INDUSTRIAL HYGIENE SURVEY REPORT

FORTY-EIGHT INSULATIONS, INC.

AURORA, ILLINOIS

MAY 1978

Prepared for: NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INDUSTRIAL HYGIENE SURVEY

OF AURORA, ILLINOIS PLANT

OF FORTY-EIGHT INSULATIONS, INCORPORATED

INTRODUCTION

As part of SRI International's performance of NIOSH contract #210-76-0120 (Industrial Hygiene Studies of Mineral Wool Exposures), an industrial hygiene survey was performed at the Aurora, Illinois plant of Forty Eight Insulations, Inc. The survey was performed over the period of June 1-3, 1977 by Douglas P. Fowler, Benjamin O. Alli, Bryan C. Lovegren, and Lea W. Sandman of SRI.

The plant and corporate management participating in the survey were: Mr. D.E. Maxam, Vice-President, Finance and Administration; Mr. E.L. Kells, Research Engineer; Mr. R. Hastings, Quality Control and Safety Manager; Mr. R. Parkison, Plants Manager; Ms. S. Sanchez, Personnel and Communications Administrator; and Mr. D. Schaidler, Director of Sales Services. Mr. Robert W. Wheeler, NIOSH Alternate Project Officer, was present for a portion of one day of the survey, as an observer. Mr. Alfonso Aguilar, Shop Steward for Local 916, Carpenters and Jointers Union, was contacted during the survey.

Air samples were taken to evaluate worker exposures to airborne particulate material, including airborne mineral wool fibers, total particulate material, and respirable particulate material. Bulk material samples were also taken.

This report includes a description of the facility, and its medical, industrial hygiene, and safety programs; survey methods and results, and conclusions and recommendations for improvement.

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 March 1976 and completed February, 1977; and a dust collection system for cutting and shifting 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 Local 916 of the Carpenters and Jointers Union.

The products currently produced at the facility are specialized insulation products ordinarily used in insulation of relatively high temperature vessels and pipes. During the survey, only "blankets" used for (usually) boiler insulation were being produced, but the plant also supplies half-round pipe insulation material for (for instance) steam line insulation. Production was being maintained on a three production shift, one fabrication shift basis, five days per week.

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 the Dreyer Medical Clinic, 1870 W. Galena, West Aurora (AC 312-859-6824). Pre-employment 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. The company is a susidiary of Foster Wheeler Corporation, and technical assistance will be available to Forty-Eight when an industrial hygienist is added to the Foster Wheeler Corporation staff. 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, except as they are available from the Dreyer Clinic. 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 a 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 and Fabrication 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). Fabrication of the latter materials was not observed.

Figure 1 is a sketch of the plant layout, adapted from one supplied by plant personnel. Formerly, two complete lines were in operation, but at the time of the survey, only one cupola and production line was 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.
- Dolomite 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 the building. 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 (see Figure 2). 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^{o} 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. The warehouse space available for storage is limited, and Forty Eight usually makes custom order materials, so that storage of large quantities of finished products is uncommon.

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 paced 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 used at this plant, although not observed by the survey team, is shown schematically in Figure 3. Pipe covering is made by this operation, in the "slotter" shown on Figure 2 next to the take off end of the production line. 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 bevel 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 Forty Eight. 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.

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. The name of the company derives from the fact that one bag of their cement product would cover forty-eight square feet to a depth of one inch. There are current lawsuits in process against the company alleging health damage to installers of these products. No claims or lawsuits have been received by the company from current or past Forty-Eight employees.

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

Many of the employees in this plant are Spanish-speaking. The rate of turnover in personnel 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 Manager
    - 1 Cupola Operator

1 Charger

1 Warehouse loader

2 Asst. Loaders

5 Take-off Workers

1 Shift Maintenance Worker

1 Carton Worker

1 Stenciler

- Fabrication Shop - 12 workers

  1 Asst. Foreman

  11 Crewpersons

- 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 (foreman's office on Figure 2) 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.

Assistant Foreman: Fabrication

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

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.

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

Physical Agents and General Safety Hazards

This portion of a complete industrial hygiene survey was not done. Company management personnel state that an agreement had been reached between Forty-Eight and NIOSH, to limit the survey to the taking of airborne dust samples only. The full text of the limitations imposed by Forty-Eight's interpretation of that agreement is given in Appendix A.

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, and appear to be technically competent individuals, with a real committment to improvement of the facility. 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 (considered to be proprietary by Forty-Eight) returns waste material to the process stream, with substantial cost savings, as well as substantial apparent benefit to the cleanliness of the plant. Although the system cannot be described because of Forty-Eight's proprietary interests, similar systems should be developed by other mineral wool manufacturers, where possible, as adjuncts to housekeeping programs. It is probable that the system was one of the major factors in the relatively low levels of airborne fibers seen in the plant.

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.

SURVEY PROCEDURES

As stated above, a complete evaluation of the working environment at this plant was not undertaken, in order to facilitate the evaluation of exposures to mineral wool fibers. The complete statement of the limitations imposed on the survey team is given as Appendix A to this report. Within the scope of those limitations, the management of the plant were cooperative, and offered much valuable assistance in the completion of the survey.

Air samples were taken to evaluate worker exposure to airborne mineral fibers, total airborne particulate material, respirable particulate material, and trace metals (Cd, Cr, Co, Ni, Mn, Pb, and Zn). Bulk samples of the finished products and intermediate products were also collected for the determination of fiber size and trace metal concentrations. No ventilation measurements were made, nor were any other environmental measurements made.

Survey Equipment

- Bendix BDX-44, portable battery-powered air sampling pumps.
- Bendix 10mm (Dorr-Oliver type) nylon cyclone preselectors.
- Millipore type AA (0.8 μm mean pore size) 37mm diameter mixed cellulose ester membrane filters.
- Gelman type VM-1 polyvinyl chloride membrane filters.
- MSA Model G, portable battery-powered air sampling pumps.

Calibration

The rotameters on each pump were calibrated in Menlo Park before the survey by 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 PVC (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 site, to check for changes due to shipping damage. The rotameter scales were marked at 1.7 and 2.0 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 re-marked 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.

Air Sampling

The major goal of the air sampling effort was to take personal air samples in the breathing zones of workers sufficient to characterize each worker's peak and time-weighted average exposure (TWA) to mineral wool fibers and total suspended particulate material (TSP). Respirable particulate material samples were taken in the breathing zones of approximately 10% of the 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 were used on each worker; one for fiber counting and one for total particulate material; or for total and respirable particulate material. A Bendix cyclone (10mm Dorr-Oliver nylon type) was used as a pre-selector before the filter for the respirable samples.

The calibrated charged 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 desired 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 desired initial flow rate (1.7 liters per minute for respirable; 2.0 liters per minute for all others) was set, using the pump rotameter scale. The filter was then re-capped, and the pump/filter unit was taken into the production 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 pair of pumps was clipped to the worker's belt and the pumps started after removing 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 period for each worker was 100 to 500 minutes.

The samples being taken were monitored at intervals throughout the sampling period, and air flow rates were adjusted back to the nominal 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 transmission to the laboratory. Fiber counting filters were changed as they became visibly colored; the usual length of time for this to occur was 2-3 hours.

ANALYTICAL PROCEDURES

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 number was then recorded on the holder, and in a laboratory record book, with the initial weight of the filter. 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 above. One filter from each box of 50 was held as a blank, and examined for contamination, 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 as used for the initial weighings. This was the sole analysis applied to the respirable particulate samples. The total suspended particulate samples were taken for atomic absorption analysis following weighing, and the Millipore filter samples were taken for microscopic examination, without weighing.

Atomic Absorption

The samples on Gelman PVC filters were placed in Teflon beakers to which 5 ml of HF was added. The beakers were heated to 110°C on a hot plate and intermittently swirled to insure complete reaction. The samples were taken to dryness, an additional 5 ml of HF added, and taken to dryness again. Five milliliters of nitric acid was added and the solution evaporated over a 20 minute period. The residue was dissolved in 3 ml of warm HNO_3 and transferred to a graduated centrifuge tube. The filters remaining in the beakers were rinsed with successive portions of distilled water and these rinses were added to the centrifuge tube. The total volume was then brought to 7.0 ml. Blanks consisted of an unused filter 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 1 for operating parameters. From calibration standards for each of the seven metals, calibration curves were constructed. Absorbance measurements corrected for non-atomic 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, was spiked with 50 μg of each of the metals of 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 is a percent recovery factor for each metal (Table 2) which was applied to the concentration results for each of the personal samples.

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 objextive, a 10X Periplan GF eyepiece, and Kohler illumination was 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 was measured and recorded on a tally sheet, similar to Figure 3.

The initial accumulation of data was made on a 10-key adding machine, using 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 utilization of research assistants for transcription of the data. In addition, the microscopists were able to avoid constant refocusing and reaccomodation of their eyes during the counting process, with reduction of "eye-strain" problems.

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

Scanning Electron Microscope (SEM) Counting and Sizing

A section of the Millipore filter was dissolved in a 1:1 mixture of MEK (methyl ethyl ketone) and methanol. The amount of the Millipore filter taken for analysis was determined by "xeroxing" the filter before and after removal of the section, carefully cutting out the xerox images and weighing them (± 0.01 mg). The MEK/methanol solution with suspended fibers was filtered through an 0.8 μm (25 mm diameter) Nuclepore filter using aspiration and mixed 3X 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 on an aluminum SEM stage with silver paint.

Before use all solvents were filtered through an 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 (200Å) and examined at 2,000X and 10,000X in the SEM (Cambridge Mark II) at 300KV and a tilt angle of 10°. The polystyrene latex spheres were also examined at 2,000X and 10,000X and the images recorded on video tape 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 video tape.

The video tape 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), so several independent vertical and horizontal measurements of the spheres were taken. A typical vertical measurement was 3.5mm/µm; a typical horizontal measurement was 4.4mm/µm.

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

$$26.8 \text{ cm} \times \frac{1 \text{ µm}}{0.44 \text{ cm}} \times 20.7 \text{ cm} \times \frac{1 \text{ µm}}{0.35 \text{ cm}} = 3602.3 \text{ µm}^2$$

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, based upon examination of those fibers that were scanned while moving from one field to the next.

Bulk Sample Analysis

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

Atomic Absorption

0.1 g of the bulk material was ball-milled in a plastic container using fired ceramic balls, 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

Bulk samples were ball-milled overnight in a plastic container using fired ceramic balls. 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 ($\pm$ 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 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 an 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 to an aluminum SEM specimen stage with silver paint.

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 (~1 µm diameter)
- Medium fibers (~4-5 µm diameter)

- Large fibers (~≥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 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 (lpm) was checked at 1000 (and found to be still sampling at 2.0 lpm); had decreased to 1.9 lpm by 1200 (and was readjusted to 2.0 lpm); and fell to 1.8 lpm by 1400, at which time the sampling period ended.

Time	Flow (lpm) Old	Flow (lpm) 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 the total suspended particulate material, and for 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 $\mu g/m^3$ for each element/sample point (seven per sample).

Fiber Counts 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

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) x 10^3 = total sample air volume (ml) = cc

Fiber Counts 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

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 ≈0.2

Geometric Mean and Standard Deviations of Fiber Size

The basic method was that of Mercer (Aerosol Technology in Hazard Evaluation), New York, Academic Press, 1973, p. 96) in which:

Geometric Mean (M_g) =

$$\text{antilog}_{10} \left\{ \frac{\sum_{i=1}^{k} n_i \cdot \log_{10} D_i}{\sum_{i=1}^{k} n_i} \right\}$$

Geometric Standard Deviation (σg) =

$$\text{antilog}_{10} \left\{ \frac{\sum_{i=1}^{k} n_i \cdot (\log_{10} D_i - \log_{10} M_g)^2}{\left(\sum_{i=1}^{k} n_i \right) - 1} \right\}^{\frac{1}{2}}$$

where:

n_i = the number of particles in the ith class interval

D_i = an average size for that interval

k = number of class intervals.

D_i was taken to be the $antilog_{10}$ of the midpoint of the logarithms of the extremes of each Porton size category (interval).

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.

Confidence Intervals

The method of Lord, based upon range, was used as outlined by Snedecor and Cochran. [Statistical Methods (6th Ed.) Ames, Iowa; The Iowa State University Press, 1967; p. 121.]

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 sample

W = the range of the logarithms

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

t_w = a value equivalent to Student's t, based upon the acceptable confidence limits (95% in this case), and upon the sample size.

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 control over the total time of sampling. The averages were calculated by the usual formula:

$$TWA = \frac{\sum_{i=1}^{n} X_i f_i}{\Sigma\, t_i}$$

where Xi = 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.

SURVEY RESULTS

The results of the bulk sample analyses are given in Appendix B, and the results of the air sample analyses are given in Tables 3 and 4, and in Figures 4-12. The survey results may be briefly summarized:

- Fiber counts, by optical microscopy were very low; the range was from less than 0.002 fibers per cubic centimeter of air (f/cc), to 0.643 f/cc.

- Total airborne particulate material concentrations and exposures were somewhat higher; the highest single sample value was 4.972 milligrams per cubic meter of air (mg/m^3) and the lowest was 0.105 mg/m^3.

- Electron microscopic examination of selected air samples showed no statistically significant difference from the optical microscopic examinations, either in fiber counts or in the sizes of fibers seen.

- Bulk sample analyses showed no significant differences between the fibers and the shot in the material produced.

- Fiber exposures were not highly correlated with functional job categories, although the chargers and the fabrication crew appeared to have somewhat higher fiber exposures than other workers, and the take-off workers appeared to have somewhat lower exposures, under some circumstances.

- The fiber diameters in the bulk material, and in the air samples, were remarkably similar.

- Correlation between logarithms of fiber counts and total airborne particulate material concentrations was fairly strong; knowledge of either would permit fairly accurate (although not precise) prediction of the other.

DISCUSSION OF RESULTS

In Figure 4 we show the cumulative frequency distribution of total airborne particulate material concentrations. The geometric mean concentration is 0.74 mg/m^3, for the 65 samples evaluated. This indicates that 50% of the sample values were above, and 50% below, this value. Approximately 60% of the samples were below 1 mg/m^3. The same sort of distribution is shown in Figure 5, for the fiber counts. The 108 samples taken and analyzed for fibers show a geometric mean of 0.13 f/cc.

Figure 6 is a display of the correlation obtained when 30 randomly-selected pairs of total particulate material samples and fiber count samples were compared. A linear regression line was drawn for the logarithms of the respective sample results, and the correlation coefficient obtained. The correlation is fairly strong; the probability is less than 0.01 that a correlation coefficient as large as 0.76 could be obtained from chance from samples with a true coefficient of zero. The 95% confidence limits on the true population correlation coefficient are shown; they are 0.54 and 0.88. This indicates fairly decent correspondence of the total and fiber concentrations in this plant. A more complete analysis of the data would perhaps be worthwhile, using the original data in Table 3, to determine if the predictability indicated here is supported by all the data. Total particulate measurement is much easier and less expensive than is fiber counting, and control evaluation may be just as effective using the former method of analysis, if this indicated correspondence is true for the larger set of data.

Figure 7 is a similar correlation for the total and respirable particulate material measurements. The correlation is again quite good, and the correspondence indicates that the respirable concentrations of particulate material may be predicted from the total, although with fairly wide limits on the precision of prediction.

Table 4, and Figures 8, 9, 10 and 11 are displays of the comparisons made between scanning electron microscopic analytical results, and the results of the optical microscopic analyses, of the air samples so evaluated. The similarities of these results (given the fairly wide limits of error implicit in examination of small numbers of fibers) indicates that the optical analysis does not miss significant numbers of fibers; the fibers in the air are mostly large enough to be visible to the optical microscope. Support for this contention is gained by analysis of the data in Table 4. "Student's" t-test was applied, and the probability is greater than 0.60 that the differences seen could be due solely to chance; it cannot be concluded that the sample means are significantly different. Figure 11 is a display of the linear correlation of the SEM and OM counts. The correlation is not significantly different from zero. Correlation of the logarithms of the counts shows a stronger correlation, as might be expected.

In Figure 12 are displayed the 95% confidence limits on mean fiber exposures for functional job categories. Although there is overlapping of the confidence intervals for most categories, some differences are apparent. The cupola chargers have higher mean exposure to airborne fibers than do the take-off workers or the maintenance personnel. Likewise, the takeoff workers have lower mean fiber exposures than do the chargers or the fabrication workers, at least during this survey period.

During this survey, no exposures to fibrous airborne particles above the recommended NIOSH standard of 3 f/cc (fibers greater than 10 μm in length,and less than 3.5 μm in diameter) were found. The additional optional standard of $5mg/m^3$ was not exceeded either. (These standards, found in the NIOSH publication "Criteria for a Recommended Standard... Occupational Exposure to Fibrous Glass" have been recommended for guidance in limiting exposure to all man-made amorphous mineral fibers, as well as fibrous glass.) Time-weighted average exposures, representing all employees in a given functional job category, were generally less than one tenth (1/10) of the fiber limit; and usually about one fifth of the gravimetric limit, with the exception of the chargers. It should be noted that the gravimetric limit is based upon the assumption that chemical analysis has been performed to determine the "glass" content of the total particulate material samples; this is not true for this survey. Thus, the chargers' exposures may be (and probably are) to other particulate materials in the air, other than strictly "glass". Coke dust, and general debris probably make up a large fraction of the chargers' exposures.

Exposures to trace elements in the air were also low. As can be seen in Table 3, the concentrations of cadmium, chromium, nickel, cobalt and lead were all below detectable limits; they were less than 1-5 $\mu g/m^3$. Zinc and manganese levels, although apparent, were also quite low.

Based on conversations with plant personnel, it is probable that past exposures were significantly higher than at present, and included exposure to asbestos fibers. It would be expected that present exposures are dramatically lower than those in the past; perhaps as much as an order of magnitude lower.

RECOMMENDATIONS AND CONCLUSIONS

- No evidence of exposures to airborne contaminants above current or recommended standards was found.

- The processes in the plant that were observed appear to be under adequate control; those not observed appear to have adequately designed control equipment installed.

- The current program of upgrading the occupational and environmental health engineering measures at this plant will probably reduce exposures still further.

- The engineering staff at the plant are aware of the potential for exposures from the several processes, and are taking measures to alleviate them.

RECOMMENDATION 1: A full industrial hygiene and safety engineering survey should be performed, to evaluate the occupational environment more fully than was possible in this survey.

RECOMMENDATION 2: The extent of exposure to asbestos in the past should be determined, as should the past exposures to mineral wool fibers.

TABLE 1

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/acet.	A/A	N_2O/acet.	A/A
Flame Stoichiometry	Oxidizing	Ox.	Ox.	Reducing	Ox.	Reducing	Ox.
Interferences	*	*	-	-	*	**	*

*Correction was made for non-atomic absorption using a hydrogen continuum lamp.

**Correct for non-atomic absorption using 231.7 line

TABLE 2

CORRECTION FACTORS FROM

METAL RECOVERY EXPERIMENTS

Mn	1.04
Co	0.93
Zn	0.998
Cd	0.97
Pb	1.11
Cr	1.03
Ni	0.949

Table 3
AURORA-AIR SAMPLING RESULTS
(Cd, Cr, Ni, Co, and Pb all below detectable limits)

			Fiber Counting				Geom. Mean (Geom. Std. Dev.)		Total Airborne Particulate Material			$\mu g/m^3$		Respirable Particulate Material		
Area	Payroll Title	Job Category	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
Cupola	Cupola Operator	Same	C 748	306	0.144				AA604	751	1.291	40	71			
			C 734	282	0.173											
			C 730	298	0.156	203	10.4 (2.4)	1.8 (1.7)								
	Cupola Operator	same	C1015	326	0.187											
			C1017	292	0.033											
	Cupola Operator	same	C 731	358	0.245				AA567	839	1.372	67	0.114			
			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					
	Cupola Charger	same	C 737	240	0.352				AA550	838	3.218	74	0.026			
			C 676	244	0.190	139	9.7 (2.3)	1.6 (1.4)								
			C 660	222	0.278											
			C 663	126	0.643											
	Cupola Charger	same	C 716	344	0.312				AA499	875	4.307	29	26			
			C 715	260	0.217	119	8.3 (2.0)	1.9 (1.5)								
			C 735	250	0.296											
									AA615	783	4.972	57	29	W70	713	0.496
			TWA	1686	0.303				TWA	2496	4.150					

AURORA - Air Sampling Results Cont'd.

Table 3, cont'.

Area	Payroll Title	Job Category	Fiber Counting: Sample Number	Fiber Counting: Flow (Liters)	Fiber Counting: f/cc	Fiber Counting: N	Geom. Mean (Geom.Std.Dev.) Length	Geom. Mean (Geom.Std.Dev.) Diameter	Total Airborne Particulate Material: Sample Number	Total Airborne Particulate Material: Flow (Liters)	Total Airborne Particulate Material: Total Mg/M^3	µg/m^3 Zn	µg/m^3 Mn	Respirable Particulate Material: Sample Number	Respirable Particulate Material: Flow (Liters)	Respirable Particulate Material: Total Mg/M^3
Production Line	Shift Mgr.	Foreman	C 720	484	0.060				AA595	807	0.626	50	0.179			
			C 711	333	0.004											
	Shift Mgr.	Foreman	C1033	220	0.627				AA607	672	1.186	4	0.039			
			C1006	460	0.315	217	21.1	2.1								
							3.3	(1.8)								
	Asst. Shift Mgr.	Asst.Foreman	C1020	383	0.100				AA510	782	0.233	1	0.009			
			C1003	386	0.056											
	Asst. Shift Mgr.	Asst.Foreman	C 706	402	0.049				AA593	764	0.387	2	53			
			C 719	379	0.077											
	Asst. Shift Mgr.	Asst.Foreman							AA590	833	0.174	11	16	W74	712	0.108
			TWA	3047	0.138				TWA	3858	0.499					
	Crewperson	Take-off	C1016	385	0.061				AA601	785	0.233	-0-	6			
			C1023	428	0.032											
	Crewperson	Take-off	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)								
	Crewperson	Take-off	C 712	160	0.037				AA561	658	0.319	9	24	W72	595	0.077
	Crewperson	Take-off	C 722	378	0.107				AA595	871	0.626	50	0.179			
			C 713	428	0.106											
	Crewperson	Take-off	C 749a	274	0.119				AA633	772	0.440	trace	20			
			C 729	436	0.028											
	Crewperson	Take-off	C 739	330	0.036				AA589	825	0.326	-0-	14			
			C 727	252	0.107											

AURORA - Air Sampling Results Cont'd.

Table 3, cont'.

Area	Payroll Title	Job Category	Fiber Counting: Sample Number	Fiber Counting: Flow (Liters)	Fiber Counting: f/cc	Fiber Counting: N	Fiber Counting: Geom. Mean (Geom.Std.Dev.) Length	Fiber Counting: Geom. Mean (Geom.Std.Dev.) Diameter	Total Airborne Particulate Material: Sample Number	Total Airborne Particulate Material: Flow (Liters)	Total Airborne Particulate Material: Total Mg/M^3	µg/m^3 Zn	µg/m^3 Mn	Respirable Particulate Material: Sample Number	Respirable Particulate Material: Flow (Liters)	Respirable Particulate Material: Total Mg/M^3
Production Line cont'd	Crewperson	Take-off							AA549	739	0.464	7	11	W80	677	0.194
	Crewperson	Take-off	C 664	316	0.113				AA565	779	0.946	43	30			
			C 655	446	0.227	140	18.7	2.3								
	Crewperson	Take-off	C1013	469	0.067		(3.1)	(1.7)	AA612	682	0.330	5	2			
			C1045	212	0.169											
	Crewperson	Take-off	C1005	431	0.098				AA627	675	2.053	4	58			
			C1029	219	0.108											
	Crewperson	Take-off	C 725	428	0.096				AA500	780	0.792	20	74			
			C 740	393	0.084											
	Crewperson	Take-off	C1009	424	0.096	130	18.3	2.2	AA616	596	1.267	40	19			
			C1038	182	0.346		(3.0)	(1.8)								
	Crewperson	Take-off	C 723	350	0.056				AA501	802	0.398	15	45			
			C 707	394	0.145											
			TWA	8150	0.264				TWA	9788	0.658					
	Crewperson	Loader	C1011	340	0.176				AA636	572	0.640	3	11			
			C1040	240	0.183											
	Crewperson	Loader	C 724	430	0.093				AA569	796	0.535	32	0.214			
			C 718	384	0.070	234	18.6	2.3								
	Crewperson	Loader	C 746	300	0.442		(2.9)	(1.7)	AA588	627	0.352	-0-	7			
			C 747	370	0.057											
	Crewperson	Loader	C 671	271	0.021				AA602	816	0.966	67	17			
			C 659	458	0.197											
	Crewperson	Loader	C 750	364	0.164				AA625	892	0.105	21	49			
			C 726	453	0.204											
			TWA	3610	0.159				TWA	3703	0.512					

AURORA - Air Sampling Results Cont'd.

Table 3, cont'.

Area	Payroll Title	Job Category	Fiber Counting: Sample Number	Fiber Counting: Flow (Liters)	Fiber Counting: f/cc	Fiber Counting: N	Geom. Mean (Geom. Std. Dev.) Length	Geom. Mean (Geom. Std. Dev.) Diameter	Total Airborne Particulate Material: Sample Number	Total Airborne Particulate Material: Flow (Liters)	Total Airborne Particulate Material: Total Mg/M^3	µg/m^3 Zn	µg/m^3 Mn	Respirable Particulate Material: Sample Number	Respirable Particulate Material: Flow (Liters)	Respirable Particulate Material: Total Mg/M^3
Fabrication	Asst. Foreman	same							AA626	214	1.112	27	10	W82	180	0.133
	Leadman	same							AA576	839	0.682	27	0.017	W79	701	0.150
	Crewperson	same	C1031 C1042	218 501	0.510 0.267				AA619	724	1.220	0.060	27			
	Crewperson	same	C1032 C1049	262 380	0.265 0.185	310	17.3 (2.8)	2.3 (1.7)	AA507	642	0.642	9	8			
	Crewperson	same	C1002 C1030	352 247	0.235 0.542				AA491	667	0.708	18	10			
	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			

AURORA - Air Sampling Results Cont'd.

Table 3, cont'.

Area	Payroll Title	Job Category	Fiber Counting: Sample Number	Fiber Counting: Flow (Liters)	Fiber Counting: f/cc	Fiber Counting: N	Fiber Counting: Geom. Mean (Geom.Std.Dev.) Length	Fiber Counting: Geom. Mean (Geom.Std.Dev.) Diameter	Total Airborne Particulate Material: Sample Number	Total Airborne Particulate Material: Flow (Liters)	Total Airborne Particulate Material: Total Mg/M^3	Total Airborne Particulate Material: µg/m^3 Zn	Total Airborne Particulate Material: µg/m^3 Mn	Respirable Particulate Material: Sample Number	Respirable Particulate Material: Flow (Liters)	Respirable Particulate Material: Total Mg/M^3
Fabrication cont'd.	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					
Warehouse	Leadman	same	C 665	342	0.205				AA600	785	1.324	63	19			
			C 654	446	0.074	108	18.3	2.1								
	Loader	same	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					
Yard	Equip.Operator	Cat Operator							AA545	730	2.397	96	94	W68	614	0.272
General Plant		Maint. Foreman	C1043	541	0.097				AA564	783	0.598	1	10			
			C1027	236	0.149											
		Maintenance	C1063	193	0.131	144	15.8	2.2	AA594	767	2.743	241	81			
			C1048	585	0.157		(3.0)	(1.7)								
		Maintenance	C1047	520	0.086				AA629	766	0.589	70	33			
			C1041	250	0.124											

AURORA - Air Sampling Results Cont'd.

Table 3, cont'.

Area	Payroll Title	Job Category	Fiber Counting Sample Number	Fiber Counting Flow (Liters)	Fiber Counting f/cc	Fiber Counting N	Fiber Counting Geom. Mean (Geom. Std. Dev.) Length	Fiber Counting Geom. Mean (Geom. Std. Dev.) Diameter	Total Airborne Particulate Material Sample Number	Total Airborne Particulate Material Flow (Liters)	Total Airborne Particulate Material Total Mg/M^3	Total Airborne Particulate Material μg/m^3 Zn	Total Airborne Particulate Material μg/m^3 Mn	Respirable Particulate Material Sample Number	Respirable Particulate Material Flow (Liters)	Respirable Particulate Material Total Mg/M^3
General Plant cont'd.		Maintenance	C1007	441	0.116				AA621	691	0.661	57	19			
			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	0.100	0.102			
			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	Lab Tech.	same	C1008	588	0.220				AA516	552	0.384	10	4			
	Receiving Clk.	same	C1044	591	0.232				AA618	776	0.954	15	30			
			C1058	167	0.297	168	15.3	2.0								
							(3.0)	(1.7)								
	Maint. Clerk	same	C1046	254	0.053				AA613	254	0.398	-0-	7			
			TWA	1600	0.206				TWA	1582	0.666					

AURORA - Air Sampling Results Cont'd.

Table 3, cont'.

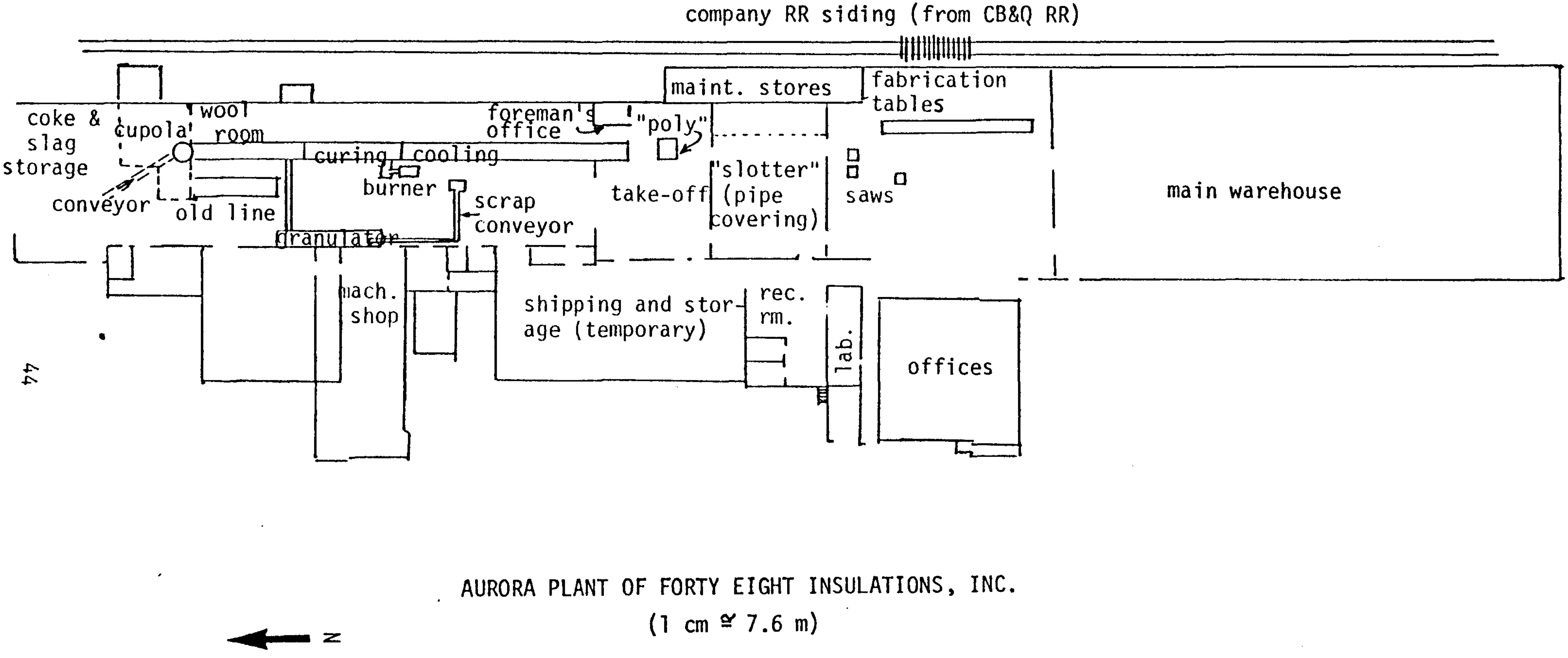
Area	Payroll Title	Job Category	Fiber Counting: Sample Number	Fiber Counting: Flow (Liters)	Fiber Counting: f/cc	Fiber Counting: N	Fiber Counting: Geom. Mean (Geom.Std.Dev.) Length	Fiber Counting: Geom. Mean (Geom.Std.Dev.) Diameter	Total Airborne Particulate Material: Sample Number	Total Airborne Particulate Material: Flow (Liters)	Total Airborne Particulate Material: Total Mg/M³	Total Airborne Particulate Material: μg/m³ Zn	Total Airborne Particulate Material: μg/m³ Mn	Respirable Particulate Material: Sample Number	Respirable Particulate Material: Flow (Liters)	Respirable Particulate Material: Total Mg/M³
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					

TABLE 4

FIBER COUNTS BY
SCANNING ELECTRON MICROSCOPY (SEM)
AND OPTICAL MICROSCOPY (OM)
AURORA

SAMPLE NO.	JOB CATEGORY	FIBERS/CC	
		OM	SEM
C731	Cupola Operator	0.245	0.221
C716	Cupola Charger	0.312	0.196
C1006	Shift Manager	0.315	0.156
C725	Crew (Take-off)	0.096	0.069
C1013	Crew (Take-off)	0.067	0.041
C709	Crew (Fabr.)	0.325	0.565
C1049	Crew (Fabr.)	0.185	0.239
C654	Lead.(Warehouse)	0.074	0.193
C1048	Maintenance	0.157	0.172
C1008	Lab. Tech.	0.220	0.108

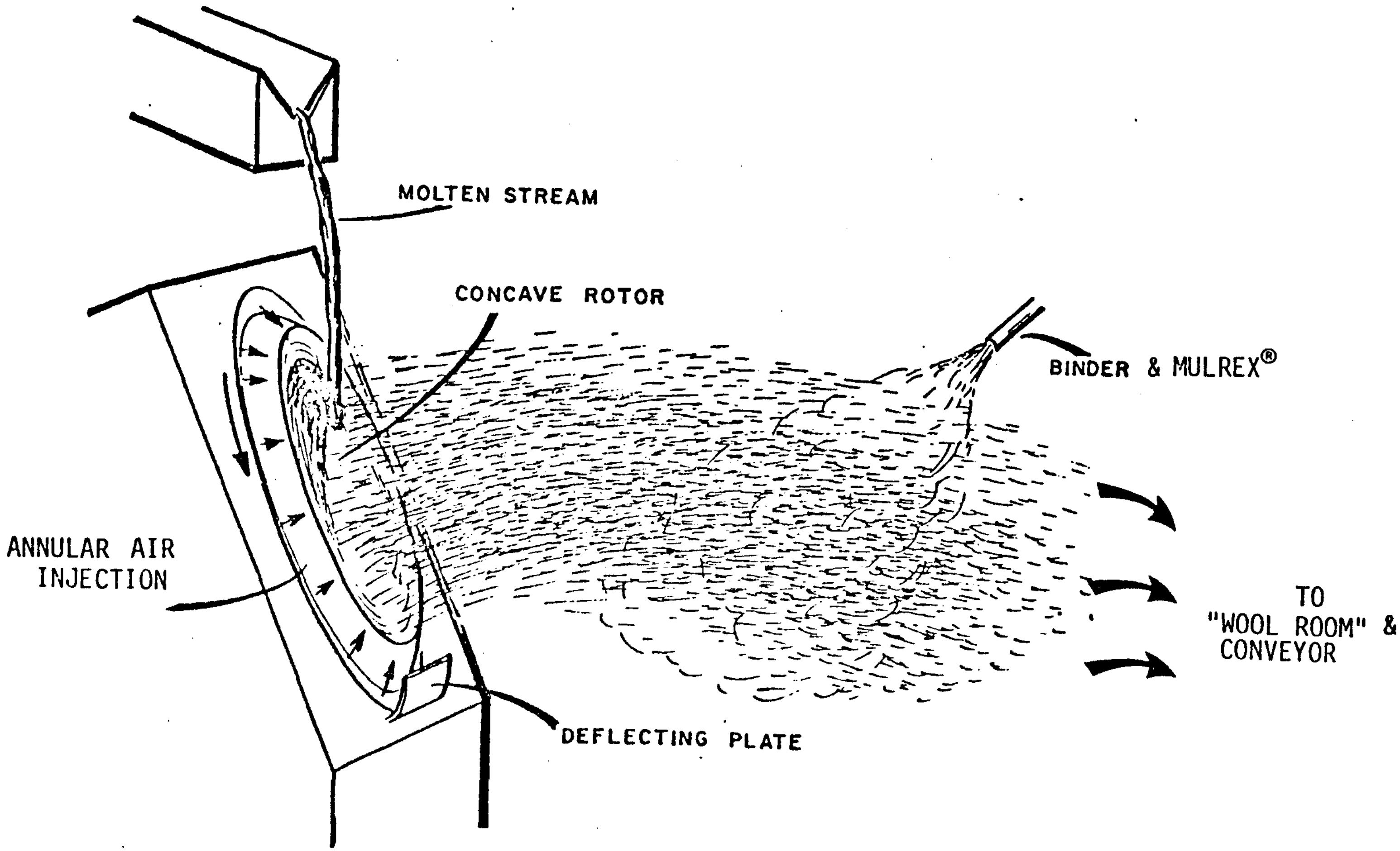
FIGURE 1



AURORA PLANT OF FORTY EIGHT INSULATIONS, INC.

(1 cm ≅ 7.6 m)

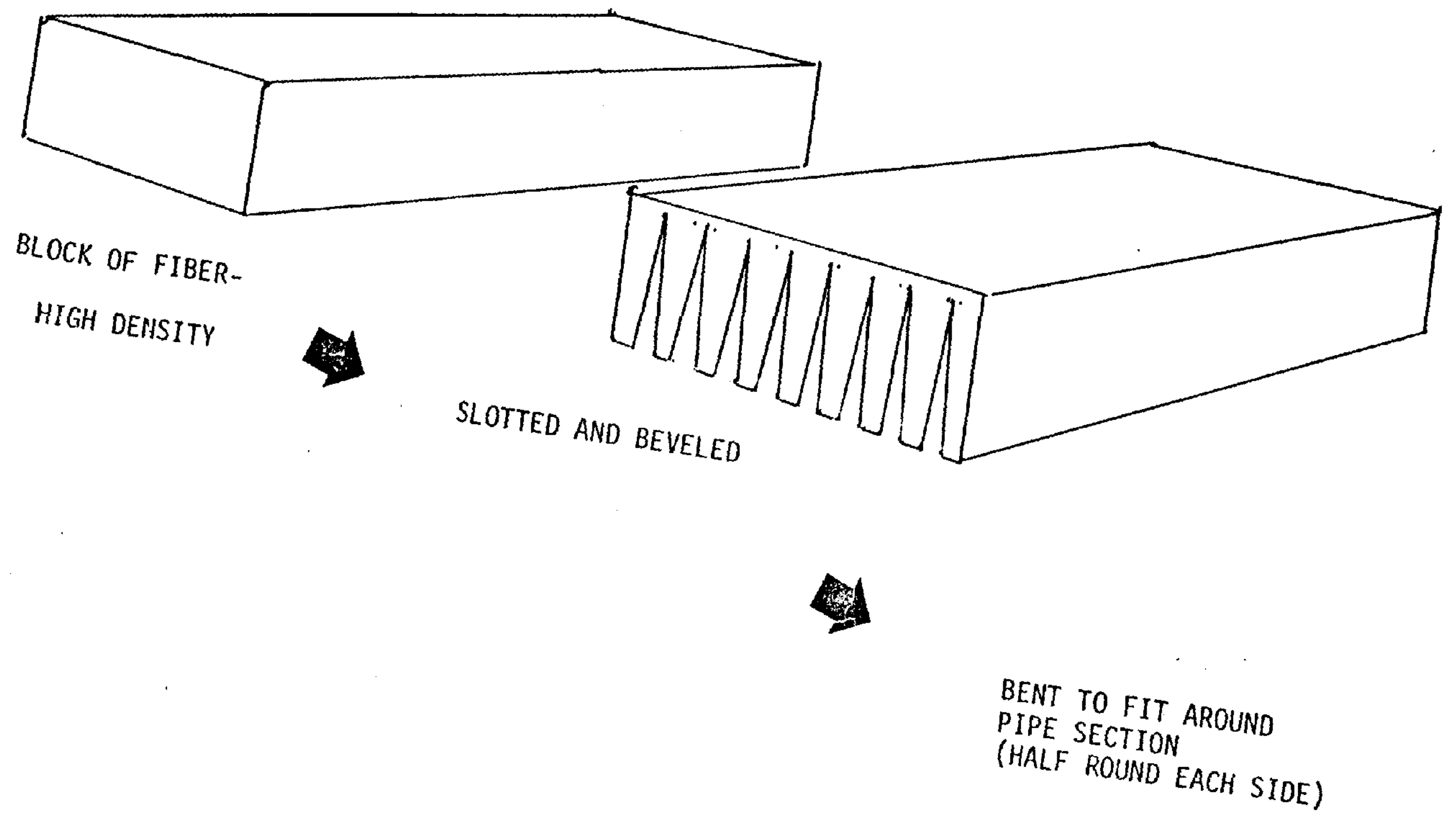
FIGURE 2



FIBERIZATION PROCESS
FORTY EIGHT INSULATIONS, INC. - AURORA

(ADAPTED FROM NIOSH PUBL. 76-151)

FIGURE 3



"SLOTTING" OPERATION

FIGURE 4

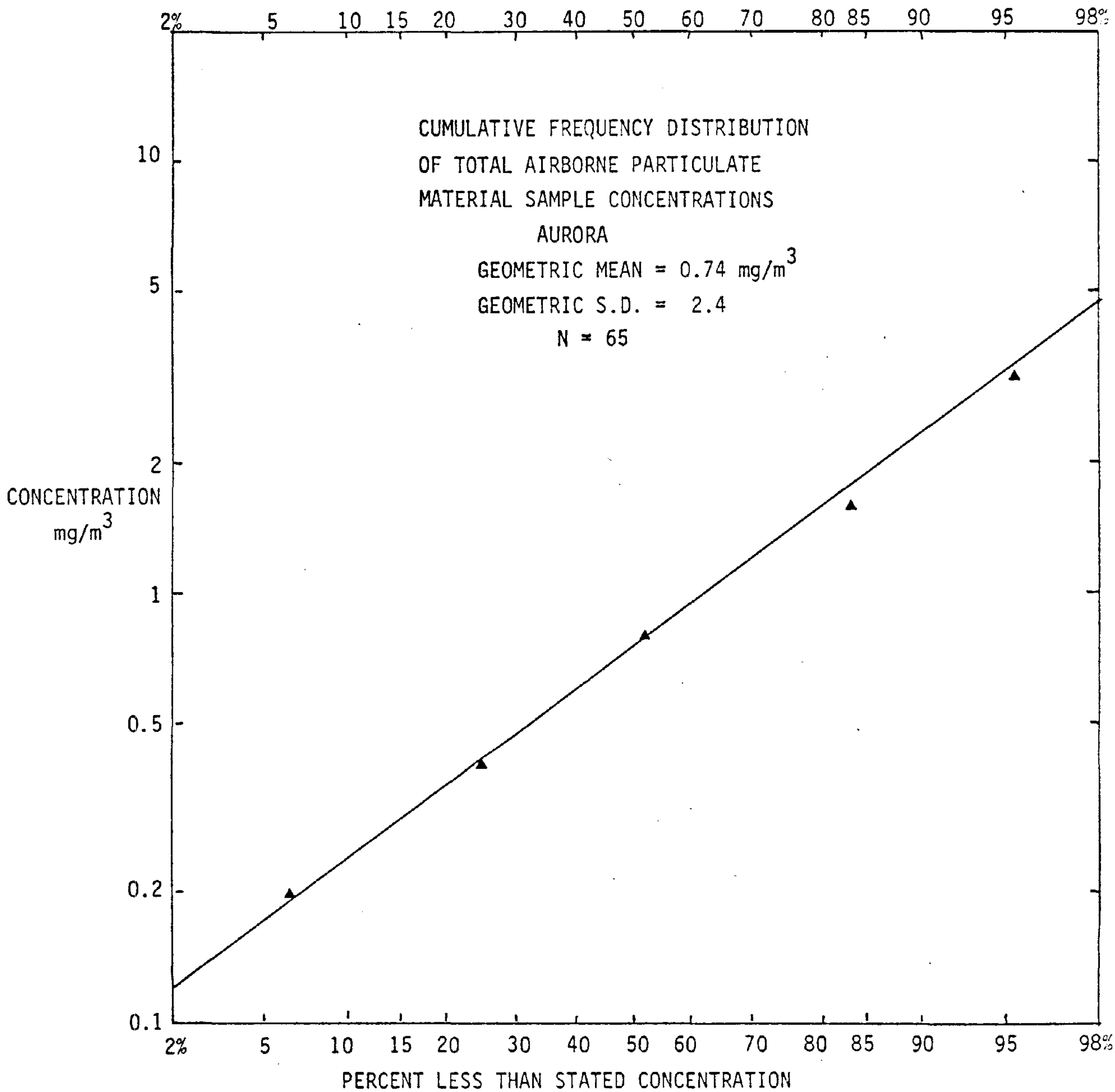

CUMULATIVE FREQUENCY DISTRIBUTION
OF TOTAL AIRBORNE PARTICULATE
MATERIAL SAMPLE CONCENTRATIONS
AURORA
GEOMETRIC MEAN = 0.74 mg/m3
GEOMETRIC S.D. = 2.4
N = 65
CONCENTRATION mg/m3
10
5
2
1
0.5
0.2
0.1
2%
5
10
15
20
30
40
50
60
70
80
85
90
95
98%
PERCENT LESS THAN STATED CONCENTRATION

FIGURE 5

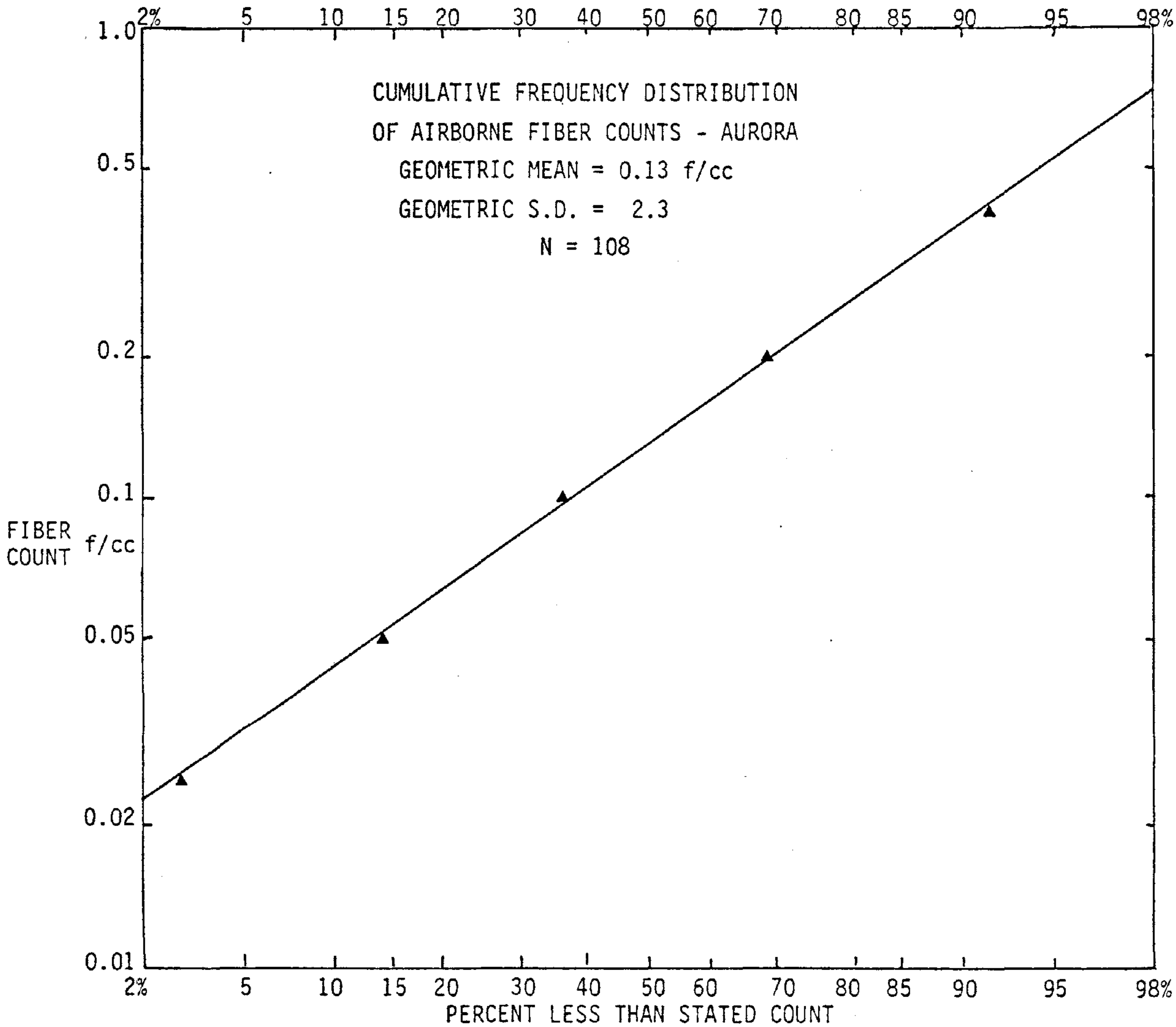

CUMULATIVE FREQUENCY DISTRIBUTION
OF AIRBORNE FIBER COUNTS - AURORA
GEOMETRIC MEAN = 0.13 f/cc
GEOMETRIC S.D. = 2.3
N = 108
FIBER COUNT f/cc
1.0
0.5
0.2
0.1
0.05
0.02
0.01
2%
5
10
15
20
30
40
50
60
70
80
85
90
95
98%
PERCENT LESS THAN STATED COUNT

FIGURE 6

LOG-LINEAR CORRELATION OF FIBER COUNTS WITH TOTAL AIRBORNE PARTICULATE MATERIAL FOR 30 RANDOMLY-SELECTED SAMPLE PAIRS - AURORA

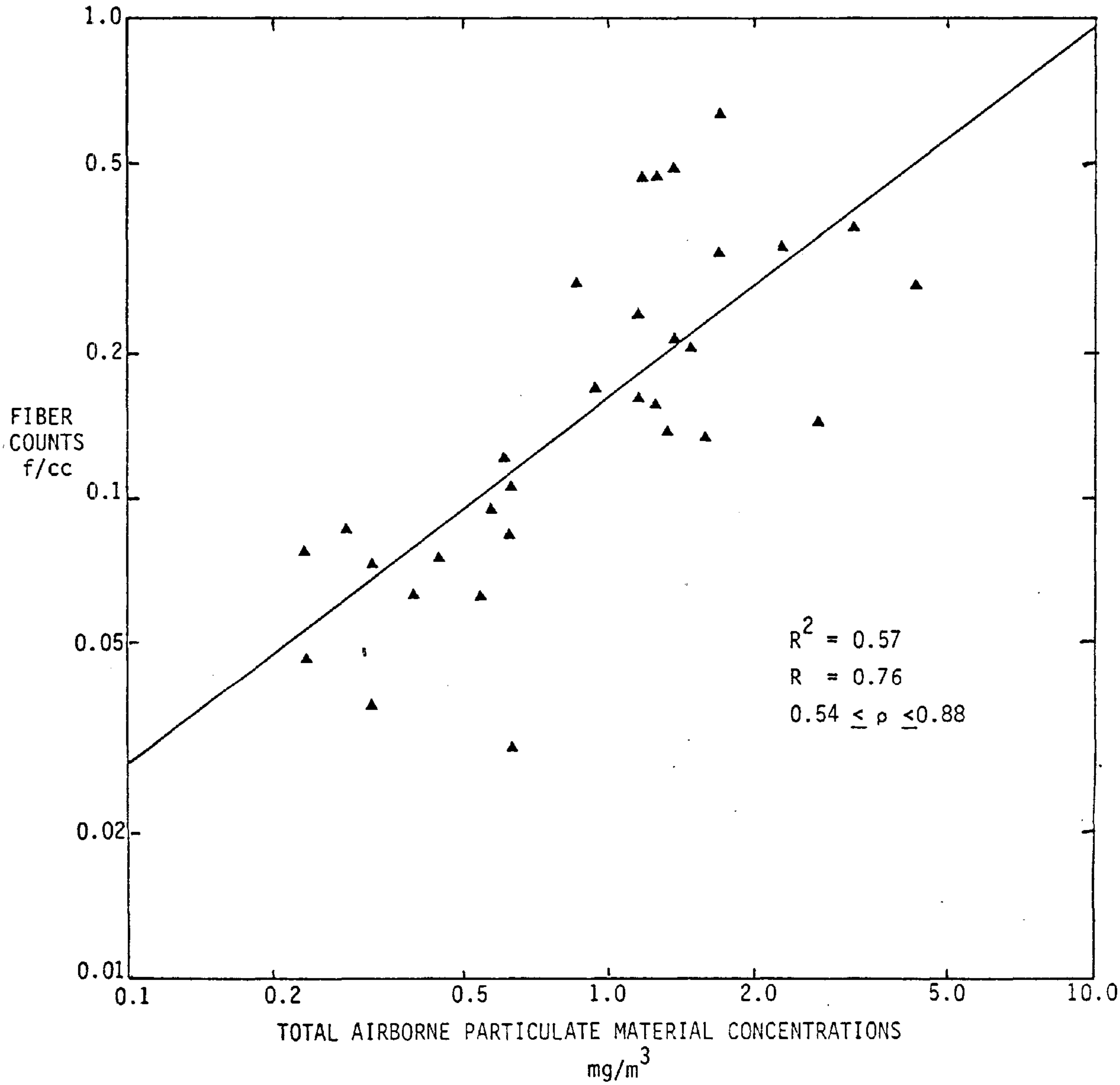


FIGURE 7

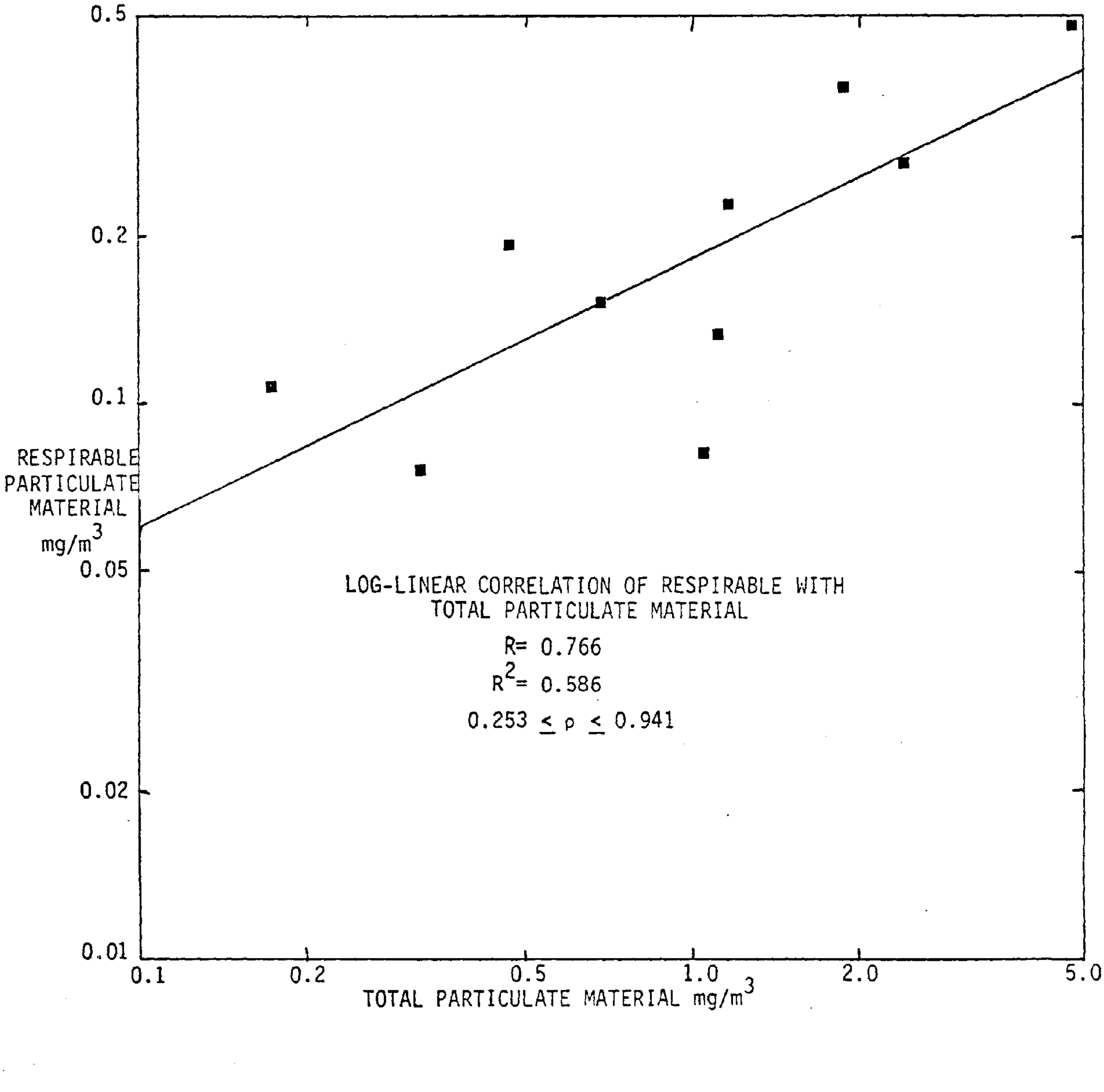

0.5
0.2
0.1
RESPIRABLE
PARTICULATE
MATERIAL
mg/m3
0.05
0.02
0.01
LOG-LINEAR CORRELATION OF RESPIRABLE WITH
TOTAL PARTICULATE MATERIAL
R= 0.766
R2= 0.586
0.253 ≤ ρ ≤ 0.941
0.1
0.2
0.5
1.0
2.0
5.0
TOTAL PARTICULATE MATERIAL mg/m3

FIGURE 8

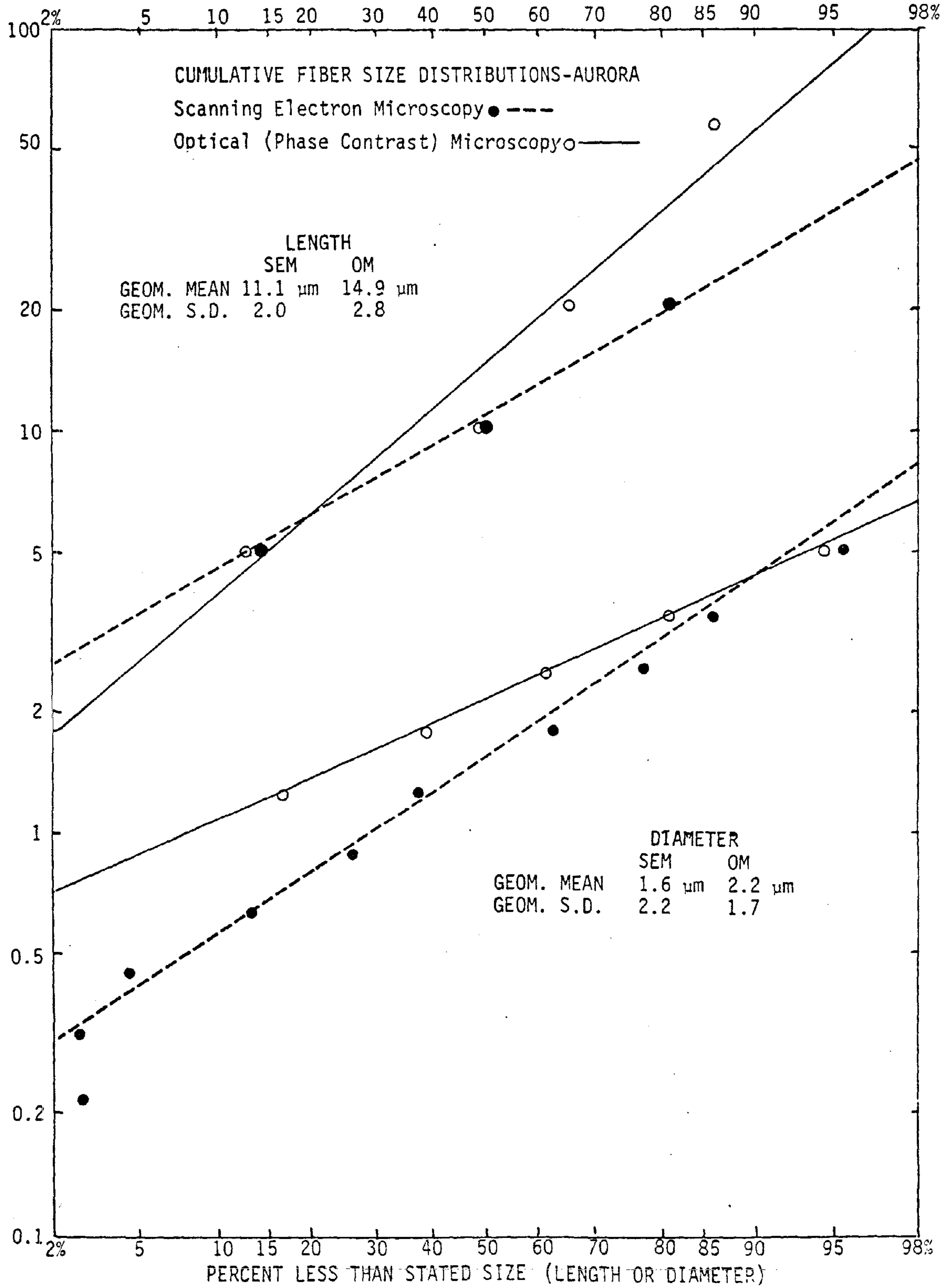

CUMULATIVE FIBER SIZE DISTRIBUTIONS-AURORA
Scanning Electron Microscopy
Optical (Phase Contrast) Microscopy
LENGTH
SEM OM
GEOM. MEAN 11.1 μm 14.9 μm
GEOM. S.D. 2.0 2.8
DIAMETER
SEM OM
GEOM. MEAN 1.6 μm 2.2 μm
GEOM. S.D. 2.2 1.7
100
50
20
10
5
2
1
0.5
0.2
0.1
2% 5 10 15 20 30 40 50 60 70 80 85 90 95 98%
PERCENT LESS THAN STATED SIZE (LENGTH OR DIAMETER)

FIGURE 9

AURORA FIBER DIAMETER DISTRIBUTIONS

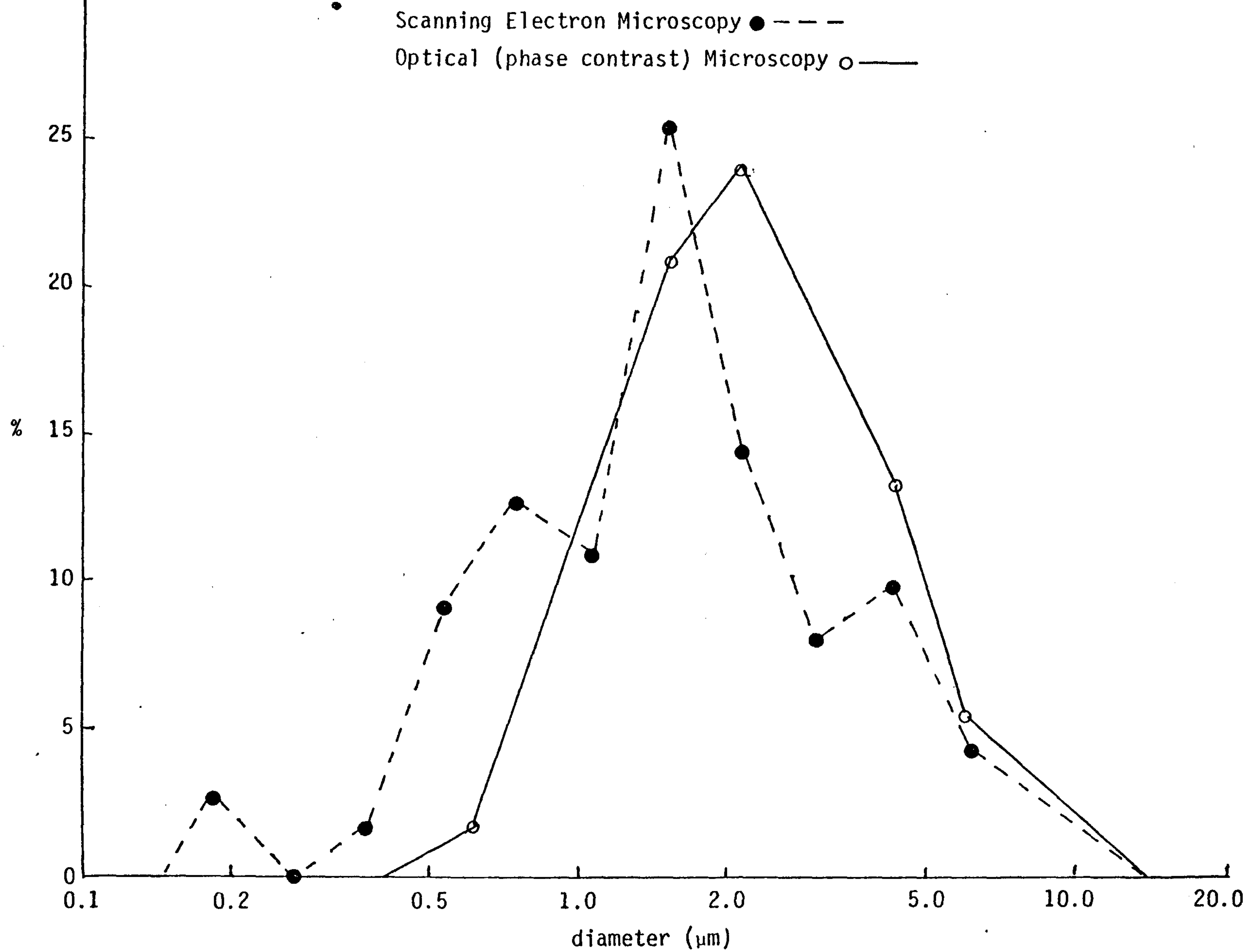


FIGURE 10

AURORA FIBER LENGTH DISTRIBUTION

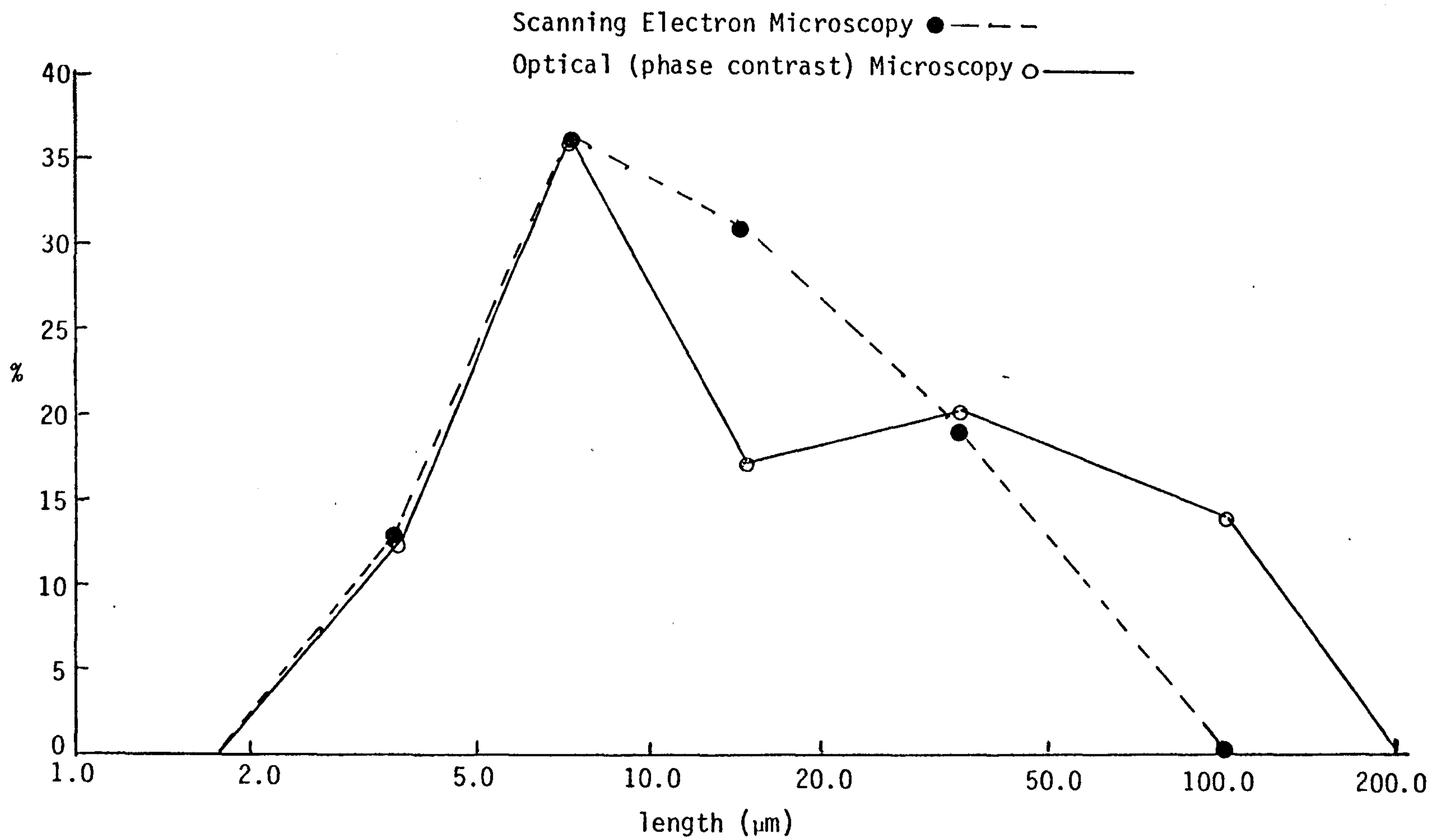


FIGURE 11

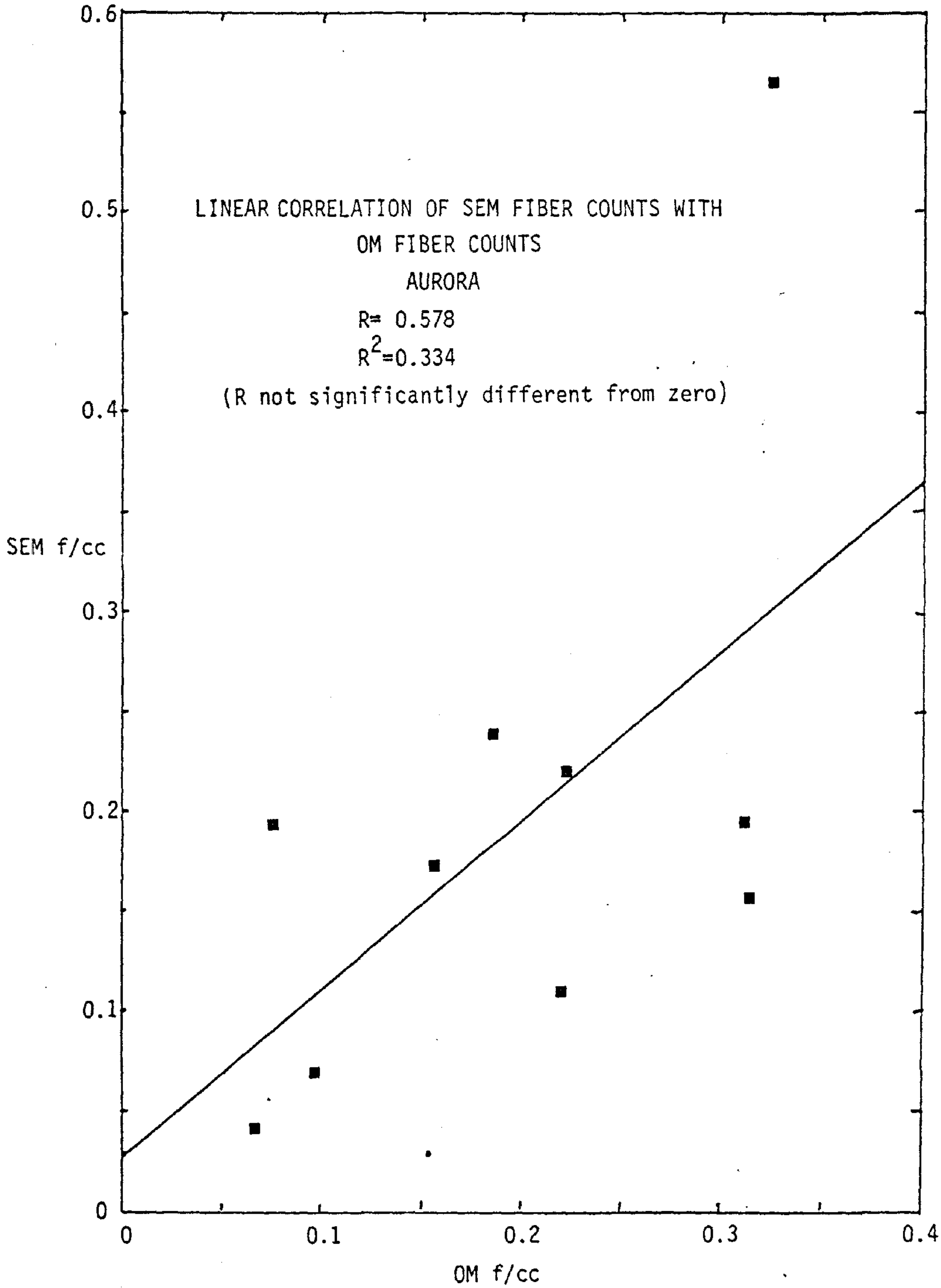
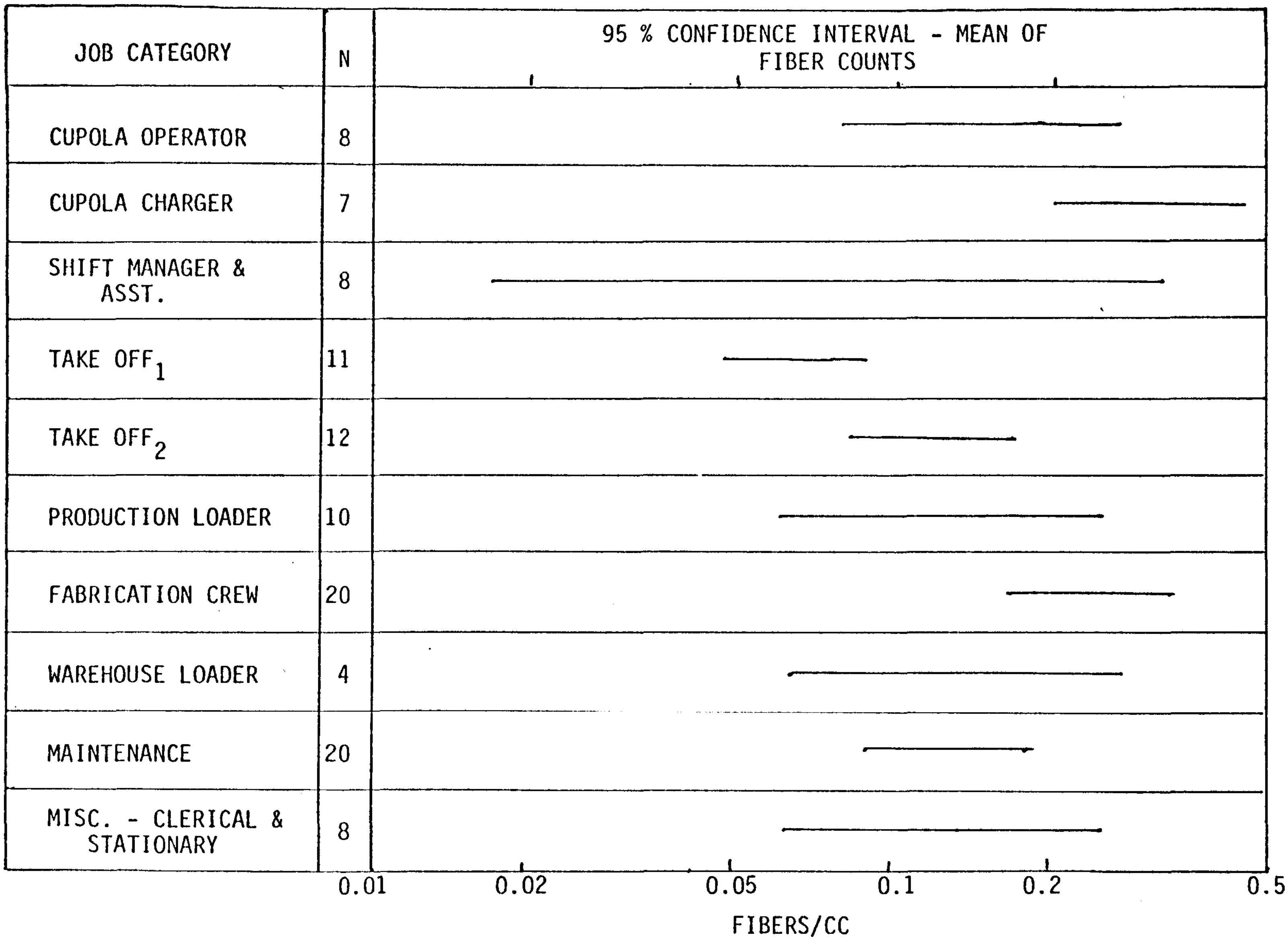

0.6
0.5
0.4
0.3
0.2
0.1
0
LINEAR CORRELATION OF SEM FIBER COUNTS WITH
OM FIBER COUNTS
AURORA
R= 0.578
R2=0.334
(R not significantly different from zero)
SEM f/cc
0
0.1
0.2
0.3
0.4
OM f/cc

FIGURE 12

95% CONFIDENCE LIMITS ON MEAN FIBER CONCENTRATIONS



1 Samples from June 1 - 2

2 Samples from June 3

APPENDIX A

LIMITATIONS ON SURVEY SCOPE

The attached letter was handed to Douglas P. Fowler of SRI International by David E. Maxam on the morning of June 1, 1977, at the beginning of the survey. Mr. Ralph D. Zumwalde, NIOSH Project Officer, gave oral permission by telephone to proceed with the survey, under the limitations stated.

FORTY-EIGHT INSULATIONS INC. AURORA, ILLINOIS

May 27, 1977

Mr. D. P. Fowler
Stanford Research Institute
Menlo Park, CA 94025

Dear Mr. Fowler:

This letter will outline the terms and conditions of FORTY-EIGHT INSULATIONS, INC.'s admission of Stanford Research Institute (SRI) to its plant at North Aurora, Illinois, in the National Institute for Occupational Safety and Health (NIOSH) study.

1. The survey of FORTY-EIGHT INSULATIONS, INC.'s North Aurora plant will be limited to a survey of occupational exposure through airborne mineral wool fibers,[1] and no other purpose.

2. SRI will agree to conduct no other tests or investigations or collect data except for airborne mineral wool fibers.

3. SRI personnel will agree at all times to comply with FORTY-EIGHT's safety rules and regulations, including the wearing of safety equipment.

4. A schedule of times when SRI personnel will be in the plant is appended to this letter, and will be arrived at by agreement. SRI agrees that it will have no personnel in the FORTY-EIGHT plant except at the times shown in the schedule attached.

5. FORTY-EIGHT, at its own expense, is furnishing an escort for each and every SRI personnel. SRI agrees to allow said escort to accompany the SRI personnel at all times while in the FORTY-EIGHT plant. FORTY-EIGHT's escort will monitor the actions of SRI personnel, but will not interfere therewith except for breach of this agreement. In case of dispute between the escort and SRI personnel, both parties involved are to advise their superiors, and a meeting will be held promptly to adjust the dispute.

6. SRI agrees to remove SRI equipment from employee's bodies whenever in the judgment of FORTY-EIGHT such equipment would create a hazard to the safety of the employee, or prevent the employee from doing his normal tasks. FORTY-EIGHT will not invoke this provision unreasonably.

7. SRI agrees in advance of submission of its report to NIOSH or any other body to whom said report must or could be submitted to submit drafts of that report, as that report is written to FORTY-EIGHT for its comments, and agrees to forward

1) Wherever used this term shall include total airborne particulate material.

FORTY-EIGHT's comments[2] with its report to the submittee or submittees, to the extent that SRI is unwilling to alter its reports to conform to FORTY-EIGHT's comments.

8. In addition to the above paragraph, in the event that FORTY-EIGHT identifies any part of the SRI report as disclosing a trade secret, SRI agrees to remove all reference to said trade secret from its report.

9. SRI agrees to give and to discuss a copy of this agreement with each of its site inspection personnel.

Very truly yours,

FORTY-EIGHT INSULATIONS, INC.

David E. Maxam
Vice President-Finance and Administration

DEM:elf

2) To be submitted to SRI within fourteen (14) days of mailing by SRI to FORTY-EIGHT INSULATIONS, INC.

PERSONNEL SCHEDULE FOR SRI/NIOSH STUDY

June 1, 1977 - June 3, 1977

DATE	TIME	DEPARTMENT	SRI PERSONNEL	48 PERSONNEL
6/1/77	8:00 - 4:00	Fabrication	B. Alli B. Lovegren L. Sandman D. Fowler	R. Hastings D. Maxam E. Kells
	4:00 - 12:00	Production	B. Alli B. Lovegren	R. Hastings R. Parkison
6/2/77	12:00 - 8:00	Production	D. Fowler L. Sandman	S. Sanchez D. Maxam
	8:00 - 4:00	Fabrication and Production	B. Alli B. Lovegren	E. Kells A. Schaidler
	4:00 - 12:00	Production and Shift Maintenance	D. Fowler L. Sandman	R. Hastings R. Parkison
6/3/77	12:00 - 8:00	Production and Shift Maintenance	B. Alli (D. Fowler & L. Sandman beginning of shift)	S. Sanchez D. Maxam
	8:00 - 4:00	Production Yard and Maintenance	B. Alli D. Fowler L. Sandman Possible 4th	E. Kells D. Maxam R. Hastings

APPENDIX B

BULK SAMPLE ANALYSES

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

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

The following analyses were applied to these samples

- Optical microscopy, to determine fiber diameter
- Atomic Absorption spectroscopy, for trace element content
- X-Ray fluorescence spectroscopy, for total elemental composition
- X-Ray microprobe analysis of individual fibers and shot, to determine if differences exist

TABLE B-1

BULK SAMPLES

FIBER DIAMETERS BY

OPTICAL MICROSCOPY

PORTON CATEGORY	DIAMETER (μm)	SAMPLES			TOTAL
		X	Y	Z	
< 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

FIGURE B-1

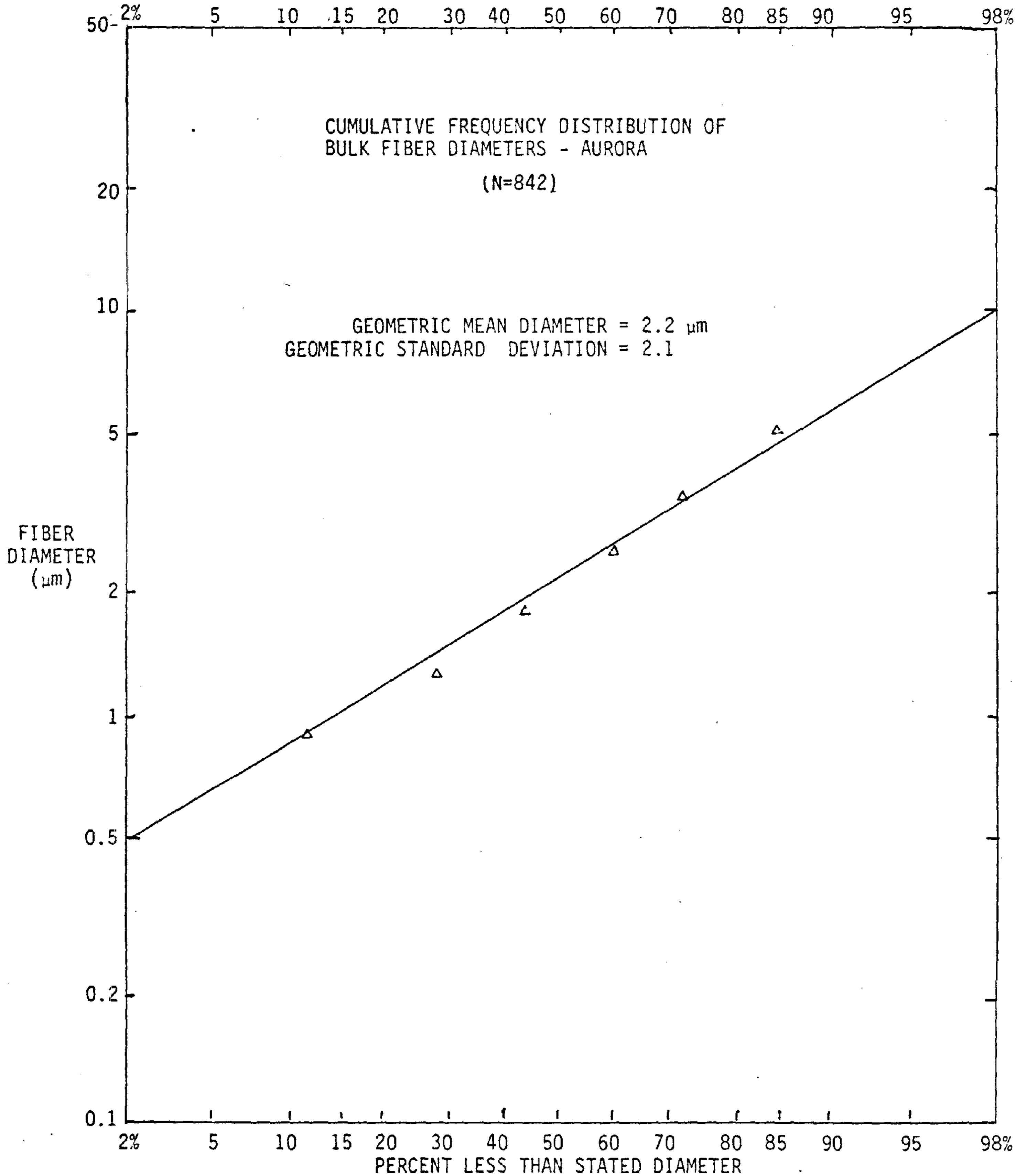

CUMULATIVE FREQUENCY DISTRIBUTION OF
BULK FIBER DIAMETERS - AURORA
(N=842)
GEOMETRIC MEAN DIAMETER = 2.2 μm
GEOMETRIC STANDARD DEVIATION = 2.1
FIBER
DIAMETER
(μm)
50
20
10
5
2
1
0.5
0.2
0.1
2% 5 10 15 20 30 40 50 60 70 80 85 90 95 98%
PERCENT LESS THAN STATED DIAMETER

TABLE B-2

X-RAY FLUORESCENCE (XRF) AND ATOMIC ABSORPTION ANALYSES OF BULK SAMPLES

ELEMENT	RESULTS - µg/gm					
	X		Y		Z	
	XRF	AA	XRF	AA	XRF	AA
Cr	< 104	56	< 95	38	< 88	35
Mn	.60%	0.52%	.39%	0.44%	.49%	0.55%
Fe	2.2%		1.7%		3.3%	
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	.45%		.34%		.31%	
Sn	< 170		< 120		< 165	
K	.21%		.22%		.11%	
Ca	20%		23%		20%	
Sr	.12%		756		913	
Ba	< 415		< 420		< 410	
Rb	< 26		< 26		< 23	
Si	OBS		OBS		OBS	

TABLE B-3
X-RAY MICROPROBE ANALYSIS OF BULK SAMPLES - AURORA

S = Small Fiber (≈1.0um)
M = Medium Fiber (≈5.0um)
L = Large Fiber (10 um)
Shot = Shot
VP = Variable, fractured particle, not identifiable

Bulk Sample "X" - 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

Bulk Sample "Y" - Microprobe

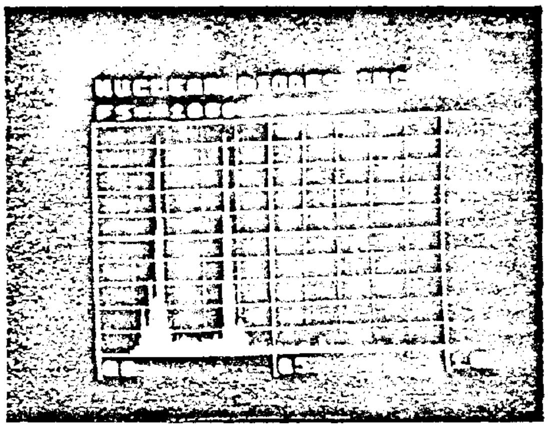
1.2	Mg	0.58	0.62	0.70	0.67	-
1.5	Al	2.25	1.55	1.10	1.20	3.00
1.7	Si	3.02	3.67	3.73	3.89	3.66
2.2	S	0.30	0.27	0.21	0.16	-
2.5	Cl	-	-	-	0.10	-
3.2	K	0.22	0.23	0.18	0.19	-
3.6	Ca	2.40	3.50	3.77	3.57	-
4.0	Ca	0.40	0.50	0.49	0.53	-
4.5	Ti	0.31	-	0.06	0.06	-
5.8	Mn	-	-	0.08	-	-
6.4	Fe	0.14	0.16	0.14	0.10	tr

Bulk Sample "Z" - Microprobe

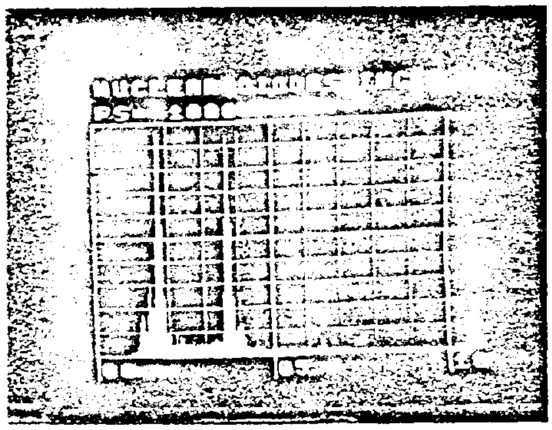
1.0	Na	-	0.05	-	-	-
1.2	Mg	0.72	0.66	0.60	0.80	0.23
1.5	Al	0.62	1.10	1.09	1.12	3.09
1.7	Si	3.59	3.74	3.45	3.78	3.50
2.2	S	0.24	0.18	0.17	0.16	0.34
2.9	Ar?	-	-	-	0.10	-
3.2	K	0.16	0.16	0.19	0.16	-
3.6	Ca	3.78	3.30	3.76	2.47	0.21
4.0	Ca	0.50	0.58	0.48	0.29	-
4.5	Ti	0.08	0.04	0.05	-	-
5.8	Mn	-	0.08	-	-	-
6.4	Fe	0.17	0.11	0.17	tr	-

FIGURE B-2.

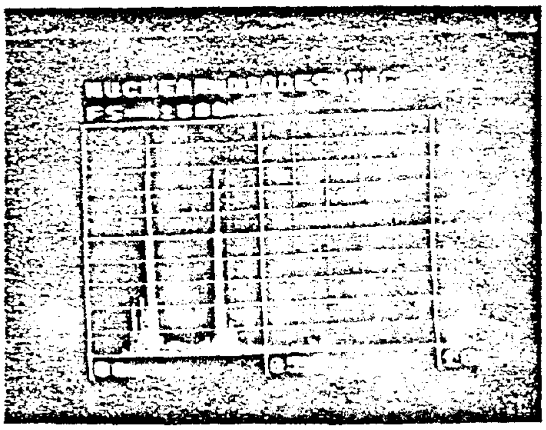
AURORA - BULK SAMPLE X - MICROPROBE ANALYSIS DISPLAYS



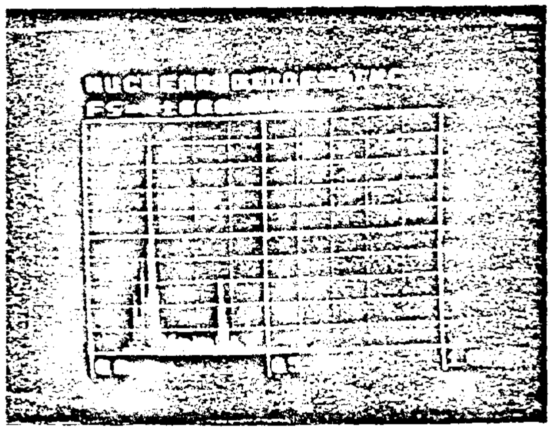
X - small



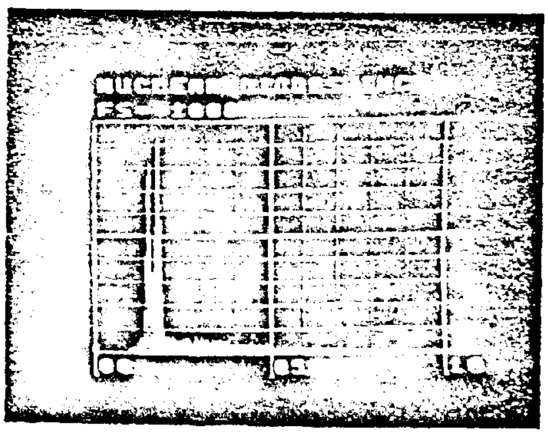
X - medium



X - large



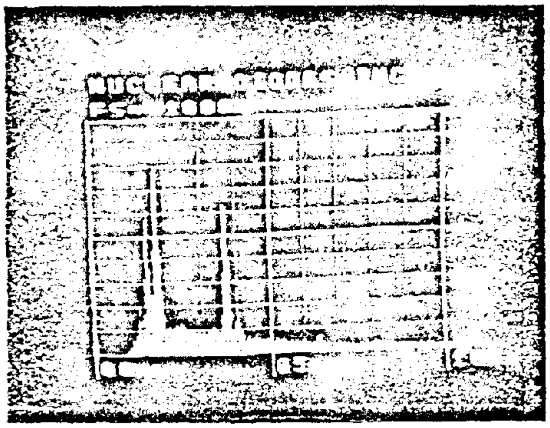
X - shot



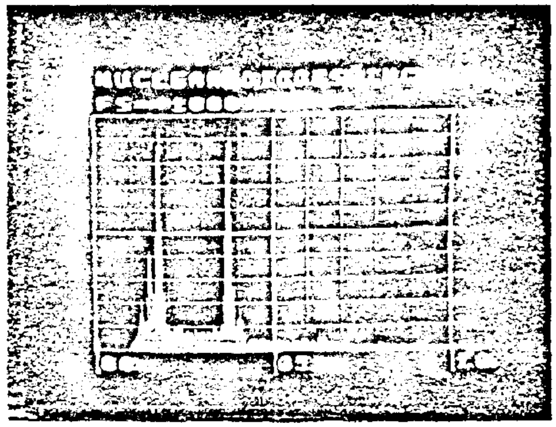
X - VP

FIGURE B-3

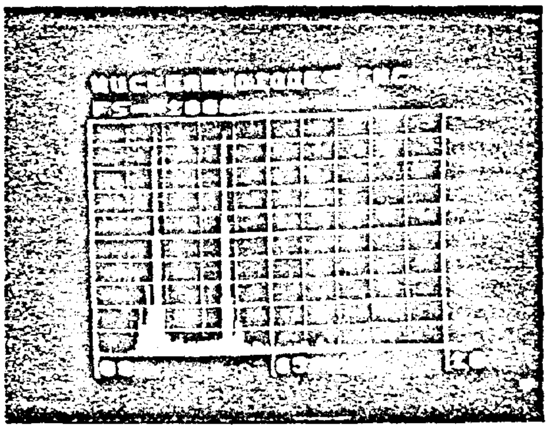
AURORA - BULK SAMPLE Y - MICROPROBE ANALYSIS DISPLAYS



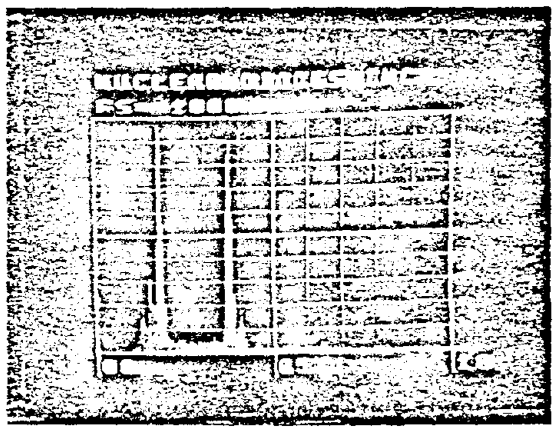
Y - small



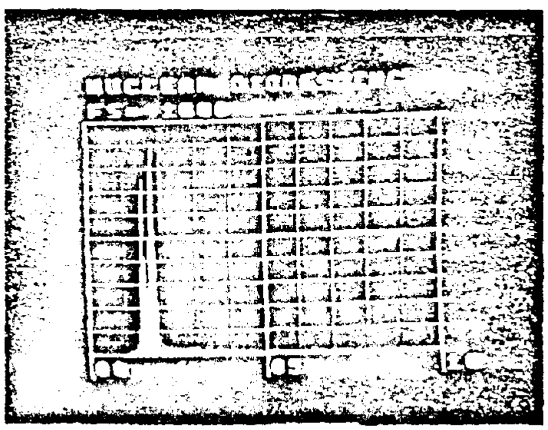
Y - medium



Y - large



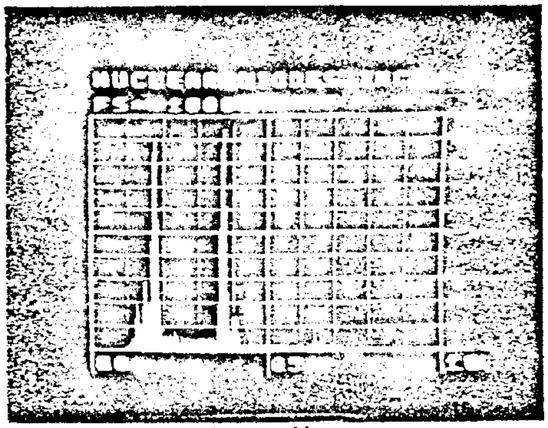
Y - snot



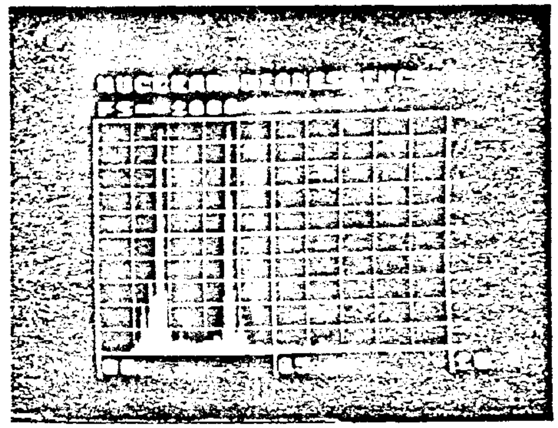
Y - /P

FIGURE B-4

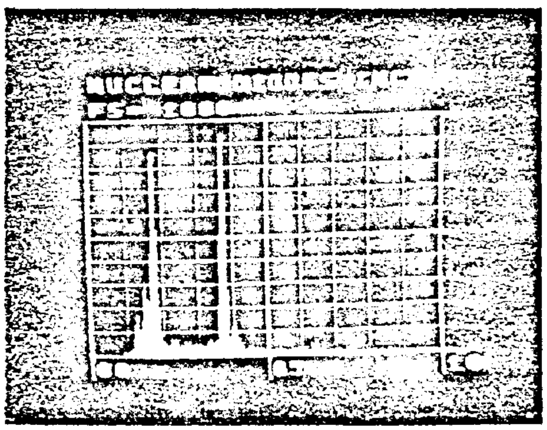
AURORA - BULK SAMPLE Z - MICROPROBE ANALYSIS DISPLAYS



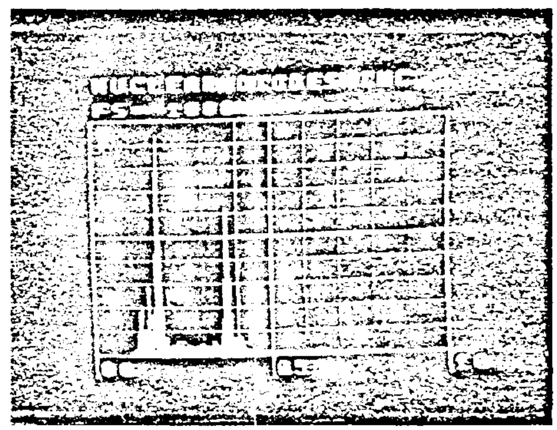
Z - small



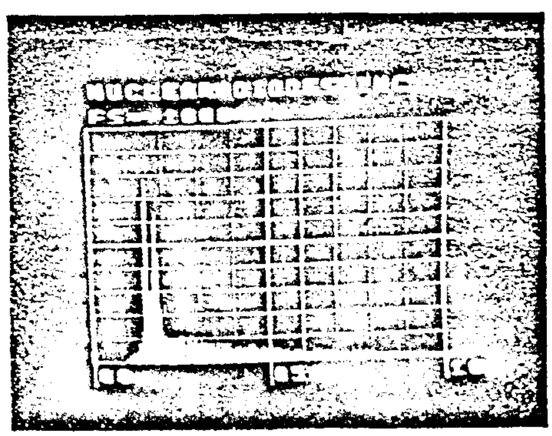
Z - medium



Z - large



Z - shot



Z - VP