction of the installations, fibrous glass materials are used. Most installations are in residential structures, with perhaps 40% of the installers' time spent in insulating commercial structures.

In the blowing operation studied for this report, the installers use a truck with a gasoline powered blower, into which the bags of insulation are emptied by one worker. The material is loosened by rotating fingers in the hopper of the blower and then pulled into a centrifugal fan and thence propelled into a corrugated hose that carries the materials to the site of application. The end of the hose is handled by the other worker, who applies the insulation material to the specified depth, to give appropriate insulation effectiveness. The usual depth now is 10-1/4 inches for an R-value (thermal resistance value) of R-30. In the case of existing sturctures, the existing insulation will be supplemented by adding new material on top of the old. Figure B-1 is a schematic of the process by which the material is applied, and Figure B-2is a representation of the installer working in the attic.

Past Operations

Past operations were similar to those at present. More fibrous glass was used, there was a smaller emphasis on re-insulating existing structures (with consequent lesser exposure to collected general dust in attics), and the (mineral wool) material used was stated to be less "dusty" than at

FIGURE B-1

SKETCH OF INSTALLATION PROCESS - BLOWING WOOL

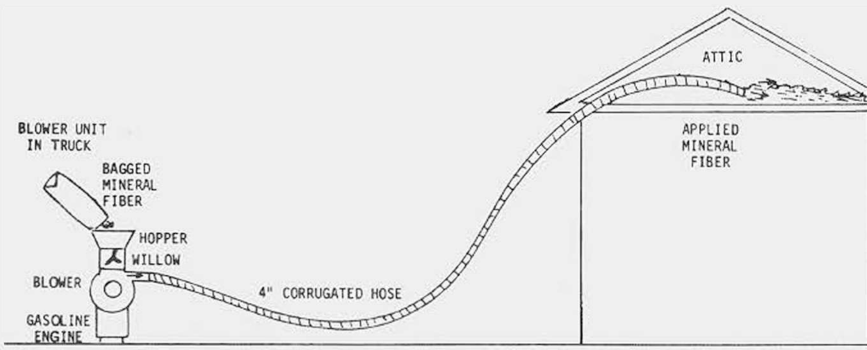
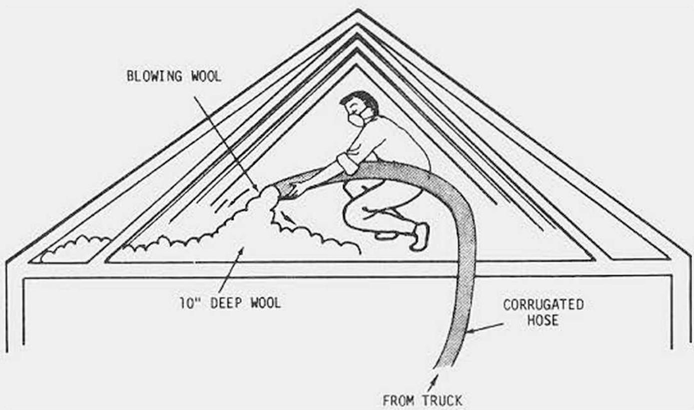


FIGURE B-2

INSULATION INSTALLER "BLOWING" MINERAL WOOL INSULATION IN ATTIC



present. However, the installers often did not wear dust respirators.

Job Descriptions and Personnel

Although the installers have been members of the Carpenters' Union in the past, the company does not currently have a union contract. This was stated to be due to recent competition from non-union contractors. One of the installers had been employed in this trade for less than two years; the other had nearly 20 years of experience.

Specific Job Categories

There is little specificity of job category in this trade. The installers will "trade off" on the two jobs seen. One will work in the truck, emptying bags of mineral wool into the hopper; the other will work inside the house, directing the flow of material from the hose.

INSPECTION OF THE FACILITY

Potential Exposures

The major potential exposures seen were to mineral wool fibers. The gasoline-powered blower was a potential source of carbon monoxide, and other exhaust gases. In existing structures, the worker handling the hose was stated to be liable to exposure to "stirred-up" settled dust

Physical Agents and General Safety Hazards

The major physical agent to which these workers were exposed was heat. It was stated that the installer inside the attic was exposed (during installations in poorly ventilated attics on hot days) to temperatures of 175^{o} F (DB). The worker in the truck is also exposed to relatively high temperatures, due to the radiant (solar) heating of the truck body and the heat generated by the blower.

There were several potential safety hazards noted. The most severe of these were the hazards facing the worker in the attic. In order to reach all corners of the attic, this worker must often crawl over exposed studs, pulling the hose with him. The head space is limited (often three to four feet) and nail points driven through the roofing, and into the ceiling joists are often exposed. The necessity to balance on the ceiling joists (to prevent breaking through the ceiling) requires awkward positioning and movement on occasion. Figure B-2 is a representation of this worker's "typical" position. This worker did not wear a safety helmet.

The worker in the truck is also potentially exposed to safety hazards. Of these, the most severe is the potential for hand injuries due to the worker distributing the mineral wool in the hopper, when he is potentially exposed to the "willow" prongs. Because of the position of the hopper, he must also repetitively lift the 40-pound bags of wool to above shoulder height, in order to empty them into the hopper.

Housekeeping and Sanitation

Housekeeping on-site was good. The site of installation was cleaned before leaving, as was the area around the truck. Sanitary facilities were not limited to those generally found on construction sites, since water service was available in the house in which the installation was made.

Engineering Control

Engineering control for the worker in the attic is limited, and no easy methods for improvement were noted. The nature of the structure dictates the existing ventilation and heat-control equipment, and major changes cannot be made. The only way in which ventilation could be improved would be by providing a portable blower, but the air exchange provided by this means would be small, since only one access opening into the ceiling is usually available, and the attic vents are often small, especially in older houses.

The worker in the truck was similarly unprotected by engineering control devices, but the potential for process redesign, and application of ventilation controls is greater.

2. Facility G - Description of the Facility

The company surveyed is a general commercial and residential insulation contractor which began business in 1931. The employees of the company include an office worker and approximately ten installers. This company is very similar in structure, organization and clientele to Facility F (above), and the general comments there are appreciable. The exceptions are:

Present Operations

The company purchases mineral wool from the lowest priced supplier and usually uses either of two major brands. Although fibrous glass products are used, approximately 85% of the installations are of mineral wool. Approximately 75% of the installations are residential.

Past Operations

Even more mineral wool was used in the past than currently with less fibrous glass.

Job Descriptions and Personnel

The insulation installers employed by the company had from six months to 20 years of experience in this trade.

Inspection of the Facility

Exposures to physical and chemical agents and to safety hazards were similar to Facility F.

3. Facility H - Description of the Facility

This is the fabrication operation associated with Plant E in the Production Facilities section of this report. The general description of the environment and plant found there also applied to this facility, with the exceptions and additions noted below.

Current Fabrication Operations

The separate fabrication operation consisted, at the time of our survey, of application of wire mesh facing to both sides of the blankets, which were either four or eight feet long. This was accomplished by a crew of (approximately) 12 workers in the fabrication shop, working at two long tables. The blanket was placed on the table, a piece of wire mesh the size of the blanket laid on top of it; wires with a hooked end pushed through, thus retaining the first piece of mesh; the blanket was then turned over, another piece of mesh applied, and the ends of the hooked wires "crimped" to hold the second piece of mesh. These blankets are commonly used for boiler insulation.

Another fabrication operation is also used at this plant, although it was not observed by the survey team. Pipe covering is made by this operation, in a "slotter." The process produces a block of high-density mineral wool fiber, with slots running longitudinally, and with beveled edges, such that it can be "wrapped" around half of a pipe, providing thermal insulation. The thickness of the block used is dictated by the thermal insulation resistance desired, and the diameter of the pipe dictates the width of the block. The depth and number of cuts made is dictated by the inside and outside diameter as is the angle of the slot cut into the sides of the block. The equipment on which this product is fabricated is a "one-of-a-kind" machine designed and built by the company. Very small diameter pipe insulation (e.g., two-inch O.D. pipe) can be made by cutting blocks with a half-annular ring cutter that forms half-round pipe covering sections from rectangular blocks, without the slots.

Job Descriptions and Personnel

The fabrication shop consisted, at the time of the survey, of 12 workers. These were: one assistant foreman and 11 crewpersons.

Assistant Foreman: Fabrication

This mainly is a supervisory position, but the assistant foreman may perform duties similar to those described below for the fabrication crewpeople.

Crewperson: Fabrication

Works on a table about 4 feet high, 8 feet long and 2 feet wide, performing the wiring of the blankets described earlier, and then packing the mesh-covered blankets into cartons for shipment. Duties also include moving skids of blankets from the production area to the fabrication area, stencilling cartons, stapling cartons, cutting wiremesh to proper size, and cutting the wire hooks used to hold the wire mesh onto the blankets.

Engineering Controls

The table saws used in the preparation of material for quality control testing, and in the sawing of blocks for fabrication into pipe covering, have newly installed local exhaust ventilation systems. Their effectiveness was not evaluated, but the configuration of the shrouds around the saw blades, and the size of the duct work, appears to be suitable for their intended purpose.

Inspection of the Facility

The fabrication workers are exposed only to the bound fibers; they are rarely exposed to smoke, combustion gases, or uncured resins. Otherwise, the comments given under Plant E are appropriate.

4. Facility I

This is the ceiling tile production portion of Plant D. The general comments listed there should be consulted.

Present Operations

The stored wool is taken from the wool bin by conveyor belt/skip loader to the next step, the formulation of the board mixture. As shown on the flow sheet (Figure A-4), wool is added to the tile mixture at an intermediate point, just before pouring into the boards. Following preparation of the mix of starch, clay, old tile dust, wax, guar gum and sodium hexametaphosphate, which is cooked to a gel, the wool is added and the mixture is mixed thoroughly. The collodial dispersion resulting is dropped onto 2 ft. x 6 ft. wire mesh trays, and the top scraped (for the characteristic texture of these boards) by a rapidly reciprocating bar as the tray goes to the board drying oven. The dried board goes to a cooling conveyor and is then stacked for storage until it goes to the tile line. The board is planed on one or both sides (face and/or back) and sanded on the face. The length of the 2 ft. x 6 ft. board is then trimmed longitudinally to an exact two foot width and then cut across to produce a square panel two ft. x two ft. This panel is then rabbeted with an edge mill (listed on the flow sheet as the beveler) and is now ready for the final stages of sizing, painting and packing. The sizing is a starch spray applied to the back of the tile. The face of the tile is sprayed with paint, which is then dried in a radiant heat dryer. The sized, painted, and dryed tile next goes for sorting and inspection, packaging, storage, and final shipment.

Past Operations

For a period of a few years, in the mid-1960's, a ceramic product was produced at this plant. Production was intermittent and it was an experiment that was not commercially successful. This was apparently a baked, brittle, ceramic material produced from clay and some silica. This was a somewhat dusty operation, although from observation of the equipment formerly used in this operation, it appears that exhaust ventilation was provided at appropriate points.

Recent enclosure of the planing, sanding and milling machines in the tile department for noise and dust control, were particularly mentioned as being beneficial to current conditions.

Specific Job Categories

Texture Control Operator - The texture control operator is the most skilled of the workers in the board department. It is his responsibility to determine whether the formulation of the mix of raw materials is adequate to produce acceptable tiles. He works below the mixing hopper at the start of the wet board line, and supervises the amount, depths, and weights of the board mix delivered to each individual tray, before drying. He also operates the reciprocating texture spreader.

Board Utility - The board utility man is responsible for cleanup around the board production area. He also will relieve almost any of the other workers on the board line. His major exposure is to the dust from sweeping up and discarding the broken boards and tiles.

Stock Preparer - The stock preparer measures, cuts, pours, and otherwise prepares the raw materials that go into the mixers for production of the board slurry. He may relieve the stock mix operator or the texture control operator. He is exposed to starch, clay, and all the other components of the board mix.

Stock Mix Operator - This worker is responsible for the proper mixture of the wet slurry, and for its delivery to the production line at the texture control operator station. He may relieve the stock preparer or the texture control operator. He is a skilled operator, and is second to the texture control man in his skill level. He is exposed to all the components of the board.

Oven Loader - The oven loader takes stacked carts of wet board, and pushes them into the oven. He is exposed to the wet material only.

Oven Operator - The oven operator removes the carts from the down-stream end of the oven, after they are dried. He then pushes the carts, using a rail-mounted car, to a position where they are unloaded automatically and go to the dry helper.

Dry Helper - The dry helper removes the dry boards from the wire trays and pushes the boards onto the one conveyor line while leaving the trays to be returned to the oven loader. The dry helper uses a long stick to push the finished boards onto the delivery line, and pushes the unloaded carts back to the oven loader as well.

Humidifier Operator-This title is now a misnomer, since humidity control of the dried boards is no longer practiced. The humidifier operator unloads the dry, cooled boards from the cooling rack, and stacks them on pallets for delivery to temporary storage, and eventual use on the tile line. He is exposed to dust from the boards.

Line Operator-The line operator is in charge of the tile line production. His station is in the approximate center of the U-shaped line, and he spends most of his time monitoring the flow of product. He is relatively less exposed to the product, than most other workers.

Line Attendant- The line attendant assists the line operator, and spends a good deal of his time in fairly close proximity to the operations of the various pieces of equipment, making appropriate adjustments on the operating machinery. He is exposed to occasional relatively high levels of dust during his duties.

Tile Utility- The tile utility worker is responsible for cleanup, and for relief of the other tile line workers. He also moves the boards from storage and prepares them for passage through the tile line.

Paint Operator- The paint operator monitors the performance of the automatic paint spraying machinery, and is responsible for the smooth flow of paint, and size, through his section of the line. His contact with the product is limited, but because of the relatively inefficient exhaust ventilation provided, he may be exposed to significant amounts of aerosolized paint.

Sorter Packers-The sorter packers receive the painted and prepared tiles, inspect them for defects, and put them into cartons using automatic packing machines. They rotate through the four positions available in the sorting-packing position, and also man the station feeding the boards into the tile line.

Stacker-The stacker takes the prepared cartons from the line following the sorting-packing station, and seals the cartons and stacks them on pallets ready for shipment.

Line Setup, Utility Setup-The setup men come in the evening, following the completion of the day's work on the tile line, and prepare for the next day's operations. They use compressed air lines to blow collected dust from the machinery, pile it up and sweep it up using brooms. They then make any appropriate adjustments to the equipment and replace cutting blades etc., with the assistance of the maintenance department. Their exposures are high, but variable.

Traffic Department (Warehouse Workers)-The warehouse workers move throughout the warehouse, loading dock, and to some extent, the main plant area. They may be exposed to any of the materials produced or used in the plant. They most often work with forklift trucks and do not have an exceptionally high exposure to the product.

Paint Technician-The paint technician mixes vats of paint that are taken by the paint operator to connect to the spray nozzle for spraying the tile. His job involves relatively intimate contact with all of the paint components.

Lab Technician-The lab technician works entirely in the laboratory, making tests of wet strength, and other relatively sophisticated measures of performance of the tiles. Some time is spent in chemical analysis and optical miscropic analysis.

Wool and Board Inspector-The wool and board inspector collects samples from the production line, and makes tests, principally upon.the boards before fabrication into tiles. He is exposed throughout the plant, and does some cutting,(using a table saw)of the board to obtain pieces of appropriate size for testing.

Tile Inspector-The tile inspector spends most of his time in an anteroom near the tile line, making tests on the tile for such things as deformation under stress, bowing, and visual acceptability of the produced tiles.

Maintenance-The mechanics maybe very highly exposed to the production processes, or spend most of their time in the maintenance shop. They do duties of a general craft nature, including electrical repairs, general mechanical repairs, welding, brazing, and soldering. The utility mechanics are responsible for maintenance and upkeep of the air pollution control devices (bag house) and for applying a filter coat of limestone to bags after cleaning for control of SO_2 emissions.

General Plant Employees-The storeroom attendant and the janitor spend major portions of their time respectively, in the storeroom and in the main office suite. They are only occasionally and intermittently exposed to the production processes.

Inspection of the Plant

Physical Agents and General Safety Hazards

Although most of the process equipment appeared to be well guarded, open chains were noted at a few process points. Relatively large chips of the board material were ejected at several points, most notably at the cutoff saws and the edge milling machines. These were ejected with sufficient velocity to cause eye injury if they should happen to lodge in a worker's eye. Intermittent high noise levels were noted during the use of air lines for cleaning processing equipment.

Housekeeping

The necessity for storing fairly large amounts of boards and broken waste tile while awaiting transportation to the tile line made for occasional near blockages of passageways and aisles. In the warehouse, and in the area where bulk raw materials were stored inside the plant near the stock mix preparation area, broken bags of clay, and starch were seen on occasion. The lunchroom and locker room appeared to be relatively neat and clean, with provision of adequate sanitary facilities.

One unacceptable procedure was the use of compressed air for cleaning process equipment in the tile area prior to setting up for the next day's operation. The shoveling of broken tile and dust into the container by the board utility worker appeared to generate relatively large amounts of airborne dust.

Engineering Controls

Enclosures have been constructed around the planers and sander for the reduction of noise, and for the control of dust. In addition, shrouds with flex hose to the exhaust ventilation system have been installed at points where dust emissions had occurred in the past on other process equipment in the tile department. These were only partially effective, however, because the flex hoses were often not connected to the shrouds. The hoses would often be merely wedged in place, and were significantly less effective than they might have been, had they been connected in accordance with original design. The noise enclosures were also only partially effective, and several of the pieces of process equipment will require additional enclosure to meet current and projected environmental standards.

Potential Exposures

The following possible inhalation exposures to potentially toxic materials were noted during the initial survey:

- Mineral wool fibers
- Clays
- Paint and paint additives and chemicals.

5. Plant J - Description of the Facility

The facility surveyed was the site of installation of a "fire-proofing" material applied to structural steel by a crew of plasterers employed by a general plastering contractor, who specializes in the application of sprayed fireproofing. This activity is not the only one for the company, however, and workers would ordinarily spend significant amounts of their time in application of more typical plastering materials. It was stated that the application of fireproofing occurs about once per month, with the rest of the time spent in general plastering trade work. The plasterers are members of the Plasterer's Union and the hod carriers are members of the Hod Carriers' Union.

Medical, Industrial Hygiene and Safety Program

No formally organized programs are in existence. The workers do not participate in union pension plans. Medical examinations are given as needed, and for pre-employment screening. The use of personal protective respirators is optional; the workers observed did not use them because of problems with fogging of spectacles and "collapse" of the disposable respirators from collection of moisture in the exhaled air. All workers wore safety helmets, and the plasterer wore safety glasses. The plasterer also placed a "hood" of polyethylene film around his head and face area, to prevent the material being sprayed from going down his neck and getting into his hair.

Present Operation

The operation is one of applying fibrous fireproofing material, containing fairly high concentrations of mineral wool fibers, to structural steel supporting members and roof decks in buildings under construction. The fibrous material is emptied into an electrically-driven blower; is blown through a corrugated flexible hose to the point of application; and is mixed at the exit from the hose with a spray of water from a spray nozzle in the center of the hose. Figures B-4 and B-5 show the process.

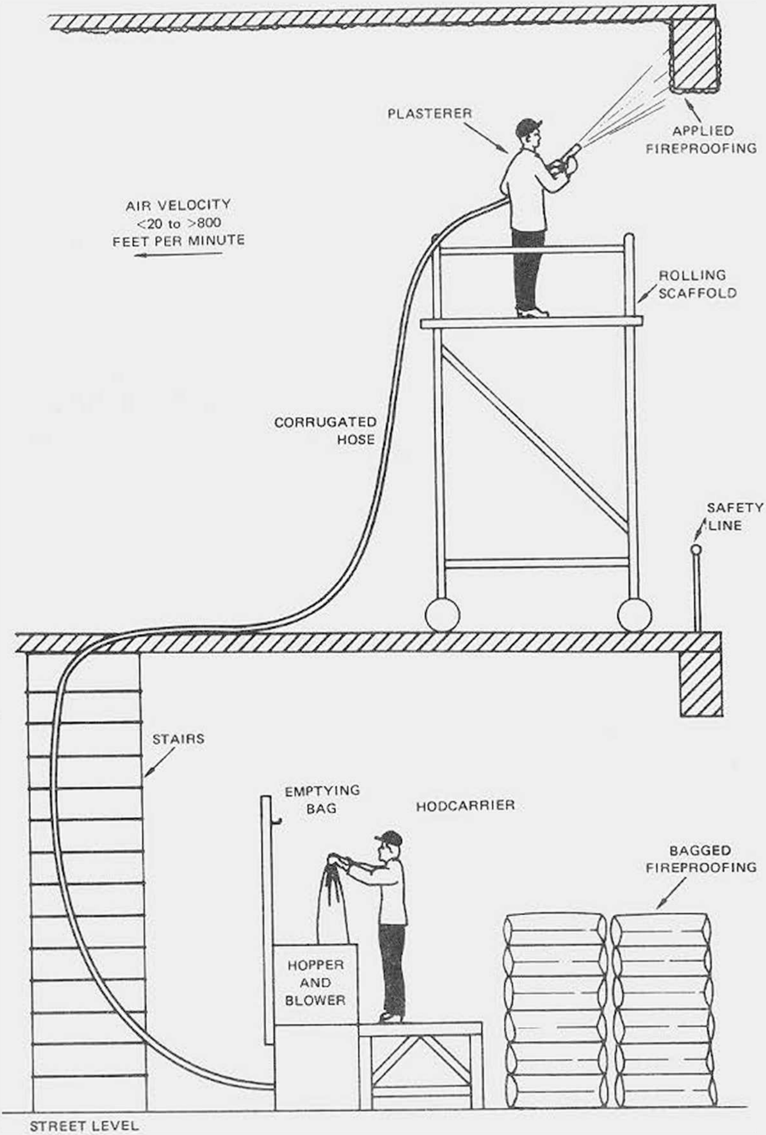


FIGURE B-4 SKETCH OF APPLICATION OF PSRAYED FIREPROOFING

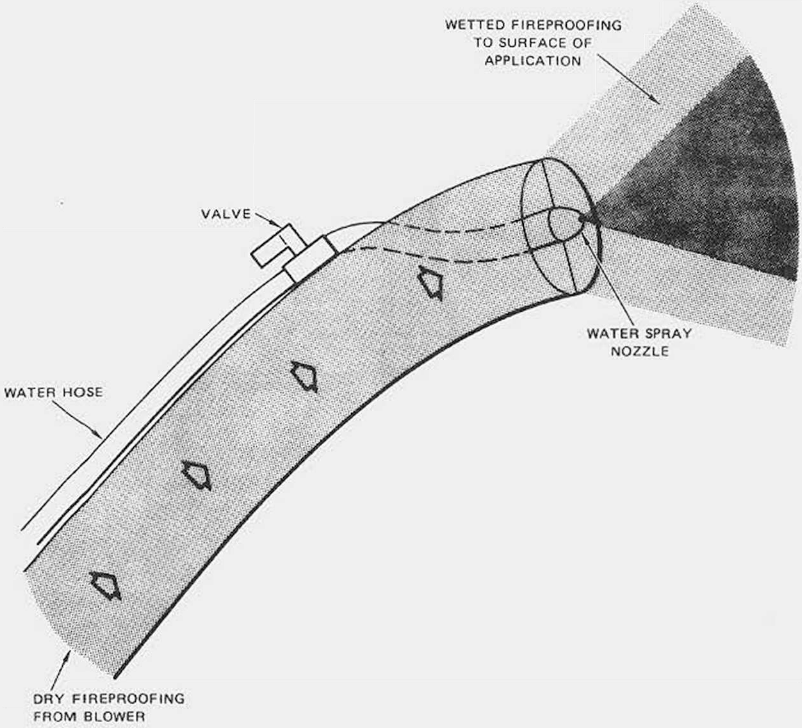


FIGURE B-5   SKETCH OF APPLICATION METHOD OF SPRAYED FIREPROOFING

Past Operation

The workers on the site had experience with the application of several varieties of fireproofing material. In prior years they had used other materials and processes, including those that formerly contained asbestos. In addition, most of their work is general plastering so that they are exposed to cement dust and mortar, lime, etc.

Job Descriptions and Personnel

There are two categories of workers on this site. The person applying the material is a plasterer and his assistant is a hod carrier. On larger jobs a laborer may be used as well.

The plasterer spends his time, except for breaks and set-up periods, on the rolling scaffolding, directing the flow of the material onto the beams and decking to be protected. He may stop from time to time to move the scaffolding to a new site, as he completes a section, and to check the depth of application. Probably 70% - 80% of his time is spent with the hose applying fireproofing. He is relatively close to the surface of application; his face is usually two to three feet from the surface. He will be liberally coated with the fibrous waste from the spraying in a relatively short time. His glasses and helmet, and the hood, will have significant amounts of material on them. He climbs down from the scaffold to help the hod carrier move to a new site on occasion, but in most cases he stays on the scaffold during the move.

The hod carrier has three principal duties. He empties the bags of material into the hopper; he moves the scaffolding for the plasterer; and he cleans up the job site. Most of his time is spent near the hopper, emptying the bags into the hopper. He opens the bag, and inverts it onto a bar grille at the top of the hopper, and then hooks the bag onto a nail, allowing the material to flow by gravity into the hopper. When needed, he moves the scaffolding for the plasterer, and assists him as necessary. At the end of the day, or upon completion of the job, he will sweep up any oversprayed material, and any waste on the floor under the sprayed area.

INSPECTION OF THE SITE

Potential Exposures

The major exposure to potentially toxic airborne material noted during the survey was the material used in the application. This material contains mineral wool fibers, and proprietary binding agents. The blower is electrically driven, so that it is not a source of potentially toxic by-products of combustion. The usual general airborne dust to be expected on a construction site was noted. An electric generator, used by the iron workers on the site for arc-welding, was near to the hopper and the hod carrier was intermittently exposed to exhaust gases from the generator.

General Safety Hazards and Physical Agents

The most apparent safety hazard was the position of the plasterer on the scaffolding. However, the scaffold had appropriate guard rails, and the plasterer used caution in approaching the edge. A ladder used by the plasterer to mount the scaffold was rather insecurely wired to the scaffold. The surface of the boards on which the plasterer stands was somewhat slippery, but the material is relatively abrasive, and relatively small amounts of water are used in the application, so that this potential hazard is usually not a problem. The application of cementitious fireproofing, in which the material is pumped as a wet slurry, is far more productive of hazard from this source. The plasterer works with his head above the level of the bottoms of the beams to which fireproofing is applied, so that he may bump his head on occasion. His safety helmet appears to be adequate protection from this potential hazard.

The hod carrier is at risk of the usual sorts of injury to be expected in vigorous physical labor involving repetitive lifting of bags of material, moving the scaffolding, and carrying the bagged material from the truck to the site of use. The use of a platform at the hopper, to bring him above the level of the hopper, appears to be effective in reducing the effort required to empty the bags.

Housekeeping

Housekeeping was adequate at the site of application, and around the hopper area. The plasterer was careful not to overspray onto the floor; the hod carrier accumulated and stacked the emptied bags and disposed of them in a waste container at the end of the day.

Engineering Controls

The major engineering control in use was the use of burlap shields around the outside edge of the floor where the application was being done. This is done to prevent inadvertant overspray from soiling cars, people, or property below. The process is not conducive to engineering control. and it is probable that personal protection is the appropriate method of reducing worker exposures.

6. Facility K - Description of the Facility

The workplace surveyed was the site of installation of industrial insulation blanket on the effluent combustion gas duct leading to a discharge stack from a commercial steam heating plant boiler. The work was being done by two employees of an industrial insulation contractor. The contractor usually has 10-12 employees who work with insulation products. All of the insulation workers are members of the Insulation Workers' Union ("Asbestos Workers").

Health and Safety Program

The workers participate in a health and safety program sponsored by their local, which includes periodic medical examinations and sickness and death benefits. The emphasis in this program is on the health effects of asbestos. The contractor furnishes respiratory protective equipment for jobs involving asbestos, and disposable respirators are available as desired for other jobs.

Present Operations

The contractor handles the full range of sound and thermal insulation materials used in industrial applications, including urethane foams, asbestos products, fibrous glass, and mineral wool. The use of mineral wool-containing products is relatively rare; a job where this is specified occurs only once every few months.

In the operation studied for this report, two workers applied the blankets to the duct, using a "pin gun;" a wire mesh ("chickenwire") covering was applied, and the whole covered with hydraulic cement. The duct being covered was approximately 30 feet above floor level, and work was done from scaffolds.

Past Operations

The workers involved in this operation had both been working in the insulation trade for approximately 15 years. They (and other employees) had been exposed to all of the potentially toxic materials associated with thermal and sound insulation materials and processes, with particular exposure to asbestos. As stated above, their exposures to mineral wool are relatively rare episodes in their experience.

Specific Job Categories

Both workers shared the job equally, and either "traded off," or worked together on specific required tasks.

Inspection of the Facility - Potential Exposures

The major potential exposures seen were to mineral wool fibers and to the dust from the cement used to coat the applied insulation.

Physical Agents and General Safety Hazards

The most serious potential hazard seen was the position of the workers on the scaffold which did not have guard rails. The position of the workers (~ 30 ft. above floor level) made the probability of serious injury very high should one of the workers have fallen. The room in which the work was done was hot (greater than the ambient temperature, which was in the low 90^{o}s).

Housekeeping and Sanitation

The site was typical of a construction/renovation site, with modest amounts of waste material lying about. Sanitary facilities were available at other buildings in the complex.

Engineering Controls

Because of the nature of insulation installation work, engineering control has traditionnally been difficult to apply. This site was no exception, and no engineering control measures were used.

APPENDIX C

AIR SAMPLING RESULTS FOR

INDIVIDUAL PRODUCTION FACILITIES SURVEYED

The following compilations of data represent the results for each individual air sample taken and analyzed during the surveys. There are several headings across the top of each table, the key for them is given below:

Description: The plant area, exposure group category, payroll title, and local job category (where payroll title is insufficiently descriptive) are given for each worker.

The "exposure group categories" are those used for grouping the results in the main body of the report; the symbols used are:

C.O. = Cupola Operator
C.G. = Cupola Charges
B.O. = Baler Operator
B = Bagger
W = Warehouse and Loader
B.M. = Batt Machine Operator
F = Foreman
M = Maintenance
T = Takeoff
C = Clerical
L = Labor (Cleanup)
B.R. = Boiler Operator
L.Q. = Laboratory and Quality Control
O.C. = Outside Crew

(Stationary, area samples were not coded or included in exposure assessments, except where they were judged to be adequate representations of exposure.)

Fiber Counting: This section contains the description of the samples taken for assessment of airborne fiber exposures. The following items are included:

Sample Number
Flow (Liters or M^3) = Air volume sampled
F/cc = total fibers per cubic centimeter of air sampled, for each sample
N = number of fibers accumulated from several samples for sizing

Length and Diameter distribution of the N fibers, presented in the format:

Geometric Mean
(Geometric Standard Deviation)

for both length and diameter.

Total Airborne Particulate Material:

This is nearly self-explanatory:

Sample number
Sample volume
Total suspended material concentration
Trace element concentrations

Respirable Particulate Material:

Sample number
Sample volume
Respirable Particulate Material concentrations

In most cases, pairs of samples were taken; usually a sample for fiber counting and a total airborne particulate material sample. The filters for fiber counting were usually changed about midway through the shift, while the total airborne particulate material filter was left throughout the shift, without changing. Respirable particulate material samples were also left throughout the shift. However, exceptions were made; filters were dropped or contaminated during sampling or analytical results were questionable due to possible errors in sample numbering, etc.

If samples could not be clearly traced to a specific worker, or if they were potentially in error, they were discarded.

Thus, there are some gaps in these tables. In general, however, there will be 2 fiber concentration results with a total airborne particulate material concentration, and one total airborne particulate concentration with a respirable particulate material concentration. The paired results (taken over the same time period for the same worker) appear on the same horizontal line.

Table C-1

PLANT A--AIR SAMPLING RESULTS
(Cd, Cr, Ni, and Co all below detectable limits)

Description			Fiber Counting						Total Airborne Particulate Material						Respirable Particulate Material		
							Geom. Mean (Geom. Std. Dev.)					$\mu g/m^3$					
Area	Exposure Category	Job Category	Sample Number	Flow Liters	F/cc	N*	Length	Diam.	Sample Number	Flow Liters	Total mg/m^3	Zn	Pb	Mn	Sample Number	Flow Liters	Total mg/m^3
Cupola		Charger	C2	474	0.127				AA36	664	1.020	16	10	5			
			C23	190	0.086												
						67	6.7 (3.0)	1.4 (1.8)									
		Charger	C17	388	0.042				A100	628	1.121	33	17	7			
		Charger	C161	454	0.046				AA12	730	1.364	31	24	8			
	C.G.	Charger							AA121	526	1.325	69	30	5	W5	447	0.083
		Charger													W16	349	0.103
			TWA	1506	0.076				TWA	2548	1.206						
		Notcher	C54	226	0.087				AA26	500	3.826	713	290	3			
		Notcher	C6	208	0.027				AA47	628	0.389	17	10	1			
			C36	420	0.054	55	16 (3.3)	2.0 (2.5)									
		Notcher	C4	662	0.003				AA5	662	3.122	186	34	1			
		Notcher	C12	664	0.049				AA2	666	0.479	59	18	1			
	C.O.	Notcher							AA29	688	0.657	13	206	2			
		Notcher							AA28	632	0.872	64	42	1	W9	537	0.462
		Notcher							AA81	570	0.812	11	13	3	W10	485	0.056
			TWA	2180	0.038				TWA	4346	1.383						
Wool Line		Bagger	C34b	504	0.091												
			C9	248	0.065												
		Bagger	C164	190	0.073	70	16 (3.4)	1.8 (2.8)	AA65	500	0.124	1	1	<1			
		Bagger	C158	310	0.066												
		Bagger	C27	584	0.076				AA3	584	0.144	6	2	2			
		Bagger							AA147	700	0.241	2	3	1	W11	578	0.090
	B		TWA	1836	0.077				TWA	1784	0.176						
		Taper	C162	280	0.007				AA13	307	0.661	3	1	1			
			C24	334	0.024												
		Taper	C5	606	0.047	69	16 (3.3)	1.9 (2.0)									
		Taper	C20	504	0.062				AA51	754	0.488	20	8	2			
		Taper	C91	212	0.141												
	B	Taper	C155	302	0.122				AA82	514	0.305	11	<1	1			
			TWA	2238	0.061				TWA	1575	0 462						
		Cleanup	C10	226	0.072				AA7	744	1.152	17	8	9			
			C39	518	0.143												
						85	13 (5.4)	1.7 (1.9)									
		Cleanup	C31	416	0.083				AA31	754	0.712	21	9	6			
			C81	338	0.133												
		Cleanup	C40	388	0.324				AA24	662	0.924	9	5	7			
			C153	274	0.124	120	18 (3.4)	1.9 (2.2)									
	L	Cleanup	C65	360	0.086				AA128	664	1.146	16	3	17			
			C88	304	0.156												
		Cleanup							AA98	308	0.688	2	<1	2			
		Cleanup							AA70	744	1.152	17	8	9			
		Relief Cleanup									0.787				W1	502	0.108
			TWA	2824	0.144				TWA	2432	0.920						
		Loader	C185	194	0.069												
	W					96	17 (3.0)	2.0 (2.0)									
		Loader	C11	372	0.260				AA32	756	1.085	63	16	3			
			C75	384	0.117												
		Loader							AA136	716	0.425	6	5	1	W4	609	<0.016
		Loader							AA33	498	0.201	6	2	<1	W13	223	0.206
			TWA	1168	0.163				TWA	1970	0.622						

Table C-1 (Continued)

Description: Area	Exposure Category	Job Category	Fiber Counting: Sample Number	Flow Liters	F/cc	N	Geom. Mean (Geom. Std. Dev.) Length	Diam.	Total Airborne Particulate Material: Sample Number	Flow Liters	Total mg/m^3	$\mu g/m^3$ Zn	Pb	Mn	Respirable Particulate Material: Sample Number	Flow Liters	Total mg/m^3
Batt Line		Machine Operator	C35	448	0.109				AA50	636	0.462	14	8	1			
			C13	188	0.102												
		Machine Operator	C192	260	0.321	172	15 (3.7)	1.8 (1.8)									
			C181	236	0.344												
	B.M.	Machine Operator	C171	258	0.081				AA11	692	0.434	2	2	1			
			C100	434	0.202												
			TWA	1824	0.167				TWA	1328	0.447						
		Assistant Machine Operator	C33	642	0.209				AA99	642	0.411	10	2	2			
		Assistant Machine Operator	C183	352	0.089				AA91	574	0.282	<2	2	<1			
			C165	222	0.204												
		Assistant Machine Operator	C37	412	0.204	174	12 (3.5)	1.6 (1.9)	AA41	548	1.215	29	14	6			
			C76	376	0.075												
	B.M.	Assistant Machine Operator	C55	276	<0.008				AA21	534	0.228	2	1	<1			
			C86	245	0.048												
		Assistant Machine Operator							AA130	616	0.583	14	6	3	W14	524	0.427
			TWA	2525	0.133				TWA	4242	0.511						
		Takeoff	C156	300	0.153				AA40	670	4.384	32	3	49			
			C21	370	0.411												
		Takeoff	C71	368	0.395	239	16 (3.2)	1.6 (1.9)	AA127	683	2.401	26	11	26			
			C72	438	0.316												
		Takeoff	C170	288	0.070				AA56	595	0.494	4	1	2			
	T		C179	321	0.237												
		Takeoff	C41	226	0.332				AA8	670	0.427	69	2	2			
			C46	444	0.198												
						193	8.2 (2.8)	1.3 (1.8)									
		Takeoff	C74	336	0.308				AA45	746	2.552	78	7	29			
			C45	410	0.131												
		Takeoff	C50	614	0.106				AA15	614	0.521	46	3	92			
		Takeoff							AA18	572	1.166	7	2	5	W17	483	0.104
			TWA	4115	0.234				TWA	4550	1.769						
		Bagger	C26	650	0.190				AA4	646	0.259	3	<1	1			
						98	13 (3.2)	1.9 (1.9)									
		Bagger	C29	236	0.164				AA52	678	0.230	5	2	1			
			C30	442	0.095												
		Bagger	C173	304	0.108	72	18 (4.3)	2.4 (1.8)									
			C160	326	0.068												
	B	Bagger	C82	408	0.151				AA39	768	0.366	2	2	1			
			TWA	2366	0.136				TWA	2092	0.289						
		Taper	C28	616	0.107				AA98	616	0.344	2	<1	2			
						66	18 (4.1)	1.8 (2.7)									
		Taper	C63	388	0.053				AA38	754	0.244	1	2	<1			
			C166	366	0.069												
	B	Taper	C94	266	0.073				AA22	564	0.335	4	2	1			
			TWA	1636	0.080				TWA	1934	0.302						

Table C-1 (Continued)

Area	Exposure Category	Job Category	Fiber Counting: Sample Number	Flow Liters	F/cc	N	Geom. Mean (Geom. Std. Dev.) Length	Diam.	Total Airborne Particulate Material: Sample Number	Flow Liters	Total mg/m^3	µg/m^3 Zn	Pb	Mn	Respirable Particulate Material: Sample Number	Flow Liters	Total mg/m^3
Batt Line,		Cleanup	C1	618	0.180				AA10	620	2.469	41	5	28			
Continued		Cleanup	C14	276	0.064				AA12	730	1.834	31	24	8			
						294	12	1.7									
		Cleanup	C177	230	0.388		(3.1)	(1.9)									
			C199	326	0.420												
		Cleanup	C62	330	0.117				AA48	782	1.125	22	6	6			
			C22	452	0.231	154	20	2.0									
							(3.3)	(2.2)									
	L	Cleanup	C16	560	0.228				AA53	736	0.863	13	6	6			
			C44	176	0.148												
		Cleanup							AA14	544	0.722	9	7	<1	W19	462	<0.022
		Cleanup							AA88	505	0.545	9	4	2	W6	464	0.188
		Cleanup							AA112	214	1.720	21	3	17	W3	483	0.054
			TWA	2968	0.220				TWA	4131	1.290						
		Loader	C3	306	0.115				AA34	776	0.709	11	6	2			
			C152	468	0.101												
		Loader	C8	214	0.217	144	16	2.0	AA1	678	0.882	16	19	3			
			C19	464	0.129		(2.6)	(2.0)									
		Loader	C48	664	0.076				AA97	664	0.560	7	4	2			
	W	Loader													W8	490	0.155
			TWA	2116	0.113				TWA	2018	0.753						
Warehouse		Forklift Op	C52	228	0.089				AA77	538	0.753	20	15	3			
			C80	298	0.094												
						134	11	1.9									
		Loader	C70	674	0.175		(2.9)	(1.9)	AA19	474	0.036	24	21	10			
	W	Loader	C84	492	0.214				AA16	443	0.993	12	9	3			
			TWA	1692	0.160				TWA	1455	0.592						
General Plant		Foreman	C16	232	0.212				AA46	686	0.515	24	15	2			
			C18	454	0.155												
		Foreman	C79	382	0.068				AA43	740	0.403	38	31	1			
			C167	358	0.048	115	14	1.9									
		Foreman	C154	246	0.092		(3.4)	(1.8)	AA55	600	0.498	11	1	1			
			C163	306	0.205												
	F	Foreman	C49	668	0.121				AA17	668	0.555	14	7	2			
			TWA	2646	0.124				TWA	2694	0.490						
		Industrial Hygienist	C184	446	0.116												
			C198	413	0.072	64	17	1.6									
							(5.2)	(1.9)									
			C25	698	0.054				AA49	458	0.439	16	5	<1			
			TWA	1557	0.077												
		Maintenance	C38	382	0.061				AA44	708	1.196	81	58	6			
			C57	326	0.082	64	12	1.6									
							(2.3)	(1.9)									
	M	Maintenance	C87	532	0.138				AA20	532	0.633	18	17	1			

Table C-1 (Concluded)

Area	Exposure Category	Job Category	Fiber Counting: Sample Number	Flow Liters	F/cc	N	Geom. Mean (Geom. Std. Dev.) Length	Diam.	Total Airborne Particulate Material: Sample Number	Flow Liters	Total mg/m^3	$\mu g/m^3$ Zn	Pb	Mn	Respirable Particulate Material: Sample Number	Flow Liters	Total mg/m^3
General Plant, Continued		Shift maintenance	C68	230	0.147												
		Maintenance	C78	528	0.052												
						111	10 (2.9)	1.3 (2.2)									
		Shift maintenance	C174	236	0.097				AA71	530	0.192	4	3	1			
			C175	322	0.052												
	M	Carpenter	C51	240	0.375				AA83	456	1.404	43	20	3			
			C58	217	0.127												
		Maintenance							AA66	531	0.631	19	3	3	W20	472	0.125
			TWA	3013	0.113				TWA	2757	0.820						
		Utility Cleanup	C56	222	0.157				AA25	440	1.786	291	348	6			
			C73	218	0.112												
						90	15 (2.2)	2.2 (1.8)									
		Payload Op	C60	450	0.189				AA139	646	1.489	108	77	10			
		Payload	C59	152	0.206				AA94	578	2.490	42	19	6			
	L	Utility Cleanup													W15	449	0.109
			TWA	1042	0.169				TWA	1664	1.915						
Boiler Room		Boiler Room Op	C191	528	0.025												
	BR	Boiler Room Op	C93	534	0.076	165	7.5 (3.1)	1.2 (1.9)	AA93	521	0.470	18	13	1			
			TWA	1062	0.051												
	LQ	Quality Control	C96	270	2.130				AA27	472	1.148	30	14	12			
Slag Pile		Utility Truck Dr	C66	238	0.085				AA30	543	1.355	16	8	5			
			C67	334	0.212												
						102	7.7 (2.3)	1.6 (1.8)									
	OC	Payload Op	C85	426	0.245				AA94	578	2.490	42	19	6			
		Laborer							AA72	555	0.620	1	1	2	W12	482	0.295
			TWA	998	0.196				TWA	1676	1.503						
Stationary		Balcony of Supt. Office	C32	236	0.211				AA37	650	0.523	30	11	<1			
			C92	414	0.094												
		Batt Tape Mach.	C61	240	0.061				AA61	482	0.317	9	2	1			
			C95	242	0.123	112	10 (3.0)	1.5 (1.9)									
		Wool Bagging Mach.	C53	234	0.061				AA89	464	0.338	11	5	1			
			C64	232	0.087												
		Filler in maintenance area	C77	513	0.012				AA92	527	0.287	16	13	1			
		Lunchroom	C168	576	0.031				AA85	576	0.158	<1	<1	N.D.			
		Over Shipping Desk-Warehouse	C180	276	0.022												
			C197	180	0.223												
			TWA	3143	0.076				TWA	2699	0.330						

*N = number of fibers counted and sized.

Table C-2

PLANT B--AIR SAMPLING RESULTS

NSF = not sufficient fibers

Area	Exposure Category	Payroll Title	Fiber Counting: Sample Number	Flow m^3	f/cc	N	Count Median: Lgth (SD)	Diam (SD)	Total Airborne Particulate Material: Sample Number	Flow m^3	Total mg/m^3	Elemental Concentration $\mu g/m^3$: Zn	Pb	Mn	Cr	Co	Ni	Cd	Respirable Particulate Material: Sample Number	Flow m^3	Total mg/m^3
									AA215	0.511	0.575	2.8	–	–	–	1.2	–	–	W35	0.483	0.130
Silo Pit	OC	Unloader	C332	0.260	0.050		NSF		AA217	0.260	0.369	1.9	–	–	–	–.	–	–			
Cupola		Cupola Charger	C390	0.235	0.207																
			C558	0.189	-o-	113	11.7 (2.5)	1.3 (1.6)	AA196	0.579	1.155	8.0	–	1.1	–	<1.1	<0.6	–	W38	0.583	0.400
			C339	0.127	0.279				AA226	0.648	1.952	0.9	–	2.0	–	–	–	–			
			C311	0.248	0.016																
	CG		C317	0.270	0.267																
Cupola & Boiler Floor		Cupola Leader	C562	0.344	0.246				AA152	0.301	neg	0.4	–	–	≤2.0	–	<5.3	–			
			C555	0.236	0.286	116	15.6 (3.2)	1.3 (1.9)	AA177	0.472	0.551	0.1	–	0.5	–	–	<3.5	–			
	CQ		C557	0.262	0.245				AA232	0.546	1.732	0.8	–	1.4	1.0	–	2.6	–	W34	0.546	0.462
		Cupola Operator	C347	0.086	2.15	99	12.7 (2.6)	1.0 (1.8)	AA227	0.642	2.278	2.3	<2.9	6.7	<1.1	<1.1	<2.7	<0.6			
			C345	0.287	0.246	118	12.8 (2.3)	1.1 (1.8)													
			C312	0.278	0.517				AA231	0.708	2.331	1.7	–	2.0	<1.0	–	<2.5	<0.6	W30	0.602	1.183
	CO		C570	0.320	0.614	98	9.2 (2.8)	1.3 (1.7)													
			C378	0.487	0.023	89	13.1 (2.7)	1.2 (1.8)	AA189	0.500	1.812	21	<2.5	<1.3	–	<1.3	<0.8				
			C386	0.180	0.411				AA185	0.395	0.959	4.1	<3.1	<1.7	<5.0	<1.7	< –	1.0			
			C361	0.236	0.371																
			C356	0.284	1.015	162	12.4 (3.0)	1.2 (1.8)	AA199	0.455	1.718	1.0	–	1.6	<1.4	–	<3.7	<0.8			
			C393	0.203	0.574				AA206	0.511	1.943	3.3	–	1.2	–	–	–	–			
			C355	0.250	0.374	94	11.1 (2.7)	1.5 (1.7)													
			C369	0.302	0.237																
			C366	0.265	0.764	205	13.8 (2.8)	1.2 (1.7)	AA213	0.538	1.985	2.6	<2.4	–	<3.9	<1.3	–	<0.7			
	CO		C374	0.264	1.250				AA232	0.546	1.732	0.8	–	1.4	1.0	–	<2.6	–	W34	0.546	0.462
Boiler Floor		Boiler Operator	C379	0.442	0.064				AA180	0.520	1.036	2.4	3.4	0.7	<1.2	<1.2	<3.2	<0.7			
			C395	0.256	0.077																
		Boiler Leadman	C388	0.280	0.045				AA179	0.560	0.505	1.8	<2.3	–	–	<1.3	–	<0.7			
		Boiler Operator	C371	0.275	0.203				AA211	0.526	1.482	2.9	<3.6	4.6	<1.3	<1.3	<3.4	<0.8			
			C376	0.240	0.126	154	8.9 (2.5)	1.4 (1.7)													
	BR	Lead Boiler Operator	C565	0.222	0.190				AA192	0.450	0.415	0.6	–	0.6	<1.2	<1.2	<3.9	–			
			C573	0.240	0.222																
		Boilerman	C575	0.213	0.110				AA175	.427	.517	0.9	–	<0.6	<1.5	–	<3.9	<0.9			
			C552	0.244	0.079																
Production (All areas)		Front End Leader	C360	0.248	2.306				AA212	0.484	5.252	0.3	–	8.3	–	–	–	–			
			C365	–	–																
			C389	0.372	0.066	171	26.1 (3.2)	1.9 (1.9)	AA159	0.372	neg.	0.6	–	–	<1.8	–	<6.2	–			
	BM		C372	0.314	0.372				AA205	0.590	0.735	5.4	–	2.2	<1.2	<1.2	<3.1	<0.7			
			C392	0.260	0.147																

Table C-2 (Continued)

Area	Exposure Category	Payroll Title	Fiber Counting: Sample Number	Flow m^3	f/cc	N	Count Median Lgth (SD)	Count Median Diam (SD)	Total Airborne Particulate Material: Sample Number	Flow m^3	Total mg/m^3	Elemental Concentration $\mu g/m^3$: Zn	Pb	Mn	Cr	Co	Ni	Cd	Respirable Particulate Material: Sample Number	Flow m^3	Total mg/m^3
Production (All areas) Continued		Factory Labor (Relief & Cleanup)	C316	0.210	0.151				AA214	0.564	0.257	<0.1	-	-	-	3.4	<2.8	-			
			C307	0.240	0.128																
			C357	0.328	0.084				AA210	0.388	0.778	5.4	-	-	-	<1.8	-	<1.0			
			C391	0.260	0.072																
			C315	0.338	0.161	229	22.4	1.9													
			C310	0.257	0.464		(3.3)	(1.9)													
			C313	0.372	0.034				A291	0.564	0.641	2.3	-	0.8	<1.1	-	<2.8	<0.6			
			C302	0.265	0.198																
	L		C323	0.328	0.132				AA283	0.532	0.124	0.8	-	<0.5	<1.2	-	<3.0	<0.7			
			C305	0.244	0.182																
		Machine Tender	C574	0.400	0.236				AA163	0.372	0.637	4.3	<5.1	<0.8	<1.9	-	<4.8	-			
							17.8	1.7	AA202	0.521	0.414	-	-	-	-	-	-	-	W24	0.537	0.140
			C358	0.302	0.063	70	(3.0)	(1.8)	AA204	0.548	0.222	3.2	-	-	<3.7	<1.2	-	-			
	BM		C399	0.258	0.080																
Batt Line		Factory Utility A Batt Line (Take off)	C336	0.362	0.178				AA225	0.362	2.508	1.7	-	3.6	-	-	-	-			
			C335	0.378	0.374				AA234	0.378	5.851	1.1	-	9.0	-	-	-	-			
			C334	0.376	0.106				AA222	0.376	0.484	3.5	-	-	<5.6	<1.9	-	-			
						205	16.0	1.8	AA235	0.353	0.407	0.4	-	-	-	-	-	-			
							(3.1)	(1.9)	AA288	0.571	0.642	2.1	-	2.6	<1.1	-	<2.8	<0.6	W27	0.473	0.180
			C319	0.199	0.126				AA296	0.482	1.1804	4.4	-	2.0	<1.5	-	<3.7	<0.8			
	T		C375	0.250	0.443																
Bagging Granulated Wool		Factory Labor & Utility A (Bagging Wool)	C363	0.318	0.053				AA197	0.534	neg	1.2	-	-	-	-	-	-			
			C396	0.256	0.087																
			C368[a]	0.302	0.050				AA195	0.501	neg	0.2	-	0.7	<1.2	1.2	<3.1	<0.7			
			C397	0.248	0.008																
			C367	0.318	0.067				AA193	0.536	0.020	4.6	-	<0.7	<1.2	-	<3.2	<0.7			
			C398	0.232	0.090		16.0	1.8													
	B		C354[a]	0.254	0.152	122	(3.1)	(1.9)	AA208	0.486	0.2078	0.3	-	0.6	1.4	-	3.7	0.8			
			C364	0.220	0.067																
			C346	0.124	0.109				AA233	0.543	0.244	0.3	-	-	1.1	-	2.9	0.6			
			C349	0.197	0.019																
			C342	0.125	0.061				AA221	0.544	0.352	0.2	-	-	1.1	-	2.9	-			
			C306	0.207	0.044																
			C322	0.246	0.030																
Granulated Bale Line		Baler Operator	C391	0.138	0.068		19.5	1.9	AA284	0.536	1.026	4.6	-	1.1	<1.2	-	<3.2	<0.7	W23	0.451	0.242
			C350	0.228	0.122	37	(3.3	(2.0)	AA207	0.652	0.510	-	<2.9	<0.5	<1.1	-	<2.8	<0.6	W25	0.538	0.143
	BO		C321	0.228	0.146				AA200	0.524	neg.	<1.2	-	-	-	-	-	-	W37	0.453	0.113
Warehouse		Loading Leader	C325	0.520	0.097				AA236	0.481	0.698	1.0	<2.5	-	<4.0	<1.3	-	-			
	W	W'house Worker	C340	0.176	0.331	89	19.6	2.3	AA223	0.185	2.4	5.8	-	2.8	<7.4	-	-	-			
							(2.7)	(1.9)													
		Loader	C373	0.306	0.154				AA209	0.394	0.220	11.4	-	11.5	<1.8	-	<4.6	<1.0			
			C400	0.236	0.039																
Batt, Wool & Bale Lines		Factory Labor (loading Wool & Batt Lines)	C352	0.320	0.278				AA198	0.500	0.26	1.0	-	<0.7	<1.3	1.3	<0.5	<0.1			
			C394	0.224	0.129																
			C353	0.278	0.175				AA194	0.524	0.255	3.3	<2.4	-	-	<1.3	-	-			
			C385	0.252	0.185		17.8	2.1													
						135	(2.8)	(2.0)	AA216	0.676	0.297	1.5	<1.8	-	<2.9	<1.0	-	-	W29	0.605	0.114
			C348	0.158	0.087				AA219	0.616	.311	1.7	<2.1	-	<3.3	<1.1	-	<0.6			
			C344	0.180	0.113																
	W		C338	0.294	0.040																

Table C-2 (Concluded)

			Fiber Counting				Count Median		Total Airborne Particulate Material			Elemental Concentration $\mu g/m^3$							Respirable Particulate Material		
Area	Exposure Category	Payroll Title	Sample Number	Flow m^3	f/cc	N	Lgth (SD)	Diam (SD)	Sample Number	Flow m^3	Total mg/m^3	Zn	Pb	Mn	Cr	Co	Ni	Cd	Sample Number	Flow m^3	Total mg/m^3
Batt Line	W	Factory	C308	0.341	0.094				AA300	0.674	1.118	10.4	<2.8	1.4	<1.0	-	<2.7	<0.6			
		Labor	C301	0.324	0.133	84	19.7	2.4													
		(Loading	C324	0.336	0.207		(2.5)	(2.0)	AA290	0.678	0.617	2.7	-	0.6	-	-	-	-			
		Batt Line)	C303	0.324	0.041																
Yard (Outside)	OC	Mobile	C328	0.078	0.103		NSF		AA229	0.290	0.110	0.5	-	<1.4	-	-	-	-			
		Equip't																			
		Operator																			
Quality	L.Q.	Tester B	C326	0.388	0.098				AA224	0.378	0.365	12.0	-	-	<5.4	<1.8	-	-			
Control		Tester A	C359	0.226	0.016	68	10.8	1.3	AA203	0.477	0.545	1.7	-	1.1	<1.5	-	<3.9	<0.9			
			C370	0.232	0.142		(2.9)	(1.6)													
		Tester A	C569	0.226	0.244				AA182	0.404	neg	0.8	-	-	-	<1.5	<3.9	-			
			C568	0.450	0.050																
Maintenance	M	Mech. A	C383	0.222	0.044				AA184	0.457	1.126	11.0	<2.6	28	<4.3	<1.4	-	-			
		(on call)	C554	0.236	0.047																
		Mech. A	C351	0.257	0.151	98	18.8	1.8	AA0186	0.380	0.415	8.3	-	-	-	1.6	-	<0.9			
			C559	0.183	0.355		(3.0)	(1.8)													
		Mech. B	C329	0.331	0.113				AA228	0.339	3.029	7.5	<3.7	<2.0	-	<2.0	-	<1.1			
		Mech. A	C331	0.359	0.061				AA230	0.350	0.548	1.0	-	1.4	-	-	-	-			
	M	Mech. A	C384	0.246	0.015				AA178	0.474	0.810	7.6	-	<1.4	<4.1	<1.4	-	-			
		(welder)	C563	0.220	0.079																
		Mech. A	C377	0.238	0.050	85	22.5	2.5	AA190	0.494	0.491	3.0	-	<1.4	-	<1.4	-	-			
		(machinist)	C564	0.219	0.008		(2.6)	(1.7)													
		Mech. A							AA285	0.622	0.366	5.7	-	0.8	-	≤1.4	-	-	W22	0.394	0.056
		Mech. A							AA294	0.423	2.44	3.6	-	1.5	-	-	-	-	W28	0.400	0.260
		Mech. A	C337	0.367	0.352				AA220	0.386	2.598	1.0	-	<1.8	-	<1.8	-	<1.0			
	M	Mechanic	C381	0.236	0.157				AA187	0.488	0.303	11.0	-	-	<2.9	<1.4	-	<0.8			
		Leader	C553	0.252	0.191																
		Mainten-	C314	0.497	0.169		16.3	1.7	AA289	0.509	1.864	26.0	-	5.8	-	-	-	-			
		ance clerk				161	(2.8)	(1.8)													
		Mechanic	C380	0.285	0.101				AA181	0.492	0.902	6.8	< 2.4	-	-	<1.3	-	-			
		Leader																			
		M'tenance	C327	0.380	0.303				AA218	0.361	1.307	8.7	-	<1.8	-	<1.8	-	-			
		helper																			
Pit under	Area		C320	0.340	0.057				AA295	0.605	0.233	1.9	-	<0.7	-	-	-	-			
batt line	(stationary)		C309	0.329	0.073	84	18.0	1.6													
Bale line-			C318	0.242	0.191		(2.9)	(1.9)	AA297	0.513	2.649	2.1	-	3.0	-	-	-	-			
back of bagger			C304	0.257	0.273																

Table C-3

PLANT C--AIR SAMPLING RESULTS

Area	Exposure Category	Payroll Title	Fiber Counting Sample No.	Flow (m^3)	f/cc	N	Count Median Length (SD)	Diam. (SD)	Total Airborne Particulate Material Sample No.	Flow (m^3)	Total mg/m^3	Elemental Concentration ($\mu g/m^3$) Zn	Pb	Mn	Cr	Co	Ni	Cd	Respirable Particulate Material Sample No.	Flow (m^3)	Total mg/m^3
General Plant	F	Foreman							AA421	0.795	0.097	0.72	<1.9	<0.6	<1.0	<1.0	<1.4	<0.6			
		Front End Loader	C934	0.341	0.045	19	21.9	2.1	AA399	0.660	0.468	<0.32	<2.0	<0.6	<0.1	<1.1	<1.4	<0.6			
	O.C.		C845	0.325	0.065		(2.6)	(1.8)													
		Front End Loader	C824	0.203	0.220	47	18.0	2.5	AA407	0.460	0.693	<0.40	<2.4	0.8	<1.3	<1.3	<2	<1.3			
	C.O.		C839	0.349	0.125		(2.4)	(1.8)													
		Cupola Operator	C808	0.371	0.185	61	16.5	1.8	AA420	0.933	0.648	1.56	<1.8	4.0	<1.0	<1.0	<1.4	<0.8			
			C837	0.383	0.121		(3.0)	(1.6)													
		Cupola Operator	C836	0.437	.042	72	20.0	1.6	AA403	0.719	0.787	5.35	<1.6	3.3	<0.9	<0.9	<1.2	<0.5			
			C829	0.464	0.258		(3.0)	(2.0)													
		Cupola Operator							AA428	0.743	0.580	0.66	<1.8	1.9	<1.0	<0.9	<1.4	<0.6	W52	0.600	0.228
		Asst.Cupola Oper.	C821	0.431	0.094	32	21.0	2.0	AA422	0.804	0.367	1.57	<1.6	1.6	<0.9	<0.9	<1.2	<0.5			
			C804	0.334	0.060		(2.8)	(1.9)													
	C.O.	Asst.Cupola Oper.	C801	0.475	0.065	32	23.5	1.7	AA431	0.919	0.631	1.85	<1.9	2.1	<1.0	<1.0	<1.4	<0.6			
			C809	0.295	0.101		(3.2)	(1.9)													
		Asst.Cupola Oper.	C950	0.443	0.105	67	7.4	1.6	AA404	0.781	0.566	0.63	<1.7	0.5	<0.9	<0.9	<1.2	<0.5			
			C850	0.247	0.336		(4.4)	(1.7)													
		Asst.Cupola Oper.	C823	0.353	0.165	50	27.3	1.8	AA401	0.762	0.829	1.10	<1.7	2.1	<0.9	<0.9	<1.2	<0.5			
			C841	0.336	0.095		(2.3)	(1.7)													
		Asst.Cupola Oper.	C820	0.397	0.068	36	20.8	2.0	AA409	0.707	0.714	0.49	<1.8	1.7	<1.0	<1.0	<1.4	<0.6			
			C848	0.319	0.118		(3.0)	(1.9)													
Production		Baler Operator							AA393	0.828	0.599	0.53	<1.6	0.9	<0.9	<0.9	<1.2	<0.5	W53	0.715	0.039
	B.O.	Baler Operator	C806	0.497	0.062	28	22.8	2.6	AA423	0.802	0.170	0.38	<1.4	<0.4	<0.8	<0.8	<0.8	<0.4			
			C813	0.330	0.071		(3.1)	(2.2)													
		Baler Operator	C814	0.430	0.113	59	26.7	2.9	A415	0.802	0.166	<0.26	<1.6	<0.5	<0.9	<0.9	<1.2	<0.5			
			C842	0.372	0.176		(2.0)	(1.9)													
Warehouse Area Bagging Mach.		Bagging Machine Oper.	C947	0.356	0.175	43	20.3	1.7	AA414	0.602	0.384	<0.32	<2.0	<0.6	<1.0	<1.0	<1.4	<0.6			
			C835	0.285	0.077		(2.9)	(1.8)													
		Bagging Machine Oper.	C948	0.421	0.163	48	12.6	1.8	AA416	0.652	0.169	<0.28	<1.7	<0.5	<1.0	<0.9	<1.4	<0.5			
			C831	0.318	0.074		(2.4)	(1.7)													
	B	Bagger-Laborer	C810	0.312	0.024	27	18.6	2.0	AA430	0.804	0.719	1.97	<1.9	0.6	<1.0	<1.0	<1.4	<0.6			
			C812	0.419	0.109		(2.9)	(2.0)													
		Bagger-Laborer	C807	0.461	0.178	88	14.8	1.6	AA427	0.794	0.494	4.11	<1.7	0.5	<0.9	<0.9	<1.2	<0.5			
			C815	0.324	0.270		(2.9)	(1.8)													
		Bagger-Laborer							A418	0.658	0.252	0.72	<1.7	<0.5	<0.9	<0.9	<1.2	<0.5	W51	0.759	0.040

Table C-3 (Concluded)

Area	Exposure Category	Payroll Title	Fiber Counting: Sample No.	Flow (m^3)	f/cc	N	Count Median Length (SD)	Count Median Diam. (SD)	Total Airborne Particulate Material: Sample No.	Flow (m^3)	Total mg/m^3	Elemental Concentration ($\mu g/m^3$): Zn	Pb	Mn	Cr	Co	Ni	Cd	Respirable Particulate Material: Sample No.	Flow (m^3)	Total mg/m^3
Warehouse		Forklift Oper.	C819 C843	0.362 0.405	0.188 0.231	84	25.5 (2.1)	3.0 (1.8)	AA405	0.776	0.424	0.36	<1.7	<0.5	<0.9	<0.9	<1.2	<0.5			
	W	Forklift Oper.							AA425	0.796	1.436	<0.27	<1.7	<0.5	<0.9	<0.9	<1.2	<0.5	W0055	0.695	0.101
		Forklift Oper.	C926 C927	0.502 0.272	0.087 0.080	33	20.5 (2.18)	2.3 (1.9)	AA433	0.466	0.264	0.74	<1.5	<0.5	<0.9	<0.9	<1.2	<0.5			
Loading Platform	W	Shipper	C817 C846	0.356 0.356	0.096 0.173	50	11.6 (2.7)	1.8 (1.8)	AA406	0.724	1.323	0.41	<1.8	1.2	<1.0	<1.0	<1.4	<0.6			
		Laborer	C822 C847	0.454 0.346	0.398 0.293	143	21.5 (2.3)	2.7 (1.9)	AA411	0.801	1.039	1.25	<1.6	0.9	<0.9	<0.9	<1.2	<0.5			
		Laborer	C805 C816	0.438 0.375	0.422 0.494	190	27.8 (2.6)	2.5 (2.0)	AA435	0.801	1.179	1.56	<1.6	1.1	<0.9	<0.9	<1.2	<0.5			
	W	Laborer	C938 C840	0.398 0.284	0.470 0.145	118	12.7 (2.4)	1.8 (1.6)	AA426	0.710	0.894	0.50	<1.8	2.0	<1.0	<1.0	<1.4	<0.6			
		Laborer	C949 C834	0.433 0.284	0.559 0.070	132	31.2 (2.3)	3.2 (1.9)	AA400	0.733	1.270	0.86	<0.4	2.0	<0.9	<0.9	<1.4	<0.5			
Shop		Millwright	C828 C833	0.418 0.264	0.042 0.030	13	13.8 (3.9)	2.1 (1.7)	AA398	0.685	0.162	0.51	<1.9	<0.6	<1.0	<1.0	<1.4	<0.6			
	M	Millwright							AA424	0.709	2.365	1.97	<1.8	2.2	<1.0	<1.0	<1.4	<0.6	W060	0.630	0.733
		Millwright	C818 C802	0.312 0.436	0.037 0.071	24	36.0 (2.8)	(2.0) (1.7)	AA434	0.770	0.629	0.65	<1.7	<0.4	<0.9	<0.9	<1.2	<0.5			
Bagging Mach.		Stationary																	W0056	0.546	0.064
Baler		Stationary							AA429	0.710	0.023	<0.27	<2.4	<0.5	<1.4	<1.3	<2	<0.8			
Near Conveyor		Stationary	C849 C844	0.360 0.347	0.064 0.145	38	14.2 (2.2)	2.2 (1.7)													

Table C-4

PLANT D--AIR SAMPLING RESULTS

Area	Exposure Category	Payroll Title	Fiber Counting: Sample No.	Fiber Counting: Flow (m^3)	Fiber Counting: f/cc	Fiber Counting: N	Fiber Counting: Count Median Length (SD)	Fiber Counting: Count Median Diam. (SD)	Total Airborne Particulate Material: Sample No.	Total Airborne Particulate Material: Flow (m^3)	Total Airborne Particulate Material: Total mg/m^3	Elemental Concentration ($\mu g/m^3$): Zn	Pb	Mn	Cr	Co	Ni	Cd	Respirable Particulate Material: Sample No.	Respirable Particulate Material: Flow (m^3)	Total mg/m^3
Wool Dept.	C.G.	Charger	C975 C856 C853	0.382 0.201 0.211	* 0.139 0.121	28	15.5 (2.8)	2.3 (1.9)	A447	0.829	2.245	2.0	<1.6	0.6	<0.9	<0.8	<1.2	<0.5			
		Charger	C941 C939	0.411 0.412	0.456 *	98	8.9 (2.3)	1.7 (1.6)	A472	0.802	7.329	4.1	<1.6	12	<0.9	<0.9	<1.2	<0.5			
		Charger							A478	0.824	4.056	0.9	<1.6	1.6	<0.9	<0.8	<1.2	<0.5	W043	0.722	1.661
		Cupola Oper.							A483	0.824	0.254	0.6	<1.6	0.8	<0.9	<0.8	<1.2	<0.5	W42	0.700	0.490
	C.O.	Cupola Oper.	C917 C942	0.404 0.376	0.284 0.326	123	10.8 (2.8)	1.7 (1.6)	A480	0.805	1.091	1.5	<1.6	0.8	<0.9	<0.9	<1.2	<0.5			
		Cupola Oper.	C871 C869	0.200 0.434	0.390 *	40	13.2 (3.3)	1.5 (1.8)	A442	0.867	1.103	1.9	<1.5	<0.5	<0.8	<0.3	<0.8	<0.4			
		Wool Utility	C903 C915	0.422 0.418	2.035 *	212	24.0 (2.5)	1.6 (2.0)	A477	0.716	11.573	1.2	<1.8	15	<1.0	<1.0	<1.4	<0.6			
	L	Wool Utility	C960 C854	0.192 0.461	0.332 *	33	21.6 (2.2)	1.9 (2.2)	A443	0.785	2.913	10.7	<1.6	2.0	<0.9	<0.9	<1.2	<0.5			
		Wool Utility							A467	0.743	5.332	4.7	<1.7	4.6	<1.0	<0.9	<1.4	<0.6	W64	0.678	0.515
	L.Q.	Wool & Board Inspec.	C925 •C956	0.193 0.466	0.484 0.503	172	17.3 (3.1)	2.0 (2.0)											W57	0.745	0.039
		Wool & Board Inspec.							A432	0.812	10.177	0.8	<1.6	2.0	<0.9	<0.9	<1.2	<0.5	W62	0.688	0.356
		Wool & Board Inspec.	C897	0.688	0.264	96	14.1 (2.5)	1.8 (1.7)	A394	0.645	1.405	0.8	<2.0	<0.6	<1.1	<4.0	<1.4	<0.6			
Maint. Dept.		Shift Mechanic	C878 C898	0.276 0.432	0.326 0.155	82	16.4 (2.7)	1.6 (1.9)	A408	0.855	1.878	2.9	2.1	1.3	0.8	0.8	<1.2	<0.5			
		Shift Mechanic	C852	0.746	0.323	125	32.7 (1.6)	2.1 (1.6)	A392	0.716	1.786	7.3	<2.3	1.0	<1.0	<1.0	1.4	<0.6			
	M	Shift Mechanic	C940 C959	0.585 0.256	0.434 0.184	154	7.5 (2.7)	1.6 (1.6)	A465	0.707	0.604	0.6	<1.8	<0.6	<1.0	<1.0	<1.4	<0.6			
		Shift Mech.(elec.)	C892	0.909	0.348	103	22.2 (2.0)	3.2 (1.8)	A413	0.743	1.883	0.9	<1.7	<0.5	<0.9	<0.9	<1.4	<0.5			
		Shift Mech.(elec.)	C951 C961	0.106 0.420	0.322 0.075	34	21.3 (2.5)	2.6 (1.8)	A459	0.727	0.245	1.4	<1.8	<0.6	<1.0	<1.0	<1.4	<0.5			
		Shift Mech.(elec.)	C887 C894	0.283 0.547	0.351 0.100	77	14.9 (2.9)	1.7 (2.1)	A417	0.906	1.152	4.1	3.8	0.7	<0.8	<0.8	<1.1	<0.4			
	M	Utility Mechanic	C962 C954	0.420 0.487	0.140 0.332	110	29.9 (2.6)	2.2 (2.0)	A462	0.577	0.740	1.9	<2.2	<0.7	<1.2	<1.2	<1.7	<0.6			
		Utility Mechanic	C886	0.725	0.164	63	10.8 (2.3)	2.4 (2.9)	A487	0.658	1.155	2.0	<2.0	1.5	<1.0	<1.1	<1.4	<0.6			
		Utility Mechanic	C888 C900	0.276 0.461	0.587 0.104	109	12.7 (2.7)	1.7 (1.8)	A397	0.860	0.735	0.5	<1.5	<0.5	<0.8	<0.8	<1.2	<0.5			

(Cd, Cr

Area	Exposure Category	Payroll Title	Job Category
Cupola		Cupola Operator	Same
	C.O.	Cupola Operator	same
		Cupola Operator	same
		Cupola Charger	same
	C.G.		
		Cupola Charger	same
Production Line	F	Shift Mgr.	Foreman
		Shift Mgr.	Foreman
	B.M.	Asst. Shift Mgr.	Asst.Foreman
		Asst. Shift Mgr.	Asst.Foreman
		Asst. Shift Mgr.	Asst.Foreman
		Crewperson	Take-off
		Crewperson	Take-off
	T	Crewperson	Take-off
		Crewperson	Take-off
		Crewperson	Take-off
		Crewperson	Take-off

Table C-5

PLANT E--AIR SAMPLING RESULTS
, Ni, Co, and Pb all below detectable limits)

Fiber Counting						Total Airborne Particulate Material					Respirable Particulate Material		
				Geom. Mean (Geom.Std.Dev.)					$\mu g/m^3$				
Sample Number	Flow (Liters)	f/cc	N	Length	Diameter	Sample Number	Flow (Liters)	Total Mg/M^3	Zn	Mn	Sample Number	Flow (Liters)	Total Mg/M^3
C 748	306	0.144				AA604	751	1.291	40	71			
C 734	282	0.173											
C 730	298	0.156											
			203	10.4	1.8								
C1015	326	0.187		(2.4)	(1.7)								
C1017	292	0.033											
C 731	358	0.245				AA567	839	1.372	67	0.1			
C 675	198	0.273											
C 658	306	0.131											
						AA509	793	1.161	10	104	W81	743	0.233
TWA	2366	0.166				TWA	2383	1.276					
C 737	240	0.352				AA550	838	3.218	74	<0.1			
C 676	244	0.190	139	9.7	1.6								
C 660	222	0.278		(2.3)	(1.4)								
C 663	126	0.643											
C 716	344	0.312				AA499	875	4.307	29	26			
C 715	260	0.217	119	8.3	1.9								
C 735	250	0.296		(2.0)	(1.5)								
						AA615	783	4.972	57	29	W70	713	0.496
TWA	1686	0.303				TWA	2496	4.150					
C 720	484	0.060				AA595	807	0.626	50	0.2			
C 711	333	0.004											
C1033	220	0.627				AA607	672	1.186	4	<0.1			
C1006	460	0.315	217	21.1	2.1								
				3.3	(1.8)								
C1020	383	0.100				AA510	782	0.233	1	<0.1			
C1003	386	0.056											
C 706	402	0.049				AA593	764	0.387	2	53			
C 719	379	0.077											
						AA590	833	0.174	11	16	W74	712	0.108
TWA	3047	0.138				TWA	3858	0.499					
C1016	385	0.061				AA601	785	0.233	-0-	6			
C1023	428	0.032											
C 717	396	0.083	159	18.7	2.3	AA508	824	0.615	0.161	36			
C 714	419	0.088		(3.1)	(1.8)								
C 712	160	0.037				AA561	658	0.319	9	24	W72	595	0.077
C 722	378	0.107				AA595	871	0.626	50	0.2			
C 713	428	0.106											
C 749a	274	0.119				AA633	772	0.440	trace	20			
C 729	436	0.028											
C 739	330	0.036				AA589	825	0.326	-0-	14			
C 727	252	0.107											

Area	Exposure Category	Payroll Title	Job Category
Production Line (Continued)	T	Crewperson	Take-off
		Crewperson	Take-off
		Crewperson	Take-off
		Crewperson	Take-off
		Crewperson	Take-off
		Crewperson	Take-off
		Crewperson	Take-off
	W	Crewperson	Loader
		Crewperson	Loader
		Crewperson	Loader
		Crewperson	Loader
		Crewperson	Loader
Warehouse	W	Leadman	same
		Loader	same
Yard	O.C.	Equip.Operator	Cat Operator
General Plant			Maint. Foreman
			Maintenance
			Maintenance

Table C-5 (Continued)

Fiber Counting						Total Airborne Particulate Material					Respirable Particulate Material		
				Geom. Mean (Geom.Std.Dev.)					$\mu g/m^3$				
Sample Number	Flow (Liters)	f/cc	N	Length	Diameter	Sample Number	Flow (Liters)	Total Mg/M^3	Zn	Mn	Sample Number	Flow (Liters)	Total Mg/M^3
						AA549	739	0.464	7	11	W80	677	0.194
C 664	316	0.113				AA565	779	0.946	43	30			
C 655	446	0.227											
			140	18.7	2.3								
C1013	469	0.067		(3.1)	(1.7)	AA612	682	0.330	5	2			
C1045	212	0.169											
C1005	431	0.098				AA627	675	2.053	4	58			
C1029	219	0.108											
C 725	428	0.096				AA500	780	0.792	20	74			
C 740	393	0.084											
C1009	424	0.096	130	18.3	2.2	AA616	596	1.267	40	19			
C1038	182	0.346		(3.0)	(1.8)								
C 723	350	0.056				AA501	802	0.398	15	45			
C 707	394	0.145											
TWA	8150	0.264				TWA	9788	0.658					
C1011	340	0.176				AA636	572	0.640	3	11			
C1040	240	0.183											
C 724	430	0.093				AA569	796	0.535	32	0.2			
C 718	384	0.070											
			234	18.6	2.3								
C 746	300	0.442		(2.9)	(1.7)	AA588	627	0.352	-0-	7			
C 747	370	0.057											
C 671	271	0.021				AA602	816	0.966	67	17			
C 659	458	0.197											
C 750	364	0.164				AA625	892	0.105	21	49			
C 726	453	0.204											
TWA	3610	0.159				TWA	3703	0.512					
C 665	342	0.205				AA600	785	1.324	63	19			
C 654	446	0.074											
			108	18.3	2.1								
C 670	340	0.118		(3.1)	(1.7)	AA631	771	1.560	52	40			
C 653	432	0.153											
TWA	1560	0.134				TWA	1556	1.441					
						AA545	730	2.397	96	94	W68	614	0.272
C1043	541	0.097				AA564	783	0.598	1	10			
C1027	236	0.149											
C1063	193	0.131	144	15.8	2.2	AA594	767	2.743	241	81			
C1048	585	0.157		(3.0)	(1.7)								
C1047	520	0.086				AA629	766	0.589	70	33			
C1041	250	0.124											

Table C-5 (Concluded)

Area	Exposure Category	Payroll Title	Job Category	Fiber Counting: Sample Number	Flow (Liters)	f/cc	N	Geom. Mean (Geom.Std.Dev.) Length	Diameter	Total Airborne Particulate Material: Sample Number	Flow (Liters)	Total Mg/M^3	μg/m^3 Zn	Mn	Respirable Particulate Material: Sample Number	Flow (Liters)	Total Mg/M^3
General Plant Continued			Maintenance	C1007	441	0.116				AA621	691	0.661	57	19			
	M			C1035	250	0.122											
			Maintenance	C1004	366	0.167	136	11.9	1.9	AA517	606	0.909	11	28			
				C1028	240	0.143		(2.6)	(1.7)								
			Maintenance							AA610	757	1.041	13	72	W66	688	0.081
			Maintenance	C 745	328	0.131				AA620	891	0.883	0.1	0.1			
				C 742	245	0.055											
				C 736	202	0.134											
							62	20.7	2.6								
			Maintenance	C1026	421	-0-		(2.8)	(1.7)	AA493	785	0.538	27	21			
				C1022	263	0.045											
				C1018	135	0.188											
			Maintenance	C1001	430	0.306				AA608	1048	0.598	128	19			
				C1034	207	0.433											
							133	15.8	1.7								
			Maintenance	C1012	500	0.035		(2.4)	(1.8)	AA597	640	0.644	73	16			
				C1037	154	0.114											
				TWA	6507	0.118				TWA	7734	0.914					
Miscellaneous	L.O.	Lab Tech.	same	C1008	588	0.220				AA516	552	0.384	10	4			
		Receiving Clk.	same	C1044	591	0.232				[illegible]618	776	0.954	15	30			
				C1058	167	0.297	168	15.3	2.0								
								(3.0)	(1.7)								
	C	Maint. Clerk	same	C1046	254	0.053				AA613	254	0.398	-0-	7			
				TWA	1600	0.206				TWA	1582	0.666					
Stationary (Lunchroom)										AA502	692	0.107	1	-0-			
(Top of Cupola)				C1025	367	0.209											
				C1021	736	0.037											
							62	9.5	2.1								
(Cupola Area)								(2.3)	(1.5)	AA610	793	1.041	13	72			
(Foreman's Office)				C1019	281	0.063				AA630	779	0.090	trace	-0-			
				C1010	489	-0-											
				TWA	1873	0.094				TWA	2264	0.482					

Appendix D

AIR SAMPLING RESULTS FOR INDIVIDUAL USER FACILITIES SURVEYED

The following compilations of data represent the results for each individual air sample taken and analyzed during the surveys. There are several headings across the top of each table, for which the key is given below:

Description: The plant area, exposure category, payroll title, and local job category (where payroll title is insufficiently descriptive) are given for each worker.

The "exposure categories" are those used for grouping the results in the main body of the report; the symbols used are:

B.W. = Installation of blowing wool

I.F. = Industrial Insulation Fabrication

T.W. = Ceiling Tile Wet Mix Operations

T.B. = Ceiling Tile Board Handling (Dry only)

T.Cl.= Ceiling Tile Cleanup

T.Cu.= Ceiling Tile Cutting Operations

T.Pt.= Ceiling Tile Painting

T.P. = Ceiling Tile Packing

T.L. = Ceiling Tile Lab. and Quality Control

T.W. = Ceiling Tile Warehouse and Loading

S.F. = Application of Sprayed Fireproofing

I.I. = Industrial Insulation Installation.

Fiber Counting: This section contains the description of the samples taken for assessment of airborne fiber exposures. The following items are included:

Sample Number
Flow (Liters or M^3) = Air volume sampled
F/cc = total fibers per cubic centimeter of air sampled, for each sample
N = number of fibers accumulated from several samples for sizing

Length and Diameter distribution of the N fibers, presented in the format:

Geometric Mean
(Geometric Standard Deviation)

for both length and diameter.

Total Airborne Particulate Material:

This is nearly self-explanatory:

Sample number
Sample volume
Total suspended material concentration
Trace element concentrations

Respirable Particulate Material:

Sample number
Sample volume
Respirable Particulate Material concentrations

In most cases, pairs of samples were taken; usually a sample for fiber counting and a total airborne particulate material sample. The filters for fiber counting were usually changed about midway through the shift, while the total airborne particulate material filter was left throughout the shift, without changing. Respirable particulate material samples were also left throughout the shift. (A shift is defined as a period of time in which the worker continued to perform the same task.) However, exceptions were made; filters were dropped or contaminated during sampling or analytical results were questionable due to possible errors in sample numbering, etc.

If samples could not be clearly traced to a specific worker, or if they were potentially in error, they were discarded.

Thus, there are some gaps in these tables. In general, however, there will be 2 fiber concentration results with a total airborne particulate material concentration, and one total airborne particulate concentration with a respirable particulate material concentration. The paired results (taken over the same time period for the same worker) appear on the same horizontal line.

Table D-1

FACILITY F--AIR SAMPLING RESULTS
(Cd, Cr, Ni, and Co all below detectable limit)

		Fiber Counting				Geom. Mean (Geom. Std. Dev.)		Total Airborne Particulate Material						Respirable Particulate Material		
											$\mu g/m^3$					
Exposure Category	Area or Job Category	Sample Number	Flow (Liters)	f/cc	N	Length	Diameter	Sample Number	Flow (Liters)	Total Mg/M^3	Zn	Pb	Mn	Sample Number	Flow (Liters)	Total Mg/M^3
B.W.	Insulation Installer (in truck)	C83	188	0.087				AA129	188	0.910	< 0.5	11.54	0.067			
		C169	114	0.238												
	Insulation Installer (in house)	C172	136	1.359	181	12.0 (3.3)	1.6 (1.8)	AA118	200	7.760	64.53	1.14	15.55			
		C98	66	0.856												
	Stationary (inside house)	C99	36	1.114				AA117	54	9.852	119.54	< 12.96	124.26	W2	46	2.565
		C157	18	0.723												
		TWA	558	0.606				TWA	442	5.102						

Table D-2

FACILITY G--AIR SAMPLING RESULTS

		Fiber Counting				Geom. Mean (Geom.Std.Dev.)		Total Airborne Particulate Material										Respirable Particulate Material		
Exposure Category	Job Title	Sample Number	Flow (Liters)	f/cc	N	Length	Diameter	Sample Number	Flow (Liters)	Total Mg/M^3	Zn	Pb	Mn	Cd	Co	Cr	Ni	Sample Number	Flow (Liters)	Total Mg/M^3
B.W.	Insulation Installer (in truck)	C614	50	0.035	9	NSF		AA624	50	<0.01	*	*	*	*	*	*	*	-	-	-
	Insulation Installer (in house)	C615	30	0.552				AA606	30	41	1070	90	50	3	25	< 33	< 47	-	-	-

*Less than detectable amounts.

Table D-3

FACILITY H--AIR SAMPLING RESULTS
(Cd, Cr, Ni, Co, and Pb all below detectable limits)

Exposure Category	Area	Payroll Title	Job Category	Fiber Counting: Sample Number	Flow (Liters)	f/cc	N	Geom. Mean (Geom.Std.Dev.) Length	Diameter	Total Airborne Particulate Material: Sample Number	Flow (Liters)	Total Mg/M^3	µg/m^3 Zn	µg/m^3 Mn	Respirable Particulate Material: Sample Number	Flow (Liters)	Total Mg/M^3
I.F.	Fabrication	Asst. Foreman	same							AA626	214	1.112	27	10	W82	180	0.133
		Leadman	same							AA576	839	0.682	27	<0.1	W79	701	0.150
		Crewperson	same	C1031	218	0.510				AA619	724	1.220	<0.1	27			
				C1042	501	0.267											
		Crewperson	same	C1032	262	0.265	310	17.3	2.3	AA507	642	0.642	9	8			
				C1049	380	0.185		(2.8)	(1.7)								
		Crewperson	same	C1002	352	0.235				AA491	667	0.708	18	10			
				C1030	247	0.542											
		Crewperson	same	C 708	204	0.486				AA582	209	1.370	17	66			
		Crewperson	same	C 710	220	0.243	109	16.9 (2.8)	2.3 (1.7)	AA581	218	1.151	1	9			
		Crewperson	same	C 704	207	0.280				AA614	196	0.857	81	8			
		Crewperson	same							AA623	206	1.864	9	10	W84	177	0.373
		Crewperson	same	C 701	232	0.638				AA634	229	1.721	21	17			
		Crewperson	same	C 702	228	0.333				AA638	232	2.263	46	29			
		Crewperson	same	C 709	224	0.325	226	19.1 (3.1)	2.4 (1.7)	AA632	224	1.679	30	14			
		Crewperson	same	C 703	226	0.207				AA580	228	1.474	44	10			
		Crewperson	same	C 705	207	0.466				AA635	196	1.260	36	12			
		Crewperson	same	C 749b	305	0.050				AA553	729	0.538	10	12			
				C 728	446	0.071											
			same	C 741	415	0.033	82	28.2	2.3	AA637	839	0.278	10	09			
				C 733	454	0.139		(3.1)	(1.7)								
			same	C 743	265	0.134				AA622	760	0.572	11	16			
				C 732	388	0.056											
				TWA	5981	0.240				TWA	7352	0.896					

Table D-4

FACILITY I--AIR SAMPLING RESULTS

Exposure Category	Area	Payroll Title	Fiber Counting: Sample No.	Fiber Counting: Flow (m^3)	Fiber Counting: f/cc	Fiber Counting: N	Fiber Counting: Count Median Length (SD)	Fiber Counting: Count Median Diam. (SD)	Total Airborne Particulate Material: Sample No.	Total Airborne Particulate Material: Flow (m^3)	Total Airborne Particulate Material: Total mg/m^3	Elemental Concentration ($\mu g/m^3$): Zn	Pb	Mn	Cr	Co	Ni	Cd	Respirable Particulate Material: Sample No.	Respirable Particulate Material: Flow (m^3)	Respirable Particulate Material: Total mg/m^3
T.W.	Board Dept.	Stock Preparer	C873 C858	0.160 0.499	0.320 0.100	52	26.4 (2.8)	2.4 (2.1)	A445	0.791	1.846	1.3	<1.6	<0.5	<0.9	<0.9	<1.2	<0.5			
		Stock Preparer	C929 C902	0.342 0.394	0.750 1.070	285	17.3 (2.7)	2.2 (1.7)	A482	0.784	4.046	0.5	<1.6	1.3	<0.9	<0.9	<1.2	<0.5			
		Stock Preparer	C921 C916	0.106 0.314	2.393 1.529	302	15.6 (2.9)	1.7 (1.8)	A484	0.532	4.919	1.5	<2.4	<0.8	<1.4	<1.3	<2	<0.8			
T.W.		Stock Mix Oper.	C868 C861	0.192 0.412	1.347 0.414	214	15.5 (2.7)	2.1 (2.0)	A450	0.903	1.168	<0.2	<1.4	<0.3	<0.8	<0.8	<0.8	<0.4			
		Stock Mix Oper.							A479	0.776	4.466	0.6	<1.7	2.06	<0.9	<0.9	<1.2	<0.5	W45	0.657	0.294
		Stock Mix Oper.	C914 C945	0.449 0.296	0.938 1.526	269	17.0 (2.9)	1.7 (1.8)	A488	0.733	1.484	1.0	<1.8	<0.5	<1.0	<1.0	<1.4	<0.6			
T.W.		Texture Control	C863 C973	0.198 0.410	0.755 0.160	110	10.4 (2.8)	1.4 (1.8)	A449	0.806	0.469	<0.2	<1.6	<0.4	<0.9	<0.9	<1.2	<0.5			
		Texture Control	C912 C930	0.534 0.294	0.343 0.597	185	18.7 (2.4)	2.1 (1.7)	A475	0.921	0.787	0.5	<1.4	<0.4	<0.8	<0.8	<0.8	<0.4			
		Texture Control	C946 C910	0.434 0.313	0.430 1.389	271	22.8 (2.3)	1.5 (1.7)	A485	0.780	0.883	<0.3	<1.7	<0.5	<0.9	<0.9	<1.2	<0.9			
T.W.		Oven Loader							A444	0.650	0.406	1.6	<2.0	<0.6	<1.0	<1.0	<1.7	<0.6	W054	0.658	0.068
		Oven Loader	C936 C0911	0.402 0.300	0.140 0.555	111	11.9 (2.5)	1.5 (2.0)	A463a	0.884	(negl.) <0.010	0.9	<1.5	0.6	<0.9	<0.8	<1.2	<0.6			
		Oven Loader	C922 C923	0.409 0.380	0.288 0.679	190	15.5 (2.5)	2.0 (1.6)	A474	0.801	1.114	<0.5	<1.6	2.0	<0.9	<0.9	<1.2	<0.5			
T.B.		Oven Oper.	C867 C862	0.536 0.425	1.393 3.280	550	4.2 (1.5)	1.2 (1.3)	A448	0.815	0.382	2.1	<1.6	<0.5	<0.9	<0.8	<1.2	<0.5			
		Oven Oper.	C924 C931	0.430 0.355	0.338 5.859	610	4.9 (1.9)	1.3 (1.4)	A481	0.702	0.510	<0.3	<1.8	<0.6	<1.0	<1.0	<1.4	<0.6			
		Oven Oper.	C943 C901	0.407 0.364	0.819 2.719	350	5.7 (2.2)	1.2 (1.7)	A456	0.607	1.601	2.3	<2.1	<0.6	<1.2	<1.2	<1.7	<0.6			
		Dry Helper	C881 C895	0.248 0.474	1.025 2.477	470	4.9 (1.8)	1.2 (1.3)	A410	0.842	0.650	0.3	<2.1	<0.5	<0.8	<0.8	<1.2	<0.5			

Table D-4 (Continued)

Exposure Category	Area	Payroll Title	Fiber Counting: Sample No.	Flow (m^3)	f/cc	N	Count Median Length (SD)	Diam. (SD)	Total Airborne Particulate Material: Sample No.	Flow (m^3)	Total mg/m3	Elemental Concentration ($\mu g/m^3$): Zn	Pb	Mn	Cr	Co	Ni	Cd	Respirable Particulate Material: Sample No.	Flow (m^3)	Total mg/m3
T.B.	Board Dept. (Cont'd)	Dry Helper	C838	0.236	2.499	270	5.5	1.4	A469	0.824	1.252	0.7	<1.5	<0.5	<0.9	<0.8	<1.2	<0.5			
			C972	0.387	0.892		(2.0)	(1.4)													
		Dry Helper	C969	0.452	0.431	139	24.7	2.8	A454	0.778	1.213	2.2	<1.7	<0.5	<0.9	<0.9	<1.2	<0.5			
			C870	0.301	0.245		(2.3)	(1.8)													
		Humidifier Oper.	C919	0.453	0.848	216	12.2	1.7	A453	0.785	2.339	1.3	<1.6	0.7	<0.9	<0.9	<1.2	<0.5			
			C918	0.426	0.504		(2.9)	(2.1)													
		Humidifier Oper.	C905	0.394	1.666	481	5.7	1.5	A476	0.691	0.566	1.3	<1.9	<0.6	<1.0	<1.0	<1.4	<0.6			
			C908	0.330	3.626		(2.1)	(1.5)													
		Humidifier Oper.	C866	0.666	0.833	275	4.6	1.3	A437	0.772	0.350	1.5	<1.7	<0.5	<0.9	<0.9	<1.2	<0.5			
			C857	0.405	1.198		(1.8)	(1.4)													
T.Cl.		Board Utility	C909	0.368	1.303	146	22.5	2.4	A471	0.804	8.479	0.5	<1.6	5.6	<0.9	<0.9	<1.2	<0.5			
			C928	0.443	0.324		(2.7)	(1.8)													
		Board Utility (Ceiling)	C882	0.056	6.911	107	21.5	2.6													
							(2.1)	(1.7)													
		Board Utility							A455	0.652	0.626	1.7	<2.0	<0.6	<1.0	<1.1	<1.7	<0.6	W050	0.683	0.126
		Board Utility	C0913	0.389	0.441	198	15.8	1.3	A473	0.762	1.079	0.2	<1.7	<0.4	<0.9	<0.9	<1.2	<0.5			
			C0904	0.344	0.623		(3.1)	(1.9)													
		Line Setup (Ceiling)	C932	0.052	4.888	295	15.9	2.1	A463b	0.844	(negl.)	0.3	<1.5	<0.5	<0.9	<0.8	<0.8	<0.4			
			C906	0.179	2.439		(2.5)	(1.8)													
			C963	0.254	0.325																
		Utility Setup	C933	0.054	3.946	268	12.9	1.9	A470	0.882	6.900	0.6	<1.5	5.0	<0.8	<0.8	<1.1	<0.5			
			C830	0.372	0.587		(2.3)	(1.8)													
			C958	0.415	0.234																
		Utility Setup	C920	0.286	0.550	129	12.2	1.4	A466	0.780	1.637	0.6	<1.6	<0.5	<0.9	<0.9	<1.2	<0.5			
			C957	0.435	0.201		(2.9)	(2.1)													
T.Cu.		Line Operator							A446	0.780	2.364	1.3	<1.7	<0.5	<0.9	<0.9	<1.2	<0.5	W47	0.641	0.275
		Line Attendant							A395	0.536	10.280	0.4	<2.4	2.1	<1.3	<1.3	<2	<0.7	W48	0.431	0.752
T.Pt.		Paint Operator	C971	0.405	1.053	303	12.9	2.0	A452	0.749	6.740	0.8	<1.7	3.0	<1.0	<0.9	<1.4	<0.6			
			C876	0.313	0.898		(2.4)	(1.6)													

Table D-4 (Concluded)

Exposure Catogory	Area	Payroll Title	Fiber Counting Sample No.	Flow (m^3)	f/cc	N	Count Median Length (SD)	Diam. (SD)	Total Airborne Particulate Material Sample No.	Flow (m^3)	Total mg/m^3	Elemental Concentration ($\mu g/m^3$) Zn	Pb	Mn	Cr	Co	Ni	Cd	Respirable Particulate Material Sample No.	Flow (m^3)	Total mg/m^3
T.P.	Board Dept. (Cont'd)	Sorter Packer	C974 C860	0.401 0.362	1.043 0.597	238	14.2 (2.5)	2.0 (1.7)	A436	0.751	3.928	0.7	1.7	1.9	<1.0	<0.9	<1.4	<0.5			
		Sorter Packer	C967 C874	0.392 0.368	0.782 0.519	260	10.6 (2.6)	2.2 (1.7)	A458	0.766	2.027	0.3	<1.7	<0.5	<0.9	<0.9	<1.2	<0.6			
		Sorter Packer	C970 C865	0.430 0.362	0.476 0.695	239	18.2 (2.6)	2.3 (1.7)	A438	0.798	2.134	1.4	<1.6	<0.5	<0.9	<0.9	<1.2	<0.5			
		Sorter Packer	C964 C859	0.425 0.315	0.739 0.239	194	18.8 (2.5)	2.3 (1.8)	A439	0.737	1.818	1.1	<1.8	<0.5	<0.9	<0.9	<1.4	<0.6			
		Sorter Packer							A457	0.729	2.336	1.6	<1.8	<0.5	<1.0	<1.0	<1.4	<0.7	W63	.0667	0.223
T.Cl.		Tile Utility	C952 C864	0.399 0.350	1.315 1.110	311	13.1 (2.4)	2.1 (1.6)	A451	0.738	1.602	0.6	<1.8	<0.5	<1.0	<0.9	<1.4	<0.6			
T.P.		Stacker	C855	0.737	1.085	233	6.3 (2.1)	1.5 (1.4)	A390	0.753	0.610	0.9	<1.7	<0.53	<0.9	<0.9	1.4	<0.5			
T.Pt.	Technical Dept.	Paint Technician							A419	0.805	2.466	<0.3	<1.6	<0.7	<0.9	<0.9	<1.2	<0.5	W041	0.651	0.367
T.L.		Tile Inspec.	C891	0.693	0.518	124	11.4 (2.4)	1.7 (1.6)	A391	0.692	1.785	1.0	<1.9	<0.6	<1.0	<1.0	1.4	<0.6			
	Board Dept.	Area Sample	C883 C887	0.248 0.283	1.666 0.362	154	13.9 (2.8)	1.3 (1.9)	A412	0.812	1.100	4.7	<1.6	<0.5	<0.9	<0.9	<1.2	<0.5			
	Tile Dept.	Area Sample							A461	0.856	1.991	0.9	<1.5	<0.5	<0.8	<0.8	<1.2	<0.4	W61	0.745	0.119
T.W.†	Traffic Dept. (Warehouse)	Area Sample	C893	0.253	0.701	92	11.0 (2.1)	1.8 (1.6)	A486	0.263	1.510	3.0	<4.9	<1.1	<2.7	<2.3	<3.8	<1.5			
		Area Sample	C966	0.776	0.051	21	7.1 (2.3)	1.7 (1.3)	A440	0.764	0.145	1.0	<1.7	<0.5	<0.9	<0.9	<1.2	<0.5			
		Area Sample	C896	0.729	0.439	109	22.4 (2.2)	2.3 (1.7)	A441	0.727	0.618	<0.2	<1.8	<0.4	<1.0	<1.0	<1.4	<0.6			
	Maint.Dept. (Storeroom)	Area Sample	C851	0.710	0.011	4	5.2 (2.0)	1.0 (1.4)													
	Maint.Shop	Area Sample	C968 C953	0.230 0.442	0.233 0.061	41	10.7 (2.5)	1.7 (1.6)													
	Lunch Room	Area Sample	C826	0.740	0.052	20	9.8 (2.1)	1.6 (1.7)													

† Near BZ samples on forklifts.

Table D-5

FACILITY J--AIR SAMPLING RESULTS

Exposure Category	Area	Job Title	Fiber Counting: Sample Number	Fiber Counting: Flow m^3	Fiber Counting: f/cc	Fiber Counting: N	Geom. Mean (Geom.Std.Dev.): Length	Geom. Mean (Geom.Std.Dev.): Diameter	Total Airborne Particulate Material: Sample No.	Flow (m^3)	Total mg/m^3	Elemental Concentration ($\mu g/m^3$): Zn	Pb	Mn	Cr	Co	Ni	Cd	Respirable Particulate Material: Sample No.	Flow (m^3)	Total mg/m^3
S.F.	Lower Floor-Near Hopper	Hod Carrier	C 622	0.320	0.496	79	28µm (3.9)	2.2µm (1.9)	AA504	0.376	2.673	1.5	<5	0.7	<2	<2	<7	<2	W88	0.320	0.291
									AA495	0.320	5.144	6.8	<6	1.3	3.4	<2	<7	<2			
									TWA	0.696	3.800										
		Area Sample	C 604	0.755	0.086	33			AA518	0.724	0.460	<.4	<3	<0.4	<.9	<2	<7	<2			
	Upper Floor-Application	Plasterer	C 609	0.176	0.639	56	45µm (3.9)	2.7µm (1.8)	AA511	0.396	10.457	<.9	<5	5.9	2.2	<2	<7	<2			
			C 610	0.219	0.384	43			AA503	0.320	21.550	3.5	<6	16.0	2.8	<2	<7	<2	W86	0.272	0.471
			TWA	0.395	0.498				TWA	0.716	15.414										
		Area Sample	C 605	0.697	0.020	7			AA520	0.697	0.357	0.5	<3	<.4	<1	<2	<7	<2			

Table D-6

FACILITY K--AIR SAMPLING RESULTS

Exposure Category	Function	Job Title	Fiber Counting: Sample Number	Fiber Counting: Flow m^3	Fiber Counting: f/cc	Fiber Counting: N	Geom. Mean (Geom. Std. Dev.): Length	Geom. Mean (Geom. Std. Dev.): Diameter	Total Airborne Particulate Material: Sample No.	Total Airborne Particulate Material: Flow (m^3)	Total Airborne Particulate Material: Total mg/m^3	Elemental Concentration ($\mu g/m^3$): Zn	Pb	Mn	Cr	Co	Ni	Cd	Respirable Particulate Material: Sample No.	Respirable Particulate Material: Flow (m^3)	Respirable Particulate Material: Total mg/m^3
I.I	Applying MW		C1039	0.150	0.108	8			AA529	0.150	5.753										
	Applying Mud								AA538	0.348	0.667								W0077	0.296	0.412
									AA537	0.160	2.369								W078	0.136	2.353
		Insulation Mechanic							AA528	0.186	1.376								W067	0.158	0.456
	Mixing Mud And Applying		C1086	0.190	0.107	10			AA530	0.340	3.903										
			C1072	0.150	0.067	5															
	Mixing Mud		C1075	0.172	0.072	6	11.8 (2.8)	1.9 (1.7)	AA513	0.172	1.308	All elemental concentrations less than detectable.									
			C1053	0.190	0.032	3			AA497	0.185	1.173										
	Near Scaffold	Area	C1095	0.290	0.056	8															
			C1092	0.258	<0.01	0															
			C1099	0.172	0.08	7			AA489	0.908	0.477										
			C1090	0.188	0.01	1															
	Near Door		C1085	0.276	<0.010	0															
			C1093	0.254	0.024	3															
			C1052	0.176	0.185	16			AA522	0.872	0.458										
			C1036	0.172	0.093	8															
						75															

Appendix E

BULK SAMPLE ANALYSES

One or more samples were taken at each facility visited. For each facility (except where noted otherwise), the following analyses were performed on the collected samples:

- X-Ray fluorescence (XRF) analysis--scan for total elemental composition. (Total sample or separated fiber and shot.)
- Atomic Absorption (AA) spectroscopy for Zn, Pb, Mn, Cd, Cr, Co, and Ni. (Total sample or separated fiber and shot.)
- X-Ray microprobe analysis of individual particles. The individual particles analyzed were selected to be representative of the following categories:
  - Small fibers; those with diameters $\lesssim$ 1.0 um.
  - Medium fibers; those with diameters $\simeq$ 4-5 um.
  - Large fibers; those with diameters $\gtrsim$ 10 um.
  - Shot particles; the compact, almost spherical head of the freshly formed fiber.
  - Variable particles; angular particles characteristic of the general background contamination.
- Optical microscopic (phase-contract at 400X) determination of mean fiber diameter for $\geq$ 100 or $\geq$ 500 fibers.

The AA and XRF results are presented together, as μg of specific elements per gram of total sample (or as weight percent) for either the total sample or the separate fiber and shot components.

The X-Ray microprobe results are presented as uncorrected peak heights (cm.) from spectra of counts/100 seconds as a function of secondary X-Ray energy (Kev). Full scale (1000 or 10,000 counts) is 2 cm. These results are intended to be qualitative aids in the comparisons of these samples, and for semi-quantitative analysis of their differences.

They are coded as follows:

S = Small fiber

M = Medium fiber

L = Large fiber

Shot = Shot particle

VP = Variable (background) particle.

The optical microscopic fiber diameter determinations are presented as tables of fiber diameters and as cumulative frequency distributions.

BULK SAMPLE ANALYSES--FACILITY A

The following samples were analyzed.

A-1 Batt line fiber, taken from line immediately following the curing oven.

A-2 Wool line fiber (blowing wool) before packaging.

A-3 Batt line fiber, as packaged.

A-4 Settled dust (face level and waist level) around wool line bagging machine.

A-5 Old blowing wool (produced 1966-1967).

A-6 Blowing wool as delivered from hose by insulation contractor.

A-7 Blowing wool as supplied to local insulation contractor.

A-8 Fly ash from bag house.

A-9 Batt line fiber before curing oven.

Table E-1

BULK SAMPLES--FACILITY A

Elemental Analysis by X-ray Fluorescence (XRF) and Atomic Absorption (AA)

	A-1		A-2		A-3		A-4		A-5		
Element	XRF	AA	XRF	AA	XRF	AA	XRF	AA	XRF (orig)	XRF (rerun)	AA
Cr	<85	23	<75	23	<110	26	130	28	<135		45
Mn	15000	13511	15000	15323	13000	2672	15000	14591	6000	6309	2957
Fe	68000		91000		57000		10000		140000		
Co	<60		<65		<65		<71		<90		
Ni	≤30		<25		<25		<30		<35		
Cu	250		341		159		396		825		
Zn	6100	5063	11000	11359	5100	4561	12000	11369	17000	16864	18464
Hg	≤25		≤25		<25		≤26		<31		
Pb	245	219	480	437	159	184	691	675	1400		1709
As	60		132		79		118		21		
Ag	<170		<140		<170		<130		<170		
Cd	<170		<140		<170		<130		<170		
Ti	975		978		1400		<375		1100		
Sn	<300		<190		<350		<270		<387		
K	12000		~7400		~8400		~8600		~9000		
Ca	280000		~220000		~240000		~23000		~210000		
Sr	1400		1000		1200		1100		517		
Ba	2700		1500		1800		2700		839		
Se	≤12		<10		<15		13		<14		
Rb	59		27		<34		27		26		
P,Cl,S	Obs		Obs		Obs		Obs		Obs		

	A-6			A-7		A-8			A-9	
Element	XRF (orig)	XRF (rerun)	AA	XRF	AA	XRF (orig)	XRF (rerun)	AA	XRF	AA
Cr	<130		30	<105	23	<300		14	<77	43
Mn	26000	26705	15401	14000	14244	513 Run I / 610 Run II		1221	13000	13048
Fe	150000			95000		2800 / 3000			56000	
Co	<96			<65		<200			<55	
Ni	<34			<20		≤112 / ≤127			≤21	
Cu	435			301		<144			338	
Zn	17000		11596	12000	12744	250000 / 230000	242617	17752	4700	7351
Hg	<45			≤20		<180			<21	
Pb	1200	1385	445	744	632	350000 / 330000	346823	13444	243	214
As	77			117		<200			≤27	
Ag	<175			<125		<500			<135	
Cd	<175			<125		<500		72	<135	
Ti	≤50			717		<750			1100	
Sn	<430			<260		<750			<220	
K	~11000			~8500		<5000			~9500	
Ca	~340000			~230000		<2200			~230000	
Sr	1800			1100		<110			1100	
Ba	4100			2300		1800			2000	
Se	16			≤10		<150			≤10	
Rb	56			<21		<150			<25	
P,Cl,S	Obs			Obs		Obs			Obs	

Table E-2

Sample #A-2

Energy (kv)	Element	Intensity (cm) S	M	L	Shot A	Shot B	VP A	VP B
1.0	Na	--	--	--	--	--	--	0.20
1.2	Mg	0.65	0.42	0.35	0.30	0.50	0.20	0.30
1.5	Al	2.70	1.10	1.60	0.60	2.35	0.80	1.30
1.7	Si	3.00	3.22	2.10	2.50	1.95	2.50	3.40
2.2	S	0.30	0.20	0.22	--	0.30	0.25	0.10
2.5	Cl	0.22	0.10	0.25	0.20	0.25	0.15	--
2.9	Ar?	--	--	0.40	--	--	--	--
3.2	K	0.30	0.35	0.50	0.40	0.43	0.35	0.22
3.6	Ca	2.90	3.50	3.20	3.65	3.60	3.60	0.15
3.9	Ca	0.35	0.60	0.52	0.55	0.75	0.55	--
4.5	Ti	0.15	--	0.15	0.12	0.30	0.15	0.20
5.3	Cr	0.15	0.10	0.10	0.05	--	--	0.05
5.8	Mn	0.25	0.30	0.30	0.20	0.45	0.25	0.05
6.3	Fe	0.85	1.20	1.45	1.15	2.65	1.40	--
6.9	Fe	0.20	0.08	0.25	0.15	0.45	0.22	--
7.5	Ni	--	0.15	--	--	0.03	--	--
8.0	Cu	0.20	--	0.20	--	0.20	0.10	--
8.6	Zn	--	0.20	0.15	0.05	0.20	0.12	--

Table E-3

Sample #A-4

Energy (kv)	Element	Intensity (cm) S	M	L	Shot A	Shot B	VP
1.2	Mg	0.20	0.30	0.05	--	--	--
1.5	Al	1.45	1.05	0.50	1.90	1.30	0.30
1.7	Si	2.60	2.70	2.35	1.80	0.55	1.75
2.2	S	0.25	0.15	0.20	0.10	--	--
2.5	Cl	--	--	--	--	--	--
3.2	K	0.15	0.22	0.36	0.30	0.30	0.20
3.6	Ca	3.30	3.42	3.60	3.60	3.40	3.45
3.9	Ca	0.32	0.55	0.45	0.45	0.50	0.45
4.5	Ti	0.10	--	0.05	--	--	0.12
5.8	Mn	0.10	0.15	0.20	0.15	0.25	0.25
6.3	Fe	1.10	1.12	1.21	1.00	1.52	1.15
6.9	Fe	0.15	0.20	0.20	0.15	0.28	0.18
8.0	Cu	0.05	0.10	--	--	0.10	--
8.6	Zn	0.10	0.05	0.10	--	--	0.12

Table E-4

Sample #A-5

Energy (kv)	Element	S	M	L	Shot A	Shot B
				Intensity (cm)		
1.2	Mg	0.40	0.30	0.10	0.05	0.45
1.5	Al	1.82	1.00	1.60	0.35	0.75
1.7	Si	3.00	2.95	2.20	1.20	3.10
2.2	S	0.22	0.22	0.12	0.10	0.22
2.5	Cl	--	--	--	0.05	--
3.2	K	0.30	0.32	0.35	0.30	0.28
3.6	Ca	3.30	3.44	3.55	3.60	3.30
3.9	Ca	0.30	0.35	0.55	0.55	0.40
4.5	Ti	0.14	0.03	0.04	0.10	0.10
5.8	Mn	0.15	0.12	0.05	0.15	0.15
6.3	Fe	1.15	1.85	2.05	1.95	0.75
6.9	Fe	0.15	0.22	0.20	0.40	0.20
8.0	Ca	0.15	--	0.10	0.05	--
8.6	Zn	0.20	0.10	0.18	0.15	0.10

Table E-5

Sample #A-7

Energy (kv)	Element	Intensity (cm) S	M	L	Shot	A VP	B VP
1.2	Mg	0.15	0.15	0.10	--	--	--
1.5	Al	0.90	0.70	0.45	0.80	--	0.30
1.7	Si	3.00	2.81	2.05	3.11	--	3.75
2.2	S	0.10	0.12	0.13	1.70	--	--
2.5	Cl	--	0.08	--	--	--	--
3.2	K	0.20	0.30	0.36	--	--	--
3.6	Ca	3.40	3.65	3.62	1.55	3.50	--
3.9	Ca	--	0.50	0.45	0.32	0.50	--
4.5	Ti	--	--	--	0.68	--	--
5.2	Cr	--	--	--	0.08	--	--
5.8	Mn	0.12	0.18	0.15	0.02	--	--
6.3	Fe	1.10	1.28	1.05	0.70	--	--
6.9	Fe	0.05	0.10	0.10	--	--	--
8.0	Cu	--	--	--	--	--	--
8.6	Zn	--	0.10	--	0.62	--	--
9.4	Zn	--	--	--	--	--	--

Table E-6

Sample #A-7 (Duplicate)

Energy (kv)	Element	Intensity (cm) S	M	L	Shot	VP
1.2	Mg	0.30	0.20	0.12	--	0.30
1.5	Al	0.90	0.45	0.60	1.40	0.85
1.7	Si	2.90	2.30	2.92	2.41	3.25
2.2	S	0.15	0.20	--	2.30	0.20
2.5	Cl	--	0.10	0.03	--	--
3.2	K	0.25	0.40	0.15	0.50	0.32
3.6	Ca	3.40	3.45	3.42	2.50	3.45
3.9	Ca	0.45	0.45	0.35	0.50	0.45
4.5	Ti	0.05	0.05	0.02	0.70	--
5.8	Mn	0.15	0.20	0.20	--	0.10
6.3	Fe	0.90	1.22	1.10	0.43	1.12
6.9	Fe	0.10	0.15	0.12	0.15	0.12
8.0	Cu	--	--	--	0.21	--
8.6	Zn	--	0.10	0.10	0.90	0.15
9.4	Zn	--	--	--	0.15	--

Table E-7

Cumulative Analyses of Fiber and Shot by

Microprobe for Selected Elements: Relative Intensities

		Small Fibers			Medium Fibers			Large Fibers			Shot		
Element	KV	Intensities	Mean	SD	Intensities	Mean	SD	Intensities	Mean	SD	Intensities	Mean	SD
Mg	1.2	0.15			0.15			0.10			-		
		0.30			0.20			0.12			-		
		0.65	0.34	0.22	0.42	0.27	0.12	0.35	0.14	0.13	0.30 0.50	0.16	0.18
		0.40			0.30			0.10			0.05 0.45		
		0.20			0.30			0.05					
Al	1.5	0.90			.70			0.45			0.80		
		0.90			.45			0.60			1.40		
		2.70	1.55	0.77	1.10	0.86	0.28	1.60	0.95	0.50	0.60 2.35	1.18	0.61
		1.82			1.00			1.60			0.35 0.75		
		1.45			1.05			0.50			1.90 1.30		
Si	1.7	3.00			2.81			2.05			3.11		
		2.90			2.30			2.92			2.41		
		3.00	2.9	0.17	3.22	2.80	0.40	2.10	2.32	0.37	2.50 1.95	2.08	0.90
		3.00			2.95			2.20			1.20 3.10		
		2.60			2.70			2.35			1.80 0.55		
Mn	5.8	0.12			0.18			0.15			0.02		
		0.15			0.20			0.20			-		
		0.25	0.15	0.07	0.30	0.19	0.08	0.30	0.18	0.11	0.20 0.45	0.17	0.16
		0.15			0.12			0.05			0.15 0.15		
		0.10			0.15			0.20			0.15 0.25		
Zn.	8.6	-			0.10			-			0.62		
		-			0.10			0.10			0.90		
		-	0.05	0.09	0.20	0.11	0.07	0.15	0.11	0.08	0.05 0.20	0.25	0.32
		0.20			0.10			0.18			0.15 0.10		
		0.10			0.05			0.10			- -		

Table E-8

BULK SAMPLE SIZE ANALYSIS--FACILITY A

Sample #	# Fibers Sized	Geometric Mean (μm)	Geometric Standard Deviation
A-5	158	4.1	1.8
A-7	163	3.7	1.9
A-6	164	4.8	1.7
A-4	539	3.7	1.9
Total	1024	3.9	1.8

Table E-9

DISTRIBUTION OF FIBER DIAMETER

Category	Diameter (μm)	Fiber Counts (by Sample) A#5	A#7	A#6	A#4	# Fibers	%	Cum. %
≤1	≤0.91	1	2	0	4	7	0.7	0.7
1≤2	0.91≤1.28	3	3	1	30	37	3.6	4.3
2≤3	1.28≤1.81	13	16	8	47	84	8.2	12.5
3≤4	1.81≤2.56	23	28	12	80	143	14.0	26.5
4≤5	2.56≤3.62	24	31	27	79	161	15.7	42.2
5≤6	3.62≤5.12	21	20	28	102	171	16.7	58.9
6≤7	5.12≤7.24	73	63	88	197	421	41.1	100.0
Total # Fibers		158	163	164	539	1024	100.00	100.0

BULK SAMPLE ANALYSES--FACILITY B

The following samples of bulk material from Facility B were examined:

Sample #	Description
B-1	Wool in process stream to baler - after second airlift
B-2	Pooled sample from stored batts in warehouse
B-3	Static-charged "flywool" found clinging to vertical surfaces following coverage test of blowing wool by quality control tester.
B-4	Coverage deposit; same test as sample BB-3.
B-5	Packed bale for delivery to ceiling tile plant
B-6	Fibers immediately after blow chamber - no airlift
B-7	Fibers immediately after blow chamber - no airlift; day following sample # BB-6
B-8	Wool in process stream to baler - following first airlift, before second airlift
B-9	Competitor's product - blowing wool from warehouse.

Table E-10

RESULTS OF X-RAY FLUORESCENCE AND ATOMIC ABSORPTION ANALYSIS OF BULK SAMPLES

Element	B-1		B-2		B-3		B-4		B-5		B-6			B-7		B-8		B-9	
	XRF	AA	XRF	AA	XRF	AA	XRF	AA	XRF	AA	XRF#1	XRF#2	AA	XRF	AA	XRF	AA	XRF	AA
Cr	<50	33	<76	19	<90	43	<79	32	<74	29	<70		22	<50	21	<103	30	<57	22
Mn	1,700	2,220	2,000	1,820	1,700	2,050	2,400	2,130	2,000	2,160	2,300	2,200	2,200	2,000	1,980	1,900	2,130	2400	1650
Fe	29,000		21,000		40,000		44,000		46,000		17,000	16,000		18,000		29,000		13000	
Co	<40	<10	<50	13	<56	15	<54	<10	<50	17	<40	-	<10	<40	<10	<40	10	<34	0
Ni	<17	19	<22	0	<23	39	<28	32	<20	26	<18	-	0	<17	<20	<17	25	<18	<20
Cu	25		57		83		≤21		25		≤18	≤17		≤15		<16		≤17	
Zn	26	640	186	105	82	18	40	11	52	17	25	24	40	34	129	22	59	<13	
Hg	<15		25		<24		<22		<20		<21	-		<20		<18		<20	
Pb	21	0	53	0	<24	0	<18	0	32	0	<18	-	<26	<15	0	≤15	0	<17	0
As	<7.5		<12		<14		<11		<9.1		<10	-		<9.1		<10		<10	
Ag	<85		<148		<164		<122		<110		<98	-		<112		<110		<115	
Cd	<85	0	<148	0	<164	0	<122	0	<110	0	<98	-	0	<112	0	<110	0	<115	0
Ti	2,000		3,000		2,500		2,800		2,100		2,500	2,500		2,300		1,900		3000	
Sn	<146		<271		<228		<200		<188		<183	-		<158		<179		<192	
K	~2,000		~2,300		~2,600		~3,400		~1,700		~2,800	~2,400		~2,300		~1,900		~1900	
Ca	250,000		290,000		210,000		230,000		270,000		250,000	230,000		280,000		250,000		230000	
Sr	592		613		485		468		706		489	559		653		576		475	
Ba	<500		<685		<576		<733		<637		<554	-		≤664		≤542		<598	
Si,S	OBS		OBS		OBS		OBS		OBS		OBS	OBS		OBS		OBS		OBS	

Table E-11

BULK SAMPLES FROM FACILITY B (SEM MICROPROBE)

Measurement in cm Taken Directly from Photographs-No Corrections for Background etc., Made

Sample		Na	Mg	Al	Si	S	K	Ca	Ti	Cr	Mn	Fe	Co	Cu	Zn	V	Cl
B1	VP†			0.8	3.4	0.1		0.1	<0.1			0.1					
	shot			0.2	0.6		0.1	3.5				0.3		<0.1			
	small		?0.2	2.3	3.0		0.2	3.6	0.1			0.2		0.1			
	medium		0.2	0.6	2.6		0.1	3.4				0.2		?<0.1			
	large		0.2	0.7	2.6	<0.1	<0.1	3.4		<0.1		0.2			<0.1		
B2*	VP†			3.7			0.1	<0.1	0.1	0.1		0.1		0.2		0.1	
	VP†	<0.1			3.5		0.3	0.1	0.3			<0.1		<0.1	<0.1	0.1	
	shot			0.4	1.1	<0.1	0.2	3.5	<0.1			0.2		<0.1		<0.1	
	small			3.3	1.3		0.2	0.2	<0.1			<0.1		0.2			
	medium			2.4	3.0	<0.1	<0.1	0.6	0.2			<0.1	<0.1	0.1			
B3	VP†	0.2			3.5		0.1	0.1				0.1		0.1	0.2		
	shot			0.5	1.5			2.7	0.1			0.3		<0.1			
	small			3.8	2.3	0.2		2.1	0.1			0.4	? 0.1	0.1	<0.1		
	medium			1.1	2.4	0.2	0.1	3.4	0.1			0.5		<0.1			
	large			0.8	1.8	<0.1		3.3	0.1			0.2				<0.1	
B4	shot		0.4	0.9	2.2	0.1	0.1	3.2		0.1		0.3					
	small			2.1	2.9	0.1	<0.1	3.1	0.1	0.1		0.4		<0.1			
	medium		0.3	0.9	1.8	0.1	0.1	3.3	<0.1	0.1		0.4	? 0.1	0.1			
	large		0.5	1.2	2.8	0.1	0.1	3.2	0.1	<0.1	<0.1	0.4					
B5	VP†				3.2		0.1			<0.1		<0.1					
	shot			0.5	1.6		0.1	3.6	<0.1		<0.1	0.2		<0.1			
	small			3.4	0.4			0.1				0.1	?<0.1	<0.1			
	medium			3.4	3.0		<0.1	0.4	0.2			0.2		0.2			<0.1
	large			1.5	3.4	0.1	0.4	3.1	0.1	<0.1		0.3					<0.1
B7*	VP†	0.1			3.4												
	shot				1.1	<0.1	0.1	3.4	0.1			0.2		<0.1			
	small	0.1		2.3	1.8		<0.1	1.1	<0.1	0.1		0.1		0.1			
	medium			1.3	2.6	0.1	0.1	3.3	0.1	<0.1	<0.1	0.2		?<0.1			
B8	VP†			1.7	2.9	0.1	0.2	1.1	0.2		<0.1	0.9	0.1	0.1	<0.1		
	shot			1.0	2.5	<0.1	0.1	3.2	<0.1	0.1		0.2			<0.1		
	small			1.4	1.5			1.3	<0.1	0.1		0.1		<0.1		<0.1	
	medium			0.8	2.2	<0.1	0.1	3.3	0.1		0.1	0.2					
	large				2.9			3.2	<0.1	<0.1		0.2		<0.1	<0.1		
B9	VP†	0.2			3.5		0.1	0.1	0.1	<0.1		<0.1				<0.1	
	shot				1.0	<0.1	0.1	3.3			<0.1	0.2		<0.1			
	small			1.5	2.1	0.1	<0.1	2.5		0.1		0.2		<0.1		<0.1	
	medium				1.9	<0.1	<0.1	3.4				0.2		<0.1		<0.1	
	large			1.4	2.2			3.2				0.2		<0.1			

*No fibers > 10μ in diameter.

†VP = Variable Particle; not a fiber.

Table E-12

BULK SAMPLES FROM FACILITY B (SEM MICROPROBE)

Measurement in cm Taken Directly from Photographs-No Corrections for Background etc., Made

Sample		Na	Mg	Al	Si	S	K	Ca	Ti	Cr	Mn	Fe	Co	Cu	Zn	V	Cl
B1	VP			0.8	3.4	0.1		0.1	<0.1			0.1					
B2	VP			3.7			0.1	<0.1	0.1	0.1		0.1		0.2		0.1	
	VP	<0.1			3.5		0.3	0.1	0.3			<0.1		<0.1	<0.1	0.1	
B3	VP	0.2			3.5		0.1	0.1				0.1		0.1	0.2		
B5	VP				3.2		0.1			<0.1		<0.1					
B6	VP				0.7		0.1	<0.1	0.2	'<0.1		<0.1			0.1	<0.1	
B7	VP	0.1			3.4												
B1	shot			0.2	0.6		0.1	3.5				0.3		<0.1			
B2	shot			0.4	1.1	<0.1	0.2	3.5	<0.1			0.2		<0.1		<0.1	
B3	shot			0.5	1.5			2.7	0.1			0.3		<0.1			
B4	shot		0.4	0.9	2.2	0.1	0.1	3.2		0.1		0.3					
B5	shot			0.5	1.6		0.1	3.6	<0.1		<0.1	0.2		<0.1			
B6	shot		0.4	0.6	1.8	0.1	0.1	3.4	<0.1	0.1		0.2					
B7	shot				1.1	<0.1	0.1	3.4	0.1			0.2		<0.1			
B8	shot			1.0	2.5	<0.1	0.1	3.2	<0.1	0.1		0.2			<0.1		
B9	shot				1.0	<0.1	0.1	3.3			<0.1	0.2		<0.1			
B1	small		?0.2	2.3	3.0		0.2	3.6	0.1			0.2		0.1			
B2	small			3.3	1.3		0.2		<0.1			<0.1		0.2			
B3	small			3.8	2.3	0.2		2.1	0.1			0.4	? 0.1	0.1	<0.1		
B4	small			2.1	2.9	0.1	<0.1	3.1	0.1	0.1		0.4		<0.1			
B5	small			3.4	0.4			0.1				0.1	?<0.1	<0.1			
B6	small			3.0	2.5	<0.1	0.1	2.1	0.1	<0.1		0.2		0.1	<0.1	<0.1	
B7	small	0.1		2.3	1.8		<0.1	1.1	<0.1	0.1		0.1		0.1			
B8	small			1.4	1.5			1.3	<0.1	0.1		0.1		<0.1		<0.1	
B9	small			1.5	2.1	0.1	<0.1	2.5		0.1		0.2		<0.1		<0.1	
B1	medium		0.2	0.6	2.6		0.1	3.4				0.2		?<0.1			
B2	medium			2.4	3.0	<0.1	<0.1	0.6	0.2			<0.1	<0.1	0.1			
B3	medium			1.1	2.4	0.2	0.1	3.4	0.1			0.5		<0.1			
B4	medium		0.3	0.9	1.8	0.1	0.1	3.3	<0.1	0.1		0.4	0.1	0.1			
B5	medium			3.4	3.0		<0.1	0.4	0.2			0.2		0.2			<0.1
B6	medium			1.1	2.5	0.1	0.1	3.3	0.1	<0.1		0.2		<0.1	0.1		
B7	medium			1.3	2.6	0.1	0.1	3.3	0.1	<0.1	<0.1	0.2		?<0.1			
B8	medium			0.8	2.2	<0.1	0.1	3.3	0.1		0.1	0.2					
B9	medium				1.9	<0.1	<0.1	3.4				0.2		<0.1		<0.1	
B1	large		0.2	0.7	2.6	<0.1	<0.1	3.4		<0.1		0.2			<0.1		
B3	large			0.8	1.8	<0.1		3.3	0.1			0.2				<0.1	
B4	large		0.5	1.2	2.8	0.1	0.1	3.2	0.1	<0.1	<0.1	0.4					
B5	large			1.5	3.4	0.1	0.4	3.1	0.1	<0.1		0.3					<0.1
B6	large			0.9	2.1	0.1	0.1	3.4	<0.1		<0.1	0.1					
B8	large				2.9			3.2	<0.1	<0.1		0.2		<0.1	<0.1		
B9	large			1.4	2.2			3.2				0.2		<0.1			

Table E-13

BULK SAMPLE FIBER DIAMETERS
BY OPTICAL MICROSCOPY--FACILITY B

Sample #	# Fibers Sized	Geometric Mean Diameter (S.D.)	
		Calculated	Graphic
B-1	117	3.1 (2.0)	3.3 (2.1)
B-2	514	4.0 (2.1)	4.1 (2.0)
B-3	129	2.8 (2.2)	2.9 (2.4)
B-4	101	3.8 (2.4)	3.9 (2.4)
B-5	142	3.6 (2.3)	3.7 (2.3)
B-6	107	4.8 (2.1)	4.9 (2.4)
B-7	109	3.2 (2.1)	3.3 (2.2)
B-8	108	3.0 (2.3)	3.1 (2.3)
B-9	182	3.4 (2.2)	3.5 (2.2)

Table E-14

FREQUENCY DISTRIBUTION OF FIBER DIAMETERS

Porton Category	Diameter (μm)	Samples (#fibers)									Total #fibers
		B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	
≤ 1	<0.91	6	14	11	7	11	1	3	8	10	71
$1 \leq 2$	0.91-1.28	4	36	6	4	6	4	12	8	15	95
$2 \leq 3$	1.28-1.81	15	38	25	14	15	9	13	14	16	159
$3 \leq 4$	1.81-2.56	15	46	17	8	17	8	13	19	20	163
$4 \leq 5$	2.56-3.62	21	55	13	8	15	18	15	12	20	177
$5 \leq 6$	3.62-5.12	32	103	29	19	22	11	21	15	38	290
$6 \leq 7$	5.12-7.24	12	102	12	15	23	13	17	15	32	241
$7 \leq 8$	7.24-10.24	7	88	13	17	22	27	10	13	20	217
$8 \leq 9$	10.24-14.48	4	26	2	5	7	13	3	2	8	70
$9 \leq 10$	14.48-20.48	1	4	1	1	4	3	2	2	3	21
$10 \leq 11$	20.48-28.96	0	2	0	2	0	0	0	0	0	4
$11 \leq 12$	28.96-40.96	0	0	0	1	0	0	0	0	0	1
Total #Fibers		117	514	129	101	142	107	109	108	182	1509

$\chi^2 = 165.01$
$\chi^2.05$ (88 d.f.) $= 111.96$
$P < 0.005$

BULK SAMPLE ANALYSIS--FACILITY C

Four bulk mineral wool samples were taken over a two-day period:

C-1 Baled wool being produced from both cupolas

C-2 Bagged wool--maleic acid addition

C-3 Bagged wool--Mulrex® addition

C-4 Packed bale from warehouse.

Table E-15

X-RAY FLUORESCENCE (XRF) ANALYSIS & ATOMIC ABSORPTION (AA) ANALYSIS OF BULK SAMPLES - FACILITY C

ELEMENT	C-1 XRF			C-1	C-2 XRF			C-2	C-3 XRF			C-3	C-4 XRF			C-4
	Total	Fiber	Shot	AA	Total	Fiber	Shot	AA	Total	Fiber	Shot	AA	Total	Fiber	Shot	AA
Cr	<55	<45	<40	<12	85	<30	<40	<12	<70	<30	<40	12	≤90	<25	≤45	<12
Mn	.39%	.36%	.32%	.29%	.30%	.32%	.31%	.23%	.36%	.31%	.31%	.28%	.38%	.29%	.37	.27%
Fe	.32%	.35%	.32%		.24%	.25%	.22%		.37%	.33%	.31%		.42%	.31%	.37%	
Co	≤30	<20	<20	<10	<40	<15	<20	<10	<30	<15	40	<10	<35	≤20	<20	<10
Ni	<15	<10	<10	<20	<25	<10	<10	<20	<25	≤10	<10	<20	<25	<10	<10	<20
Cu	<15	≤15	<10		≤20	<10	<10		<20	30	<10		<20	<10	<10	
Zn	≤20	50	≤15	8	<20	≤10	35	<8	≤25	20	<10	< 8	≤20	<10	26	< 8
Hg	<20	<10	<10		<20	<10	<10		<15	<10	<10		<15	<10	<10	
Pb	<20	85	≤12	<20	<15	25	110	<20	≤17	20	30	<20	<15	20	67	<20
As	<20	<10	<10		<30	<10	<10		<25	<10	<10		<20	<10	<10	
Se	<10	<10	<10		<15	<10	<10		<15	<10	<10		<15	<10	<10	
Ag		<50	<60			<40	<60			<50	<65			<40	<60	
Cd	<100	<50	<60	<4	400	<40	<60	< 4	<80	<50	<65	< 4	<90	<40	<60	< 4
Ti	.42%	.37%	.33%		.41%	.31%	.33%		.43%	.34%	.35%		.55%	.30%	.40%	
Sn	<200	<110	<125		<155	<65	<100		<155	<70	<125		<200	<50	<95	
K	.37%	.47%	.47%		.43%	.36%	.33%		.47%	.36%	.38%		.65%	.30%	.57%	
Ca	20%	22%	20%		17%	17%	18%		23%	17%	18%		27%	15%	21%	
Rb	≤250	<15	<15		<25	17	25		<30	<10	<15		<35	22	<15	
Sr	445	425	390		265	415	340		455	390	320		430	360	390	
Ba	<30	560	<350		275	315	≤310		<410	<260	575		<350	≤215	545	
Y		≤25	<20			<15	≤25			≤20	≤25			≤15	<20	

Table E-16

SEM MICROPROBE ANALYSIS--FACILITY C
Measurements in mm

		S	M	L	Shot
C-1	1.3 Mg	5.0	6.0	5.5	2.0
	1.5 Al	16.0	11.0	11.0	6.0
	1.8 Si	29.0	30.0	30.5	15.0
	2.3 S	2.0	1.5	1.0	0.5
	3.3 K	2.0	1.0	1.5	1.5
	3.7 Ca	28.5	29.0	27.0	32.0
	4.5 Ti	-	1.0	1.0	1.0
	5.4 Cr	-	-	-	-
	5.8 Mn	-	-	-	-
	6.3 Fe	1.0	0.5	1.0	1.0
C-2	1.3 Mg	5.5	4.5	4.0	5.0
	1.5 Al	13.0	14.0	10.5	10.0
	1.8 Si	30.0	30.0	25.0	29.0
	2.3 S	1.0	2.0	1.5	1.0
	3.3 K	1.0	1.0	2.0	1.5
	3.7 Ca	26.0	30.0	31.0	31.0
	4.5 Ti	0.5	1.0	0.5	-
	5.4 Cr	-	-	0.5	-
	5.8 Mn	-	-	0.5	1.0
	6.3 Fe	1.0	1.0	1.0	1.0
C-3	1.3 Mg	-	4.2	3.0	0.6
	1.5 Al	22.0	9.0	13.0	11.0
	1.8 Si	28.0	29.0	25.0	31.0
	2.3 S	1.0	1.0	1.0	1.0
	3.3 K	1.0	1.5	1.0	-
	3.7 Ca	22.0	31.0	30.0	21.0
	4.5 Ti	-	-	0.5	0.5
	5.8 Mn	-	-	-	-
	6.3 Fe	2.0	1.0	1.5	1.0
C-4	1.3 Mg	4.5	2.5	3.5	6.0
	1.5 Al	11.5	8.0	9.0	10.0
	1.8 Si	31.0	25.0	29.0	31.0
	2.3 S	1.5	0.8	1.0	1.0
	3.3 K	1.5	1.0	1.5	1.0
	3.7 Ca	28.0	31.0	31.0	22.0
	4.5 Ti	-	-	0.5	1.0
	5.8 Mn	1.0	0	0.5	-
	6.3 Fe	1.0	0.5	1.0	1.0

Table E-17

OPTICAL MICROSCOPE DETERMINATION OF FIBER DIAMETERS
FACILITY C

Sample No.	N*	FIBER DIAMETER Geometric Mean	FIBER DIAMETER Geometric S.D.
C-1	109	4.31 um	2.27
C-2	111	3.14	3.00
C-3	107	3.39	2.50
C-4	510	3.21	2.56
Total	837	3.4	2.73

*N = number of fibers sized

BULK SAMPLE ANALYSES--FACILITIES D AND I

Ten samples were taken for analyses. Five of these were sections of the ceiling tile produced over the period 1957-1976 and retained for quality control purposes; five were bulk samples collected during the survey.

Ceiling Tile Samples:	Date of Production:
D-1	July 1957
D-2	April 1962
D-3	April 1967
D-4	February 1973
D-5	December 1976
Current Bulk Samples:	
D-6	Flywool--rafter sample
D-7	Product wool, as delivered to tile line
D-8	Rafter sample--wool room at head height
D-9	Product wool, as delivered
D-10	Cutting scraps near cutoff saw--tile line.

X-RAY FLUORESCENCE (XRF)

Sample / Element	D-1 XRF	D-1 AA	D-2 XRF	D-2 AA	D-3 XRF	D-3 AA	D-4 XRF	D-4 AA
Cr	< 90	< 11	< 75	< 12	< 75	70	< 75	20
Mn	2500	2600	1600	1900	1100	600	950	1200
Fe	2100		2500		2900		2600	
Co	< 40	< 10	< 35	< 10	< 35	< 10	< 30	< 10
Ni	< 20	< 20	< 25	< 20	< 20	< 20	< 25	< 20
Cu	< 30		< 20		70		< 25	
Zn	6400	10000	4800	12000	≤ 50	< 8	< 45	< 8
Hg	< 20		< 15		< 20		< 15	
Pb	< 15	< 20	< 15	< 20	≤ 25	< 20	< 20	< 20
As	< 25		< 20		< 30		< 35	
Se	< 10		< 10		< 10		< 15	
Cd	< 75	< 4	< 80	< 4	< 105	< 4	< 100	< 4
Ti	< 140		< 300		7900		6700	
Sn	< 210		< 150		< 200		< 200	
K	5600		2400		≤ 550		1600	
Ca	180000		160000		100000		110000	
Sr	950		260		110		115	
Ba	19000		14000		< 350		< 350	
Rb	< 25		< 40		< 40		< 30	

Table E-18

AND ATOMIC ABSORPTION (AA) ANALYSIS OF BULK SAMPLES--FACILITY D
(μg/gram)

D-5		D-6		D-7		D-8		D-9				D-10	
XRF	AA	XRF	AA	XRF	AA	XRF		XRF			AA	XRF	AA
								Total	Fiber	Shot			
< 100	12	< 95	< 11	< 95	< 14	< 75	< 11	< 90	< 40	< 30	< 11	< 110	13
1100	900	2100	1100	2300	1300	1600	1300	2500	2200	1900	1300	1200	1200
3600		7100		5800		7400		5200	5500	4300		4400	
< 40	< 10	< 45	< 10	< 45	< 10	< 40	< 10	< 50	≤ 20	25	< 10	< 31	< 10
< 25	< 20	< 20	< 20	< 25	< 20	< 25	< 20	< 25	< 10	< 10	< 20	< 20	< 20
≤ 30		< 20		≤ 65		≤ 60		< 25	≤ 10	≤ 10		≤ 50	
≤ 50	< 8	≤ 50	9	≤ 40	< 10	≤ 72	32	< 42	15	20	< 8	≤ 70	9
< 25		< 25		< 25		< 15		< 30	< 10	< 10		< 10	
< 25	< 20	< 25	< 20	< 15	< 20	< 15	< 20	< 25	35	30	< 20	< 15	< 20
< 30		< 30		< 40		< 30		< 15	< 10	< 10		< 25	
< 15		< 15		< 15		< 15		< 10	< 10	< 10		< 10	
< 110	< 4	< 200	< 4	< 130	< 4	< 95	< 4	< 225	< 50	< 40	< 4	< 85	< 4
8300		4400		4600		4000		3700	3400	2800		6100	
< 150		< 300		< 250		< 210		< 350	< 70	< 55		< 155	
4700		4000		4900		4000		5800	2600	3400		2100	
130000		270000		230000		190000		230000	250000	200000		120000	
< 35		386		335		200		290	350	325		235	
< 350		< 570		< 300		< 350		< 375	≤ 300	< 250		< 400	
< 40		< 30		< 35		< 40		< 35	< 20	< 10		< 20	

Table E-19

ELEMENTAL INTENSITIES (UNCORRECTED CM) MICROPROBE ANALYSIS OF BULK SAMPLES

Particle	Sample	Element (K.e.u.) Mg (1.3)	Al (1.5)	Si (1.8)	S (2.3)	K (3.3)	Ca (3.7)	Ti (4.5)	Cr (5.4)	Mn (5.8)	Fe (6.3)	Cu (8.1)
Small Fibers	D-1	-	0.9	2.7	0.2	0.2	3.2	0.1	0.1	0.1	0.1	-
	2	0.5	0.8	3.2	0.1	0.1	2.9	-	-	-	0.1	-
	3	0.4	0.8	2.8	0.1	0.1	3.1	0.1	-	-	0.1	-
	4	0.3	0.9	3.0	0.1	0.2	2.9	0.1	-	-	0.1	-
	5	0.3	1.0	2.6	0.1	-	3.0	0.1	-	-	0.1	-
	6	-	2.0	2.8	0.2	-	2.7	0.1	0.1	-	0.1	-
	7	0.4	1.3	2.5	0.1	-	3.1	0.1	0.1	0.1	0.1	-
	8	0.4	1.1	2.7	0.1	0.2	3.1	0.1	-	-	0.1	-
	9	0.5	1.3	2.8	0.2	0.1	3.0	-	0.1	-	0.2	-
	10	0.4	0.9	2.4	0.1	-	3.2	-	-	-	0.1	-
Medium Fibers	D-1	0.2	0.9	2.9	0.1	0.2	3.2	-	0.1	-	0.1	-
	2	0.4	1.0	3.1	0.1	-	3.1	0.1	-	-	0.1	-
	3	0.5	0.9	3.0	0.2	-	2.6	-	-	-	-	-
	4	0.2	1.0	2.9	0.1	0.2	3.0	0.1	0.1	-	0.1	-
	5	0.5	1.4	3.0	0.1	0.2	2.9	-	-	-	0.1	-
	6	0.3	0.7	2.3	0.1	-	3.1	0.1	0.1	0.1	0.1	-
	7	0.5	1.1	2.7	0.2	0.2	3.1	0.1	-	0.1	0.1	-
	8	0.4	0.9	2.7	0.1	0.1	3.1	0.1	-	-	0.1	-
	9	0.3	0.6	1.9	0.1	-	3.2	0.1	-	-	0.1	-
	10	0.3	0.7	2.4	0.2	0.2	3.1	-	-	-	0.1	-
Large Fibers	D-1	0.2	0.8	2.9	0.1	0.2	3.1	-	0.1	-	0.1	-
	2	0.3	1.0	2.5	0.1	0.5	3.1	0.1	-	-	0.1	-
	3	0.5	0.7	3.1	0.2	-	2.8	0.1	-	-	0.1	-
	4	0.4	1.3	3.0	0.1	-	2.3	0.1	-	-	0.1	-
	5	-	2.3	3.1	-	-	1.2	-	-	-	0.1	-
	6	0.4	0.9	2.6	0.1	0.1	3.0	-	-	-	0.1	-
	7	0.4	1.0	2.4	0.1	0.1	3.1	0.1	-	-	0.1	-
	8	0.2	0.7	2.0	0.1	0.2	3.2	0.1	-	-	0.1	-
	9	0.4	0.6	2.2	0.1	-	3.2	-	-	-	0.1	-
	10	0.4	1.0	2.7	0.1	0.1	3.1	-	-	-	0.1	-
Shot	D-1	0.2	0.7	2.3	0.1	0.2	3.1	-	0.1	-	0.1	-
	2	0.5	0.9	3.1	0.1	0.1	3.2	0.1	0.1	-	-	-
	3	0.5	0.8	3.1	0.1	0.1	2.2	0.1	-	-	0.1	-
	4	0.3	0.7	2.9	-	0.1	3.1	-	-	-	0.1	-
	5	0.6	1.5	3.1	0.2	0.1	1.5	-	0.1	-	0.2	-
	6	-	1.9	1.2	0.1	-	3.0	0.1	-	-	0.5	0.1
	7	0.7	1.2	3.1	0.1	0.1	2.5	0.1	-	-	0.1	-
	8	0.3	0.6	2.0	-	-	3.1	0.1	-	-	0.1	-
	9	0.3	0.6	2.1	0.1	0.2	3.2	0.1	-	-	0.1	-
	10	0.5	0.9	2.9	0.1	0.2	3.1	0.1	0.1	-	0.1	-

Table E-20

CEILING TILE FIBER DIAMETERS
1957-1976--FACILITIES D AND I

Sample #	Date	Geometric Mean (μm)	Geometric S.D.	# of Fibers Sized
D-1	July 1957	5.1	2.1	110
D-2	April 1962	3.2	1.9	525
D-3	April 1967	3.7	2.3	107
D-4	Feb. 1973	3.6	1.9	119
D-5	Dec. 1976	3.6	2.3	111

Table E-21

CURRENT BULK SAMPLE FIBER DIAMETERS

Sample #	Description	Geometric Mean (μm)	Geometric S.D.	N
D-6	"Flywool" - Rafter sample	4.1	2.3	113
D-7	Product wool - as delivered to line	3.5	2.6	101
D-8	Rafter sample-wool room @ head height	3.1	2.5	111
D-9	Product wool-as delivered to line	2.9	2.3	108
D-10	Cutting scraps near cutoff saw - tile	4.0	1.9	161

BULK SAMPLE ANALYSES--FACILITIES E AND H

Three samples of the bulk mineral wool product were taken during the survey. They are:

- Sample E-1--Taken June 2, 0700 hrs, mix of cured and uncured fiber
- Sample E-2--Taken June 2, 2215 hrs, uncured fiber, before entering curing oven
- Sample E-3--Taken June 1; sample of 8 lb/ft^3 blanket at end of takeoff table, just before packaging

Table E-22

X-RAY FLUORESCENCE (XRF)
AND ATOMIC ABSORPTION (AA)
ANALYSES OF BULK SAMPLES--FACILITIES E AND H
(μg/gram)

ELEMENT	Samples					
	E-1		E-2		E-3	
	XRF	AA	XRF	AA	XRF	AA
Cr	< 104	56	< 95	38	< 88	35
Mn	6000	5200	3900	4400	4900	5500
Fe	22000		17000		33000	
Co	< 54	<10	< 54	<10	< 55	<10
Ni	< 27	<40	< 21	77	< 22	101
Cu	41		15		20	
Zn	74	<2	19	<2	21	<2
Hg	< 16		< 10		< 17	
Pb	78	<20	110	<20	28	<20
As	≤23		21		< 15	
Se	< 18		< 10		< 15	
Ag	< 170		< 120		< 165	
Cd	< 170	<5	< 120	<5	< 165	<5
Ti	4500		3400		3100	
Sn	< 170		< 120		< 165	
K	2100		2200		1100	
Ca	200000		230000		200000	
Sr	1200		756		913	
Ba	< 415		< 420		< 410	
Rb	< 26		< 26		< 23	
Si	OBS*		OBS*		OBS*	

*Observed but not a quantitative peak.

Table E-23

X-RAY MICROPROBE ANALYSIS OF BULK SAMPLES
FACILITIES E AND H

E-1

Bulk Sample Microprobe

		Intensity (cm)				
Energy (kv)	Element	S	M	L	Shot	VP
1.0	Na	-	-	tr	0.16	-
1.2	Mg	0.68	0.63	0.93	0.88	-
1.5	Al	1.16	1.16	0.90	1.50	3.18
1.7	Si	3.69	3.82	3.70	3.77	3.60
2.2	S	0.20	0.24	0.15	0.20	-
2.5	Cl	-	-	-	-	-
3.2	K	0.20	0.20	0.19	-	-
3.6	Ca	3.70	3.76	3.13	1.19	-
4.0	Ca	0.46	0.45	0.45	0.20	-
4.5	Ti	0.10	0.12	0.12	-	-
5.3	Cr		-	-	-	-
5.8	Mn	0.09	-	-	-	-
6.4	Fe	0.17	0.15	0.13	0.09	tr

E-2

Bulk Sample Microprobe

1.2	Mg	0.58	0.62	0.70	0.67	-
1.5	Al	2.25	1.55	1.10	1.20	3.00
1.7	Si	3.02	3.67	3.73	3.89	3.66
2.2	S	0.30	0.27	0.21	0.16	-
2.5	Cl	-	-	-	0.10	-
3.2	K	0.22	0.23	0.18	0.19	-
3.6	Ca	2.40	3.50	3.77	3.57	-
4.0	Ca	0.40	0.50	0.49	0.53	-
4.5	Ti	0.31	-	0.06	0.06	-
5.8	Mn	-	-	0.08	-	-
6.4	Fe	0.14	0.16	0.14	0.10	tr

E-3

Bulk Sample Microprobe

1.0	Na	-	0.05	-	-	-
1.2	Mg	0.72	0.66	0.60	0.80	0.23
1.5	Al	0.62	1.10	1.09	1.12	3.09
1.7	Si	3.59	3.74	3.45	3.78	3.50
2.2	S	0.24	0.18	0.17	0.16	0.34
2.9	Ar?	-	-	-	0.10	-
3.2	K	0.16	0.16	0.19	0.16	-
3.6	Ca	3.78	3.80	3.76	2.47	0.21
4.0	Ca	0.50	0.58	0.48	0.29	-
4.5	Ti	0.08	0.04	0.05	-	-
5.8	Mn	-	0.08	-	-	-
6.4	Fe	0.17	0.11	0.17	tr	-

Table E-24

BULK SAMPLE FIBER DIAMETERS BY OPTICAL MICROSCOPY

PORTON CATEGORY	DIAMETER (μm)	SAMPLES			TOTAL
		E-1	E-2	E-3	
< 1	0.91	75	18	3	96
1< 2	1.28	99	28	12	139
2< 3	1.81	102	22	8	132
3< 4	2.56	81	34	26	141
4< 5	3.62	62	20	15	97
5< 6	5.12	58	20	27	105
6< 7	7.24	79	18	35	132
TOTAL FIBERS		556	160	126	842
GEOMETRIC MEAN DIAM.		2.0 μm	2.1 μm	3.2 μm	2.2 μm
GEOMETRIC STD. DEV.		2.1	2.0	2.0	2.1

BULK SAMPLE ANALYSES--FACILITY F

Two bulk samples were taken for analysis. Sample F-1 was taken from a bag of blowing wool on the truck, and sample F-2 was caught as it came from the hose inside the house being insulated.

Table E-25

Elemental Analysis by X-Ray Fluorescence (XRF) and Atomic Absorption (AA)

Element	elemental concentrations µg/gram bulk sample				
	sample F-1		sample F-2		
	XRF	AA	XRF (orig.)	XRF (rerun)	AA
Cr	<105	23	<130		30
Mn	14000	14244	26000	26705	15401
Fe	95000		150000		
Co	<65		<96		
Ni	<20		<34		
Cu	301		435		
Zn	12000	12744	17000		11596
Hg	≤20		<45		
Pb	744	632	1200	1385	445
As	117		77		
Ag	<125		<175		
Cd	<125		<175		
Ti	717		≤50		
Sn	<260		≤430		
K	~8500		~11000		
Ca	~230000		~340000		
Sr	1100		1800		
Ba	2300		4100		
Se	≤10		16		
Rb	<21		56		
P, Cl, S	Obs*		Obs*		

*Observed peak, but not quantitative.

Table E-26

MEASUREMENT OF PEAK HEIGHTS
MICROPROBE ANALYSIS OF BULK SAMPLE F-1
FACILITY F

Element	Intensity (cm) 1S	1M	1L	Shot	1A VP	1B VP
Mg	0.15	0.15	0.10	--	--	--
Al	0.90	0.70	0.45	0.80	--	0.30
Si	3.00	2.81	2.05	3.11	--	3.75
S	0.10	0.12	0.13	1.70	--	--
Cl	--	0.08	--	--	--	--
K	0.20	0.30	0.36	--	--	--
Ca	3.40	3.65	3.62	1.55	3.50	--
Ca	--	0.50	0.45	0.32	0.50	--
Ti	--	--	--	0.68	--	--
Cr	--	--	--	0.08	--	--
Mn	0.12	0.18	0.15	0.02	--	--
Fe	1.10	1.28	1.05	0.70	--	--
Fe	0.05	0.10	0.10	--	--	--
Cu	--	--	--	--	--	--
Zn	--	0.10	--	0.62	--	--
Zn	--	--	--	--	--	--

Table E-27

BULK SAMPLE SIZE ANALYSIS--FACILITY F

Category	Diameter (μm)	samples #1	#2
≤1	≤0.91	2	0
1≤2	0.91≤1.28	3	1
2≤3	1.28≤1.81	16	8
3≤4	1.81≤2.56	28	12
4≤5	2.56≤3.62	31	27
5≤6	3.62≤5.12	20	28
6≤7	5.12≤7.24	63	88
Total # Fibers		163	164
geometric mean (μm)		3.7	4.8
geometric S.D.		1.9	1.7

BULK SAMPLE ANALYSES--FACILITY G

Nine samples of mineral wool insulation products were obtained from various sites of installation. The contractor surveyed had records of all installations made during the forty six year history of this family firm.

Sample #	Date - Type
G-1	Attic Fill insulation installed April 1943
G-2	Wall batts, installed April 1943
G-3	Wall batts, installed July 1946
G-4	Attic Fill insulation, installed July 1946
G-5	Blowing wool in use, April 1977
G-6	Attic Fill, installed April 1943
G-7	Wall batts, purchased 1972-1973, still in stock by the contractor
G-8	Wall batts, purchased from the same manufacturer as for sample #5, 1976
G-9	Attic Fill insulation, installed June 1937

Table E-28

X-RAY FLUORESCENCE (XRF) AND ATOMIC ABSORPTION (AA) ANALYSES OF COLLECTED BULK SAMPLES--FACILITY G (μg/gram)

Element	G-1 XRF	G-1 AA Shot	G-1 AA Fiber	G-2 XRF	G-2 AA Shot	G-2 AA Fiber	G-3 XRF	G-3 AA Shot	G-3 AA Fiber	G-4 XRF	G-4 AA Shot	G-4 AA Fiber
Cr	160	92	72	356	146	129	< 65	16	29	126		< 9
Mn	190	1262	1185	305	1411	1105	3300	3727	2785	163		87
Fe	270000			220000			19000			530000		
Co	< 140	25	30	< 100	21	23	< 44	46	48	< 30		12
Ni	< 100	138	116	< 75	118	131	≤ 18	25	425	< 15		< 19
Cu	275			240			107			38		
Zn	72000	93000	87000	58000	99900	77900	1200	1236	2321	133		1342
Hg	< 35			< 25			< 17			< 12		
Pb	9000	9500	9300	8400	11400	8900	205	82	104	81		< 20
As	< 50			< 45			21			≤ 13		
Se	< 25			≤ 27			15			< 11		
Ag	< 114			< 100			< 125			< 94		
Cd	< 114	6	8	< 100	5	< 1	< 125	< 1	2	< 94		2
Ti	< 400			≤ 281			1700			748		
Sn	< 175			< 125			< 125			< 94		
K	< 500			≤ 800			1000			7600		
Ca	58000			44000			230000			92000		
Sr	330			182			495			144		
Ba	< 500			< 425			< 375			< 240		
Rb	≤ 25			23			< 10			< 24		
Si	OBS			OBS			OBS			OBS		

Element	G-5 XRF	G-5 AA Shot	G-5 AA Fiber	G-6 XRF	G-6 AA Shot	G-6 AA Fiber	G-7 XRF	G-7 AA Shot	G-7 AA Fiber	G-8 XRF	G-8 AA Shot	G-8 AA Fiber	G-9 XRF	G-9 AA Shot	G-9 AA Fiber
Cr	77	205	145	≤ 145	85	84	143	173	122	116	125	120	< 55	39	40
Mn	1700	1988	1688	214	1248	1143	1500	3010	2895	1900	1526	1401	6700	6681	6770
Fe	15000			230000			64000			74000			5000		
Co	< 37	< 14	24	< 118	36	33	< 40	81	84	< 59	30	22	< 31	9	11
Ni	< 17	62	53	< 28	106	85	≤ 20	34	38	≤ 19	51	71	< 14	< 17	< 20
Cu	31			196			501			567			19		
Zn	36	16	28	62000	92000	94000	3100	1645	1528	3500	696	42	684	797	176
Hg	< 10			< 27			66			< 23			< 10		
Pb	≤ 15	< 25	< 19	7200	8714	8803	86	170	151	197	< 18	< 20	105	39	28
As	< 10			< 30			150			130			41		
Se	< 10			< 21			< 15			< 10			≤ 13		
Ag	< 85			< 96			< 68			< 63			< 100		
Cd	< 85	< 1	< 1	< 96	< 1	6	< 68	< 1	< 1	< 63	< 1	< 1	< 100	< 1	< 1
Ti	4300			≤ 310			1100			1500			2300		
Sn	< 85			< 96			< 70			< 63			< 100		
K	1200			≤ 857			467			1400			1200		
Ca	170000			53000			98000			140000			270000		
Sr	595			284			459			520			567		
Ba	< 320			< 465			350			290			< 236		
Rb	< 15			27			19			≤ 16			≤ 18		
Si	OBS			OBS			OBS			OBS			OBS		

Table E-29

SEM MICROPROBE SAMPLE G-1

Energy (kv)	Element	Intensity (cm)				
		S	M	L	Shot	VP
1.0	Na	--	0.08	0.11	--	--
1.2	Mg	--	--	0.16	0.17	--
1.5	Al	--	--	--	--	--
1.7	Si	1.80	3.60	3.71	3.73	3.78
2.2	S	0.29	0.58	0.39	0.30	--
2.5	Cl	0.17	--	0.12	0.18	--
2.9	Ar?	--	--	--	--	--
3.2	K	0.17	0.14	0.14	0.16	--
3.6	Ca	0.60	1.71	1.74	1.74	--
4.0	Ca	--	0.30	--	0.26	--
4.5	Ti	--	--	0.10	0.08	--
5.3	Cr	0.05	--	0.06	0.05	0.05
5.8	Mn	--	0.05	--	--	--
6.4	Fe	0.94	2.35	1.90	2.37	--
7.0	Fe	0.12	0.35	0.22	0.3	--
7.5	Ni	0.03	--	--	--	--
8.0	Cu	--	0.05	--	--	--
8.6	Zn	0.17	0.42	0.30	0.39	--
9.6	Zn	0.07	0.08	0.08	0.05	--

Table E-30

SEM MICROPROBE SAMPLE G-2

Energy (kv)	Element	Intensity (cm) S	M	L	Shot	VP
1.0	Na	0.12	0.16	0.03	0.05	--
1.2	Mg	--	--	--	--	--
1.5	Al	0.17	0.82	0.37	0.17	--
1.7	Si	3.67	3.76	3.75	1.77	--
2.2	S	0.44	0.32	0.32	0.25	--
2.5	Cl	0.12	0.20	0.12	--	--
2.9	Ar?	0.10	0.19	--	--	--
3.2	K	0.18	0.21	0.11	0.17	--
3.6	Ca	1.45	1.5	1.53	1.90	--
4.0	Ca	0.18	0.26	0.29	0.31	--
4.5	Ti	--	0.09	--	--	--
5.3	Cr	--	--	0.08	0.10	--
5.8	Mn	--	--	--	0.11	--
6.4	Fe	1.90	0.62	1.99	3.72	--
7.0	Fe	0.21	0.21	0.30	0.69	--
7.5	Ni	--	--	--	--	--
8.0	Cu	--	--	--	--	--
8.6	Zn	0.34	0.35	0.29	0.60	--
9.6	Zn	--	--	--	0.10	--

Table E-31

SEM MICROPROBE SAMPLE G-3

Energy (kv)	Element	Intensity (cm)				
		S	M	L	Shot	VP
1.0	Na	--	--	--	--	--
1.2	Mg	0.20	--	0.24	0.40	0.22
1.5	Al	0.70	1.10	0.89	0.14	0.84
1.7	Si	2.90	3.80	3.22	3.86	1.55
2.2	S	0.12	--	0.19	0.15	0.54
2.5	Cl	0.10	--	0.10	0.12	--
2.9	Ar?	--	--	--	--	--
3.2	K	0.12	--	0.16	0.13	0.30
3.6	Ca	3.78	1.88	3.87	3.40	0.90
4.0	Ca	0.44	0.24	0.60	0.44	0.21
4.5	Ti	0.05	0.08	0.05	--	--
5.0	V	--	0.05	--	--	--
5.3	Cr	--	--	--	--	--
5.8	Mn	trace	--	--	--	--
6.4	Fe	0.10	--	0.12	0.10	2.39
7.0	Fe	--	--	--	--	0.30
7.5	Ni	--	--	--	--	--
8.0	Cu	--	--	--	--	--
8.6	Zn	--	--	--	--	--
9.6	Zn	--	--	--	--	--

Table E-32

SEM MICROPROBE SAMPLE G-4

Energy (kv)	Element	Intensity (cm)				
		S	M	L	Shot	VP
1.0	Na	0.16	0.12	0.20	0.15	--
1.2	Mg	0.22	0.17	0.30	0.30	--
1.5	Al	0.60	0.39	0.38	0.70	--
1.7	Si	3.80	3.91	3.79	3.70	--
2.2	S	0.05	--	--	0.08	--
2.5	Cl	--	0.09	--	--	--
2.9	Ar?	--	--	--	0.13	--
3.2	K	0.23	0.17	0.16	0.10	--
3.6	Ca	1.28	1.13	1.30	0.33	--
4.0	Ca	0.11	0.26	0.18	--	--
4.5	Ti	--	--	--	--	--
5.3	Cr	--	--	--	--	--
5.8	Mn	--	--	--	--	--
6.4	Fe	0.05	--	trace	0.39	--
7.0	Fe	--	--	--	0.10	--
7.5	Ni	--	--	--	--	--
8.0	Cu	--	--	--	--	--
8.6	Zn	--	--	--	--	--
9.6	Zn	--	--	--	--	--

Table E-33

SEM MICROPROBE SAMPLE G-5

Energy (kv)	Element	Intensity (cm) S	M	L	Shot	VP
1.0	Na	--	--	--	--	--
1.2	Mg	0.54	0.50	0.49	0.76	--
1.5	Al	1.70	1.72	1.86	1.60	--
1.7	Si	3.40	2.90	3.30	3.67	--
2.2	S	0.20	0.15	0.18	0.12	--
2.5	Cl	--	0.08	--	--	--
2.9	Ar?	--	--	--	0.10	--
3.2	K	0.17	0.12	0.15	0.14	--
3.6	Ca	3.55	3.79	3.84	3.62	--
4.0	Ca	0.45	0.44	0.34	0.49	--
4.5	Ti	0.08	0.07	trace	0.06	--
5.3	Cr	0.05	--	--	--	--
5.8	Mn	0.09	--	--	--	--
6.4	Fe	0.18	0.05	0.11	0.10	--
7.0	Fe	--	--	--	--	--
7.5	Ni	--	--	--	--	--
8.0	Cu	0.11	--	--	--	--
8.6	Zn	--	--	--	--	--
9.6	Zn	--	--	--	--	--

Table E-34

SEM MICROPROBE SAMPLE G-6

Energy (kv)	Element	Intensity (cm)				
		S	M	L	Shot	VP
1.0	Na	--	0.05	trace	--	--
1.2	Mg	0.12	0.10	--	--	--
1.5	Al	0.63	0.42	0.43	0.11	--
1.7	Si	3.46	3.70	3.76	1.71	--
2.2	S	0.39	0.43	0.40	0.12	--
2.5	Cl	--	--	--	--	--
2.9	Ar?	--	--	--	--	--
3.2	K	0.19	0.18	0.16	0.14	--
3.6	Ca	1.53	1.75	1.89	1.90	--
4.0	Ca	0.25	0.29	0.30	0.38	--
4.5	Ti	0.04	--	0.10	0.11	--
5.3	Cr	--	0.03	0.07	0.08	--
5.8	Mn	--	--	--	0.11	--
6.4	Fe	2.15	2.10	2.34	3.63	--
7.0	Fe	0.29	0.24	0.29	0.40	--
7.5	Ni	--	--	--	0.05	--
8.0	Cu	--	--	--	--	--
8.6	Zn	0.29	0.36	0.35	0.58	--
9.6	Zn	0.05	0.08	0.05	0.01	--

Table E-35

SEM MICROPROBE SAMPLE G-7

Energy (kv)	Element	Intensity (cm) S	M	L	Shot	VP
1.0	Na	--	--	--	0.10	--
1.2	Mg	0.25	0.28	0.15	0.46	--
1.5	Al	1.24	1.41	0.98	1.63	--
1.7	Si	2.90	3.59	2.80	3.60	--
2.2	S	0.17	0.21	0.15	--	--
2.5	Cl	--	--	--	0.20	--
2.9	Ar?	--	0.10	--	0.18	--
3.2	K	0.28	0.23	0.15	--	--
3.6	Ca	3.80	3.79	3.80	1.12	--
4.0	Ca	0.62	0.50	0.35	0.16	--
4.5	Ti	trace	0.09	0.03	--	--
5.3	Cr	trace	--	--	0.03	--
5.8	Mn	--	--	--	--	--
6.4	Fe	0.65	0.47	0.70	0.10	--
7.0	Fe	trace	0.10	0.06	--	--
7.5	Ni	--	--	--	--	--
8.0	Cu	--	--	0.04	--	--
8.6	Zn	--	--	0.02	--	--
9.6	Zn	--	--	--	--	--

Table E-36

SEM MICROPROBE SAMPLE G-8

Energy (kv)	Element	Intensity (cm) S	M	L	Shot	VP
1.0	Na	--	0.09	--	--	--
1.2	Mg	0.49	--	--	0.22	--
1.5	Al	1.47	0.66	1.02	0.81	--
1.7	Si	3.20	3.72	0.80	0.22	--
2.2	S	0.20	0.43	trace	--	--
2.5	Cl	--	--	--	--	--
2.9	Ar?	0.11	--	--	--	--
3.2	K	0.17	0.18	0.19	0.10	--
3.6	Ca	3.79	1.67	3.80	3.69	--
4.0	Ca	0.48	0.24	0.56	0.52	--
4.5	Ti	0.08	0.10	--	0.06	--
5.0	V	--	0.10	--	--	--
5.3	Cr	--	0.08	--	--	--
5.8	Mn	--	0.05	--	--	--
6.4	Fe	0.19	2.37	0.33	0.16	--
7.0	Fe	--	0.36	--	--	--
7.5	Ni	--	--	--	--	--
8.0	Cu	--	--	--	--	--
8.6	Zn	--	0.40	--	--	--
9.6	Zn	--	0.08	--	--	--

Table E-37

SEM MICROPROBE SAMPLE G-9

		Intensity (cm)				
Energy (kv)	Element	S	M	L	Shot	VP
1.0	Na	--	--	--	--	0.14
1.2	Mg	0.20	0.30	0.18	0.47	--
1.5	Al	0.87	0.97	0.70	1.32	0.22
1.7	Si	2.85	3.37	2.91	3.72	3.73
2.2	S	0.15	0.21	0.12	0.16	--
2.5	Cl	--	--	--	0.12	--
2.9	Ar?	--	--	--	--	--
3.2	K	--	0.18	0.17	0.20	0.10
3.6	Ca	3.70	3.85	3.80	2.50	0.09
4.0	Ca	0.51	0.59	0.43	0.30	--
4.5	Ti	--	--	0.06	--	--
5.3	Cr	--	--	--	--	--
5.8	Mn	trace	0.10	--	--	--
6.4	Fe	--	0.05	--	trace	--
7.0	Fe	--	--	--	--	--
7.5	Ni	--	--	--	--	--
8.0	Cu	--	--	--	--	--
8.6	Zn	--	--	--	--	0.12
9.6	Zn	--	--	--	--	--

Table E-38

OPTICAL MICROSCOPIC ANALYSIS
OF FIBER DIAMETER--FACILITY G
(Number of Fibers in a Given Size Category)

Porton Category	*D(μm)	G-1	G-2	G-3	G-4	G-5	G-6	G-7	G-8	G-9
		Sample								
1	0.91	2	2	6	75	30	9	24	38	48
2	1.28	15	10	20	5	38	34	19	14	6
3	1.81	54	6	9	2	71	58	5	12	7
4	2.36	24	13	4	-	52	49	9	7	12
5	3.62	53	27	14	3	102	70	11	10	7
6	5.12	25	22	26	2	88	20	13	14	16
7	7.24	9	12	11	2	57	2	4	11	7
8	10.24	4	6	9	16	70	6	12	6	8
9	14.48	-	-	3	13	16	2	3	10	10
10	20.48	1	3	-	-	2	-	1	-	-
11	28.96	-	-	1	-	1	-	-	-	-
Total		187	101	103	118	527	250	101	122	121
Geom. Mean (μm)		2.4	3.3	3.4	0.08	3.2	2.1	1.9	1.7	1.5
Geom. S.D.		1.6	1.7	2.5	300.0	2.7	1.7	4.5	4.0	4.6

*D = The upper limit (μm) of the Porton Category.

BULK SAMPLE ANALYSES--FACILITY J

Two bulk samples were examined:

J-1 The sprayed fireproofing in use at the time of the survey;

J-2 Another fireproofing made by the same manufacturer, and commonly used by the fireproofing crew.

These samples were examined by X-Ray fluorescence atomic absorption, and optical microscopy. An air sample (number C-610) was examined by microprobe for elemental composition of individual fibers.

Table E-39

X-RAY FLUORESCENCE (XRF) AND ATOMIC ABSORPTION (AA)
ANALYSIS OF BULK SAMPLES--FACILITY J

(Micrograms element/gram sample)

	Sample J-1		Sample J-2	
Element	XRF	AA	XRF	AA
Cr	110	81	<35	125
Mn	405	347	134	1104
Fe	11000		4000	
Co	<26	<22	<25	≤ 20
Ni	≤10	<20	<10	< 20
Cu	≤10		<10	
Zn	≤10	22	14	33
Hg	<15		<15	
Pb	<13	<20	<11	<18
As	<10		<10	
Ag	< 140		<175	
Cd	< 140	<5	<175	<5
Ti	1500		435	
Sn	< 140		<175	
K	2100		< 1500	
Ca	150000		200000	
Sr	560		587	
Ba	< 530		<600	
Rb	<13		<21	
P,Cl,S, Si	OBS		OBS	

Table E-40

ELEMENTAL INTENSITIES (UNCORRECTED) FOR
SMALL, MEDIUM, AND LARGE FIBERS AND SHOT PARTICLES IN AIR

SEM Sample #610

Energy (kv)	Element	Intensity (cm)			
		610S	610M	610L	Shot
1.0	Na	--	--	--	--
1.2	Mg	0.10	--	0.42	0.16
1.5	Al	0.52	0.14	0.62	0.35
1.7	Si	0.80	0.47	3.81	2.18
2.2	S	--	--	0.26	--
2.5	Cl	--	--	0.26	--
2.9	Ar?	0.12	--	--	--
3.2	K	--	0.10	0.20	--
3.6	Ca	0.96	3.70	3.31	3.86
4.0	Ca	0.12	0.57	0.36	0.54
4.5	Ti	--	--	--	--
5.3	Cr	--	--	--	--
5.8	Mn	--	--	--	--
6.4	Fe	0.19	--	0.30	--
7.0	Fe	--	--	--	--
7.5	Ni	--	--	--	--
8.0	Cu	--	--	--	--
8.6	Zn	--	--	--	--
9.6	Zn	--	--	--	--

Table E-41

BULK SAMPLE FIBER DIAMETER
BY OPTICAL MICROSCOPY--FACILITY J

Sample	# Fibers Sized	Fiber Diameter	
		Geom. Mean	Geom. Std. Dev.
J-1	149	3.1	1.9
J-2	522	2.1	2.2
Total	671	2.3	2.2

Porton Category	μm	Samples		
		J-2	J-1	Total
≤1	<0.91	9	78	87
≤2	0.91≤1.28	7	81	88
≤3	1.28≤1.81	12	72	84
≤4	1.81≤2.56	22	60	82
≤5	2.56≤3.62	29	62	91
≤6	3.62≤5.12	26	56	82
≤7	5.12≤7.24	44	113	157
	Total	149	522	671

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BULK SAMPLE ANALYSIS--FACILITY K

The sole analysis applied was optical microscopic determination of fiber diameter.

Table E-42

OPTICAL MICROSCOPIC DETERMINATION OF FIBER DIAMETER--FACILITY K

Porton Category	Number of Fibers
≤ 1	0
1 ≤ 2	13
2 ≤ 3	16
3 ≤ 4	25
4 ≤ 5	30
5 ≤ 6	34
> 6	43
Total	161

Geometric Mean Diameter = 3.4 μm

Geometric Standard Deviation = 2.0