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INDUSTRIAL HYGIENE SURVEY REPORT

U.S. GYPSUM CORPORATION

BIRMINGHAM, ALABAMA

April 1978

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INDUSTRIAL HYGIENE SURVEY OF
BIRMINGHAM, ALABAMA PLANT OF
U.S. GYPSUM

Introduction

As part of SRI performance of NIOSH Contract #210-76-0120, an industrial hygiene survey was performed at the Birmingham, Alabama plant of U.S. Gypsum Corp. The survey was performed over the period of October 25-29, 1976, by Douglas P. Fowler, Eugene G. Wood, Robert A. Curtis and Usha Wright. Air samples were taken to evaluate worker exposure to mineral wool fibers, total airborne particulate material and respirable particulate material.

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

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. The plant was owned by American Rockwool at that time and continued under that ownership until 1959, when sale of the plant to U.S. Gypsum (USG) occurred. There is presently no employee organization at the plant. One supervisory and one hourly employee, of the current staff, were employed by American Rockwool prior to 1959.

There are approximately 92 employees at this plant. (See Job Description and Personnel for breakdown of payroll titles). 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 U.S.G.'s Greenville, Mississippi 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. Traveler's Insurance is the worker's compensation carrier. The medical program is administered locally, by the works manager, with direction from corporate headquarters.

The industrial hygiene and environmental control programs are also technically and administratively directed from corporate headquarters. Mr. James D. Cornell is U.S. Gypsum's Safety Director, and is responsible for technical performance of such programs. Mr. Michael R. Helton, an attorney in the corporate legal department, coordinates activities with governmental agencies and contractors.

There is no full-time local safety or industrial hygiene program manager at this plant. The Works Manager, Mr. Asbell, and the Personnel Superintendent, Mr. Lapko, are both active in the promotion of safe practices. Principal operational responsibility rests upon Mr. Lapko. 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 1, which is the process flow diagram for the Birmingham plant.

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 rail shuttle) operated by the "charger" and offloaded into a skip hoist which delivers it to the cupola. The raw materials are later changed 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 1 m, 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 apprently not changed significantly in its mode of operations since 1959, when U.S.G. took possession. The process 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; 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

These aspects of the survey are discussed in Appendix B to this report.

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, by U.S.G. 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 two pages, as received from Mr. Lapko, 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.

The Birmingham 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	

MANAGEMENT AND SUPERVISION

S. L. Asbell	Works Manager
A. Miller	Production Superintendent (effect. 11-15-76)
M. Lee	Production Foreman
V. Jackson	Production Foreman
J. Jackson	Warehouse Foreman
S. E. Dow	Quality Superintendent
B. G. Roberts	Engineering Superintendent
E. E. Mizzell	Maintenance Foreman
W. D. Dedman	Maintenance & Procurement Supervisor
D. L. Crawford	Project Engineer
R. L. Holloway	Office Superintendent
N. L. Lapko	Personnel Superintendent
D. Rice	Production Foreman

CLERICAL

V. Rasco	Accountant
M. Corsentino	Stenographer
B. Margie	Accounting Clerk

PLANT TOTAL

Management and Supervision	- 13
Production	- 56
Engineering	- 17
Quality	- 3
Clerical	- 3
	92

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; they did not appear to smoke either markedly more or less than other industrial workers.

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.

Survey Procedure

Air samples were taken using portable battery-powered personal air sampling pumps (Bendix BDX-44) to evaluate worker exposures to airborne mineral fibers, total airborne particulate matter, respirable particulate matter, and trace metals (Cd, Cr, Co, Ni, Mn, Pb, Zn). Bulk samples of the raw materials, intermediate products, and final product, were also collected for the determination of fiber size, and trace element concentrations. Filters used were Millipore type AA for fiber counting, and Gelman VM-1 for total and respirable particulate matter sampling. Two pumps were used on each worker; one for fiber counting and one for total particulate matter, in most cases. For approximately 10% of the workers; total and respirable particulate matter samples were taken.

Pumps were calibrated before use by "bubblemeter" (timing passage of a soap bubble through a 500 ml burette). The rotameters on each pump were used to monitor air flow rates during the sampling periods. In some cases, the flow rates indicated fell below the nominal initial flow rate by the end of the sampling period. In these cases, a linear decrease in flow rate from the initial to the final flow rate was assumed for computation of the total sampling volume.

Nominal initial flow rates were 2.0 liters/minute for the fiber-counting and total airborne particulate material samples; 1.7 liters/minute for the respirable particulate material samples.

Analytical Procedures

Atomic Absorption

Samples on 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 brough to 7.0 ml. Blanks consisted of an unused filter treated in the same manner as above. For analysis of bulk samples, 0.1 gm of the sample was ball milled until a homogeneous powder formed, and was digested as described above.

The solutions of solubilized mineral wool and the blank samples were analyzed for zinc, lead, manganese, chromium, cobalt, nickel, and cadmium by stomic absorption spectrometry. See Table I 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 was 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.

<u>Preparation of Samples for SEM</u>

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 ($\pm$ 0.01 mg). This solution was filtered through an 0.8 μ Nuclepore filter using aspiration and mixed 3 x with filtered water. (The Nuclepore filter must not run dry between rinses. The rinses should be added so that the walls of the filter holder are rinsed also.) A section of the Nuclepore filter was then cut out and mounted on an aluminum stage with silver paint.

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

SEM Counting and Sizing

A drop of dilute suspension of 1.011 μm (± 0.005 mm) polystyrene latex balls (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 aluminum and examined at 2,000X and 10,000X in the SEM (Cambridge Mark II). The polystyrene latex spheres were 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 monitor and 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 the mean of several vertical and horizontal measurements of the spheres was taken. For all filters examined, this mean was 5 mm at 2,000X, giving an effective magnification of 5,000X. A typical vertical measurement was 6 mm; a typical horizontal measurement was 4 mm.

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:

$$26.8 \text{ cm} \times \frac{1 \text{ mm}}{0.6 \text{ cm}} \times 20.7 \text{ cm} \times \frac{1 \text{ mm}}{0.4 \text{ cm}} = 2311.5 \text{ mm}^2$$

Using the total screen area presented one 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 observation of those fibers seen in moving from one scanning field to another, during the examination.

Counting and Sizing by Optical Microscopy

The general procedures used for mounting the personal filters and for counting and sizing the filters are described in detail in the NIOSH manual, Sampling and Evaluation 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 10 x eyepiece, and Kohler illumination was used. A standard Porton reticle was placed at the focal point of the eyepiece. Adjustments for Kohler illumination, alignment of phase contrast rings, and the quantitative calibration of the system were

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

checked periodically. All particles having an aspect ratio of 3:1 were counted. The diameter and length were sized independently and recorded on a tally sheet.

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 are able to avoid constant refocusing and reaccomodation of their eyes during the counting process, with reduction of "eye-strain" problems.

Bulk Sample Analyses

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 ($\sim$0.1 g) representative sample of the bulk material was placed in a test tube with $\sim$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 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 ($\sim$1 um diameter)
- medium fibers ($\sim$4-5 um diameter)
- large fibers ($\sim\geq$ 10 um 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	2.0	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) $\times 10^3$ = total sample air volume (ml)

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 # of fibers counted

fields = total # 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 (Mg) =

$$\text{antilog}_{10} \frac{\sum_{i=1}^{k} ni \cdot \log_{10} Di}{\sum_{i=1}^{k} ni}$$

Geometric Standard Deviation (σg) =

$$\text{antilog}_{10} \left[\frac{\sum_{i=1}^{k} ni \cdot (\log_{10} Di - \log_{10} Mg)^2}{\sum_{i=1}^{k} ni - 1} \right]^{\frac{1}{2}}$$

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.

Time-Weighted Averages (TWA)

"Time weighted averages" were calculated as "flow-weighted averages", because the variability in flow rates of the Bendix pumps were 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:

$$TWA = \frac{\sum_{i=1}^{n} Xifi}{\sum fi}$$

where Xi = the concentration (μg/m^3; f/cc) found for the ith sample

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

Survey Results

There are four major elements to the sampling and analytical results for this survey:

Air Sampling:
- Fiber counting and sizing results
- Total suspended particulate material results (total and elemental concentrations)
- Respirable particulate material results

- Bulk material results

In Table 3 are shown the total air sampling and analysis results for the first three elements, with the exception of the fiber counting and sizing results by SEM.

Air Samples:

Fiber Counting and Sizing: Optical Microscopy

The single sample airborne fiber concentrations determined by optical microscopy ranged from "zero" (below the detection limit of approximately 0.005 fibers/cc)to a maximum of 2.306 fibers/cc for the front-end leader. The time-weighted average (TWA) concentrations for job categories were in a range from 0.05 f/cc (a single sample from the unloader) to 0.629 f/cc which was the average of four samples for personnel working in the front-end leader category. The geometric mean job category concentrations measured ranged from 0.05 f/cc to 0.448 f/cc (for the cupola operators). (See Table 4.)

The overall distribution of fiber concentrations to which all workers were exposed during the survey period is given in Table 6, and Figure 2. The geometric mean concentration was 0.12 f/cc, with a geometric standard deviation of 2.7. As shown in Figure 2, less than 2% of the samples were taken at concentrations above 1 f/cc.

Figure 9 is a display of the size distribution of all airborne fibers collected during the survey. The geometric mean (GM) length was 14.5 µm, with a geometric standard deviation (GSD) of 3.3; the GM diameter was 1.5 µm, with a GSD of 2.1. 87% of the fibers were less than 3.5 µm diameter, and approximately 62% were longer than 10 µm.

Scanning Electron Microscopy (SEM)

The fiber counting and sizing results by SEM are shown in Table 9, and Figures 6, 7 and 8. Although the SEM results are higher for some of the samples with low fiber concentrations by optical microscopy (OM), the SEM results are substantially lower than OM at the higher concentrations. Because of the strong correlation between the OM and SEM results ($r^2 = 0.89$) a consistent artifact of SEM sample preparation is suggested.

Total Suspended (Airborne) Particulate Measurements

The total suspended partuculate material results are given in Table 5 for job categories. The minimum samples had less than detectable amounts of airborne dust (less than 0.01 mg/filter; less than approximately 0.015-0.02 mg/m^3). The highest concentration observed was 5.851 mg/m^3, for the batt-line take-off job category. The TWA's for the several job categories ranged from 0.110 mg/m^3 for a single sample from the mobile equipment operator, and 0.139 mg/m^3 for the baggers, to 1.906 mg/m^3 for the cupola operators and 2.058 for the front-end leaders.

Table 7 and Figure 3 are displays of the overall total suspended particulate material results for all samples. The geometric mean concentration was 0.65 mg/m^3, with GSD of 3.1. Only two of the samples were above 3.2 mg/m^3.

Respirable Airborne Particulate Material

No special display of the respirable sampling results was prepared. From Table 3, it can be seen that the minimum result was 0.056 mg/m^3 for a maintenance worker, and the maximum was 1.183 mg/m^3 for a cupola operator.

Trace Elements

The concentrations of airborne trace elements in the plant atmosphere were uniformly low. As shown in Table 8, maximum concentrations nowhere approach current or recommended workplace standards.

Comparisons of Results

Several comparisons were made to attempt to elicit relationships between the several variables measured. Figure 4 shows the linear correlation of fiber concentrations and total particulate concentration. Although a correlation does exist, it is not strong, and the observed scatter of results makes any attempt to predict one of these values from the other uncertain at best.

Similarly, the relationship between total and respirable particulate material in Figure 5 is uncertain. Although the correlation is stronger, the small number of pairs, and the observed scatter prevents prediction with any reasonable degree of certainty.

Bulk Sample Results

Appendix A contains the results of the bulk sample analyses performed. Tables A-1 and A-2 are compilations of the SEM microprobe results for the individual fibers and shot particles analyzed, taken from Figures A-1 to

A-9, where the spectra are displayed. Table A-3 contains the results of the elemental analyses performed on the bulk samples by X-Ray Fluorescence (XRF) and atomic absorption (AA), given as micrograms of element per gram of sample. Table A-4 shows the fiber-sizing work done by optical microscopy. The bulk samples geometric mean diameters range from 2.8 μm for the the static-charged "flywool" found clinging to vertical surfaces, to 4.8 μm for a sample of wool taken immediately after the blow-chamber.

Because of the apparent differences in the sizes of the fibers examined, the elemental composition of the samples was examined. Large apparent differences in the iron (Fe) - manganese (Mn) ratios were seen, so the distribution of these ratios for the samples were examined in Table A-5, to determine whether there was reason to suspect that the samples were different in elemental composition.

Discussion of Results

In no case were levels of any of the air contaminants measured in this survey above recommended limits of the American Conference of Governmental Industrial Hygiene (ACGIH) or the National Institute for Occupational Safety and Health (NIOSH). The major standards that should govern exposure in this plant are the nuisance dust limits of 10 mg/m^3 (total) and 5 mg/m^3 (respirable) and the NIOSH-proposed limit on fibrous gloss exposure of 3 fibers/cc (fibers longer than 10 μm and less than 3.5 μm diameter).

Examining Figure 9, it can be seen that approximately 54% (87% times 62%) of the airborne fibers fit the above size criteria, and thus the already low fiber concentration in this plant may be considered to be substantially lower, for comparison with the standard. As an example, the highest single concentration (2.306 f/cc for sample C-360) was obtained from 102 fibers counted. Fifty seven of those 102 (56%) fibers were both longer than 10 μm and thinner than 3.5 μm. The SEM results are equivocal, but indicate that a small fraction of the airborne fibers may be below the limit of resolution of the optical microscope.

The workers with the highest exposures to total airborne particulate material appear to be the chargers, the cupola operators, the front-end leaders and the battline take-off workers. The highest fiber exposures are those of the cupola operators and leaders and the front-end leaders. Suprisingly, the battline take-off workers exposures (TWA = 0.244 f/cc, GM = 0.208 f/cc) were not as high as others (e.g. the cupola operators') with less apparent intimate contact with mineral wool. No explanation for this discrepancy between expectation and reality is readily apparent.

The highest repirable particulate material level observed was for the cupola operator. This result is not surprising when one considers that these workers are closest to the cupolas, where smoke generation is expected. Taken together with the total particulate and fiber counting results, it appears that the cupola operators are at greatest risk of exposure to all forms of airborne particulate material, of all job categories in this plant.

The bulk sample analyses did not reveal any unusual or unexpected results. No gross differences in the elemental composition of the shot and fibers were seen in the micro probe analysis of individual particles although there is a suggestion of a slightly lower calcium content in the "small" ($\sim$ 1.0 μm diameter) fibers.

The average of the geometric means of the bulk sample fiber diameters is approximately 3.5 μm, while the geometric mean of all airborne fibers is 1.5 μm. The GSD is similar for both, around 2.1. Although it is tempting to ascribe the larger geometric mean diameter of sample BB-6 to the fact that it was taken immediately after formation, and before airlifting, it should be noted that sample BB-7 was taken at the same location on the next day. Interday differences in cupola conditions may explain this difference. The important point to note is that the airborne fibers are substantially smaller (and hence more likely respirable) than are the fibers in the bulk samples.

There were several observations made during the course of the survey that were not evaluated by environmental measurements. The potential for exposures to apparently high noise levels in the cupola area as mentioned in Appendix B was one such observation. Another was the occasionally observable dense smoke in the main plant area, during brief periods. The source of such smoke appeared to be combustion of oil mist or phenol-formaldehyde resin in the curing oven area, as well as the cupolas. H_2S was detectable by odor in several areas on the plant.

Exposures to all airborne contaminants in past years were probably higher than those observed during this survey. It is, of course, impossible to state what the quantitative levels might have been, without recourse to historical air-sampling data which apparently do not exist. According to the memory of the more senior workers, conditions in this plant were significantly more "dusty" in the past, with heavy smoke particularly mentioned.

Two conditions were judged to be likely to have contributed to the past exposures. The first of these was the general lower level of control of product flow in past years; the raw materials were cheap, and loss of product was not stringently controlled. The second was the lower level of environmental control. In spite of the present deficiencies in the operating equipment, (principally due to age) a continuing effort is being made to upgrade and maintain ventilation equipment, in the face of rapid wear due to the abrasive nature of the product and wastes. This was generally not true in the past (approximately 20 years ago).

The current management of this plant appears to have identified and to have begun addressing the major areas of importance in occupational health-related issues at this plant.

Conclusions

- Exposures (single sample and time-weighted average) to all airborne contaminants evaluated were below all currently recommended standards.
- Cupola operators were the workers exposed to the highest combined overall levels of airborne fibers and total airborne particulate material.

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

BIRMINGHAM - AIR SAMPLING RESULTS

NSF = not sufficient fibers

Area	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	Zn	Pb	Mn	Cr	Co	Ni	Cd	Respirable Particulate Material: Sample Number	Flow m^3	Total mg/m^3
											Elemental Concentration $\mu g/m^3$									
Silo Pit	Unloader	C332	0.260	0.050		NSF		AA215	0.511	0.575	2.8	-	-	-	1.2	-	-	W35	0.483	0.130
								AA217	0.260	0.369	1.9	-	-	-	-	-	-			
Cupola	Cupola Charger	C390	0.235	0.207	113	11.7 (2.5)	1.3 (1.6)													
		C558	0.189	-o-																
		C339	0.127	0.279				AA196	0.579	1.155	8.0	-	1.1	-	<1.1	<0.64	-	W38	0.583	0.400
		C311	0.248	0.016				AA226	0.648	1.952	0.9	-	2.0	-	-	-	-			
		C317	0.270	0.267																
Cupola & Boiler Floor	Cupola Leader	C562	0.344	0.246	116	15.6 (3.2)	1.3 (1.9)	AA152	0.301	neg	0.41	-	-	≤2	-	<5.3	-			
		C555	0.236	0.286				AA177	0.472	0.551	0.14	-	0.5	-	-	<3.5	-			
		C557	0.262	0.245				AA232	0.546	1.732	0.82	-	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
		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	<0.76				
		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	-	-	-	-			

BIRMINGHAM - Air Sampling Results (page 2)

Area	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
	Cupola	C355	0.250	0.374	94	11.1	1.5													
	Operator	C369	0.302	0.237		(2.7)	(1.7)													
	(cont'd)	C366	0.265	0.764		13.8	1.2	AA213	0.538	1.985	2.6	<2.4	-	<3.9	<1.3	-	<0.74			
		C374	0.264	1.250	205	(2.8)	(1.7)													
								AA232	0.546	1.732	0.82	-	1.4	1.0	-	<2.6	-	W34	0.546	0.462
Boiler Floor	Boiler	C379	0.442	0.064				AA180	0.520	1.036	2.4	3.4	0.7	<1.2	<1.2	<3.2	<0.7			
	Operator	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	C371	0.275	0.203	154	8.9	1.4	AA211	0.526	1.482	2.9	<3.6	4.6	<1.3	<1.3	<3.4	<0.8			
	Operator	C376	0.240	0.126		(2.5)	(1.7)													
	Lead Boiler	C565	0.222	0.190				AA192	0.450	0.415	0.61	-	0.61	<1.2	<1.2	<3.9	-			
	Operator	C573	0.240	0.222																
	Boilerman	C575	0.213	0.110				AA175	.427	.517	0.91	-	<0.6	<1.5	-	<3.9	<0.9			
		C552	0.244	0.079																
Produc-tion (All areas)	Front End	C360	0.248	2.306				AA212	0.484	5.252	0.29	-	8.3	-	-	-	-			
	Leader	C365	-	-																
		C389	0.372	0.066	171	26.1	1.9	AA159	0.372	neg.	0.56	-	-	<1.8	-	<6.2	-			
		C372	0.314	0.372		(3.2)	(1.9)	AA205	0.590	0.735	5.4	-	2.2	<1.2	<1.2	<3.1	<0.7			
		C392	0.260	0.147																
	Factory	C316	0.210	0.151				AA214	.564	0.257	<0.11	-	-	-	3.4	<2.8	-			
	Labor	C307	0.240	0.128																
	(Relief &	C357	0.328	0.084				AA210	0.388	.778	5.4	-	-	-	<1.8	-	<1.0			
	Cleanup)	C391	0.260	0.072																
		C315	0.338	0.161	205	22.4	1.9													
		C310	0.257	0.464		(3.3)	(1.9)													
		C313	0.372	0.034				A291	0.564	.641	2.3	-	0.8	<1.1	-	<2.8	<0.6			
		C302	0.265	0.198																
		C323	0.328	0.132				AA283	0.532	.124	0.8	-	<0.5	<1.2	-	<3.0	<0.7			
		C305	0.244	0.182																

[illegible] Results (5)

Area	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
Product-ion (cont'd)	Machine Tender	C574	0.400	0.236				AA163	0.372	0.637	4.3	<5.1	<0.8	<1.9	-	<4.8	-			
					70	17.8 (3.0)	1.7 (1.8)	AA202	0.521	0.414	-	-	-	-	-	-	-	W24	0.537	0.140
		C358	0.302	0.063				AA204	0.548	0.222	3.2	-	-	<3.7	<1.2	-	-			
		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 (3.1)	1.8 (1.9)	AA235	0.353	0.407	0.38	-	-	-	-	-	-			
								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			
		C375	0.250	0.443																
Bagging Granu-lated 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																
		C354[a]	0.254	0.152	122	16.0 (3.1)	1.8 (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	0.34	-	-	1.1	-	2.9	0.6			
		C349	0.197	0.019																
		C342	0.125	0.061				AA221	0.544	0.352	0.22	-	-	1.1	-	2.9	-			
		C306	0.207	0.044																
		C322	0.246	0.030																
Granu-lated Bale line	Baler Operator	C391	0.138	0.068				AA284	0.536	1.026	4.6	-	1.1	<1.2	-	<3.2	<0.71	W23	0.451	0.242
		C350	0.228	0.122	37	19.5 (3.3	1.9 (2.0)	AA207	0.652	0.510	-	<2.9	<0.5	<1.1	-	<2.8	<0.6	W25	0.538	0.143
		C321	0.228	0.146				AA200	0.524	neg.	<1.2	-	-	-	-	-	-	W37	0.453	0.113

BIRMINGHAM - Air Sampling Results (4)

		Fiber Counting						Total Airborne Particulate Material										Respirable Particulate Material		
						Count Median					Elemental Concentration μg/m³									
Area	Payroll Title	Sample Number	Flow m³	f/cc	N	Lgth (SD)	Diam (SD)	Sample Number	Flow m³	Total mg/m³	Zn	Pb	Mn	Cr	Co	Ni	Cd	Sample Number	Flow m³	Total mg/m³
Ware-	Loading	C325	0.520	0.097				AA236	0.481	0.698	1.0	<2.5	-	<4.0	<1.3	-	-			
house	Leader																			
	W'house	C340	0.176	0.331	89	19.6	2.3	AA223	0.185	2.4	5.8	-	2.8	<7.4	-	-	-			
	Worker					(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,	Factory	C352	0.320	0.278				AA198	0.500	0.26	1.0	-	<0.7	<1.3	1.3	<0.5	<0.1			
Wool &	Labor (load-	C394	0.224	0.129																
Bale	ing Wool &	C353	0.278	0.175		17.8	2.1	AA194	0.524	0.255	3.3	<2.4	-	-	<1.3	-	-			
Lines	Batt Lines)	C385	0.252	0.185	135	(2.8)	(2.0)													
								AA216	0.676	0.297	1.5	<1.8	-	<2.9	<0.98	-	-	W29	0.605	0.114
		C348	0.158	0.087				AA219	0.616	0.311	1.7	<2.1	-	<3.3	<1.1	-	<0.63			
		C344	0.180	0.113																
		C338	0.294	0.040																
Batt	Factory	C308	0.341	0.094				AA300	0.674	1.118	10.4	<2.8	1.4	<1.0	-	<2.7	<0.6			
Line	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	-	0.59	-	-	-	-			
	Batt Line)	C303	0.324	0.041																
Yard	Mobile	C328	0.078	0.103		NSF		AA229	0.290	0.110	0.5	-	<1.4	-	-	-	-			
(Outside)	Equip't																			
	Operator																			

BIRMINGHAM - Air Sampling Results (5)

Area	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
Quality	Tester B	C326	0.388	0.098				AA224	0.378	0.365	12	-	-	<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	0.76	-	-	-	<1.5	<3.9	-			
		C568	0.450	0.050																
Main-	Mech. A	C383	0.222	0.044				AA184	0.457	1.126	11	<2.6	28	<4.3	<1.4	-	-			
tenance	(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	-	<0.92			
		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	-	-	-	-			
Main-	Mech. A	C384	0.246	0.015				AA178	0.474	0.810	7.6	-	<1.4	<4.1	<1.4	-	-			
tenance	(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	-	0.82	-	≤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			
Main-	Mechanic	C381	0.236	0.157				AA187	0.488	0.303	11	-	-	<2.9	<1.4	-	<0.82			
tenance	Leader	C553	0.252	0.191																
	Mainten-	C314	0.497	0.169		16.3	1.7	AA289	0.509	1.864	26	-	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																			

BIRMINGHAM - Air Sampling Results (6)

Area	Payroll Title	Fiber Counting				Count Median		Total Airborne Particulate Material			Elemental Concentration μg/m^3							Respirable Particulate Material		
		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
Pit under	Area	C320	0.340	0.057				AA295	0.605	0.233	1.9	-	<0.65	-	-	-	-			
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 4

Fiber Counting Results - Birmingham

Job Category	# Samples	Fiber Counting (f/cc) Min	Max	TWA	Geometric Mean	S.D.
Unloader	1	-	-	0.05	0.05	-
Charger	5	0	0.279	0.150	0.125	3.97
Cupola Leader	3	0.246	0.286	0.257	0.258	1.09
Cupola Operator	13	0.023	2.15	0.544	0.448	2.98
Boiler Operator	9	0.045	0.222	0.118	0.108	1.75
Front End Leader	4	0.066	2.306	0.629	0.302	4.61
Factory Labor (Relief and Cleanup)	10	0.034	0.464	0.153	0.130	2.00
Machine Tender	3	0.063	0.236	0.140	0.106	2.02
Factory Utility A (Batt Line Take-off)	5	0.106	0.443	0.244	0.208	1.90
Factory Labor (Bagging)	13	0.008	0.152	0.063	0.052	2.18
Factory Utility A (Baler Operator)	3	0.068	0.146	0.119	0.107	1.49
Warehouse	4	0.039	0.331	0.133	0.118	2.45
Factory Labor (Loader)	11	0.040	0.278	0.138	0.115	1.86
Mobile Equipment Operator	1	-	-	0.103	0.103	-
Quality Control	5	0.016	0.244	0.100	0.077	2.86
Maintenance	17	0.008	0.355	0.143	0.090	2.83
Area	4	0.057	0.273	0.137	0.121	2.12

Table 5

Total Airborne Particulate Results - Birmingham

Job Category	# Samples	Total Mass (mg/m^3) Min	Max	TWA
Unloader	2	0.369	0.575	0.506
Charger	2	1.155	1.952	1.576
Cupola Leader	3	negl.	1.732	0.914
Cupola Operator	8	0.959	2.278	1.906
Boiler Operator	5	0.415	1.482	0.809
Front End Leader	3	negl.	5.252	2.058
Factory Labor (Relief and Cleanup	4	0.124	0.778	0.427
Machine Tender	3	0.372	0.548	0.399
Factory Utility A (Batt Line Take-off)	6	0.407	5.851	1.737
Factory Labor (Bagging)	6	negl.	0.352	0.139
Factory Utility A (Baler Operator)	3	0.409	1.026	0.649
Warehouse	3	0.220	2.400	0.817
Factory Labor (Loader)	6	0.255	1.118	0.498
Mobile Equipment Operator	1	-	-	0.110
Quality Control	3	negl.	0.545	0.316
Maintenance	13	0.303	3.029	1.176
Area	2	0.233	2.649	1.342

Table 6

Frequency Distribution of Fiber Concentrations
(Birmingham)

f/cm^3	#	%	Cum. %
<0.02	6	5	5
0.02-0.04	4	4	9
0.04-0.079	26	24	33
0.08-0.159	30	27	60
0.16-0.319	26	24	84
0.32-0.639	13	12	96
0.64-1.279	3	3	99
≥1.28	2	2	101
TOTAL	110	101	

Table 7

Frequency Distribution of
Total Airborne Particulate Samples

		%	Cum. %
<0.05	4	5.6	5.6
0.051-0.100	0	0	5.6
0.101-0.200	2	2.8	8.5
0.201-0.400	15	21.1	29.6
0.401-0.800	21	29.6	59.2
0.801-1.600	11	15.5	74.6
1.601-3.200	16	22.5	97.2
>3.200	2	2.8	100.0
	71	100.0	

Table 8

Trace Element Concentrations in Air
Birmingham

Element	Concentration ($\mu g/m^3$) Min.	Max.	TLV (ACGIH)
Zn	0.11	26	5000 (ZnO)
Pb	LDQ	3.4	150
Mn	LDQ	28	5000
Cr	LDQ	<7.4	500
Co	LDQ	3.4	100 (a)
Ni	LDQ	3.7	100 (b)
Cd	LDQ	1.0	50

(LDQ = Less than detectable quantity, less than approximately 0.5 $\mu g/m^3$)

(a) Notice of Intended Change to 50 $\mu g/m^3$

(b) NIOSH Recommended Standard is 15 $\mu g/m^3$

Table 9

FIBER COUNTING AND SIZING: OPTICAL (OM) AND SCANNING ELECTRON (SEM) MICROSCOPY - BIRMINGHAM

Sample Number	Job Category	Fiber Count		Fibers/CC		Geometric Mean (Geom. Std. Dev.)	
		OM	SEM	OM	SEM	Diameter	Length
C307	Relief/Cleanup	17	17	0.128	0.112		
C313	Relief/Cleanup	7	17	0.034	0.109	OM	OM
C323	Relief/Cleanup	22	11	0.132	0.109	1.6	16.6
C326	Quality Control Tester	21	23	0.098	0.086	(1.9)	(2.9)
C337	Mechanic	67	28	0.352	0.143		
C339	Cupola Charger	18	10	0.279	0.150		
C354	Wool Line Bagger	18	11	0.152	0.100	SEM	SEM
C356	Cupola Operator	101	35	1.015	0.270	0.8	25.7
C357	Relief/Cleanup	14	24	0.084	0.137	(2.1)	(4.0)
C374	Cupola Operator	101	44	1.250	0.287		
C394	Truck Loader	17	9	0.129	0.093		
C560	Maintenance Leadman	10	6	0.084	0.038		
	TOTAL	413	235				

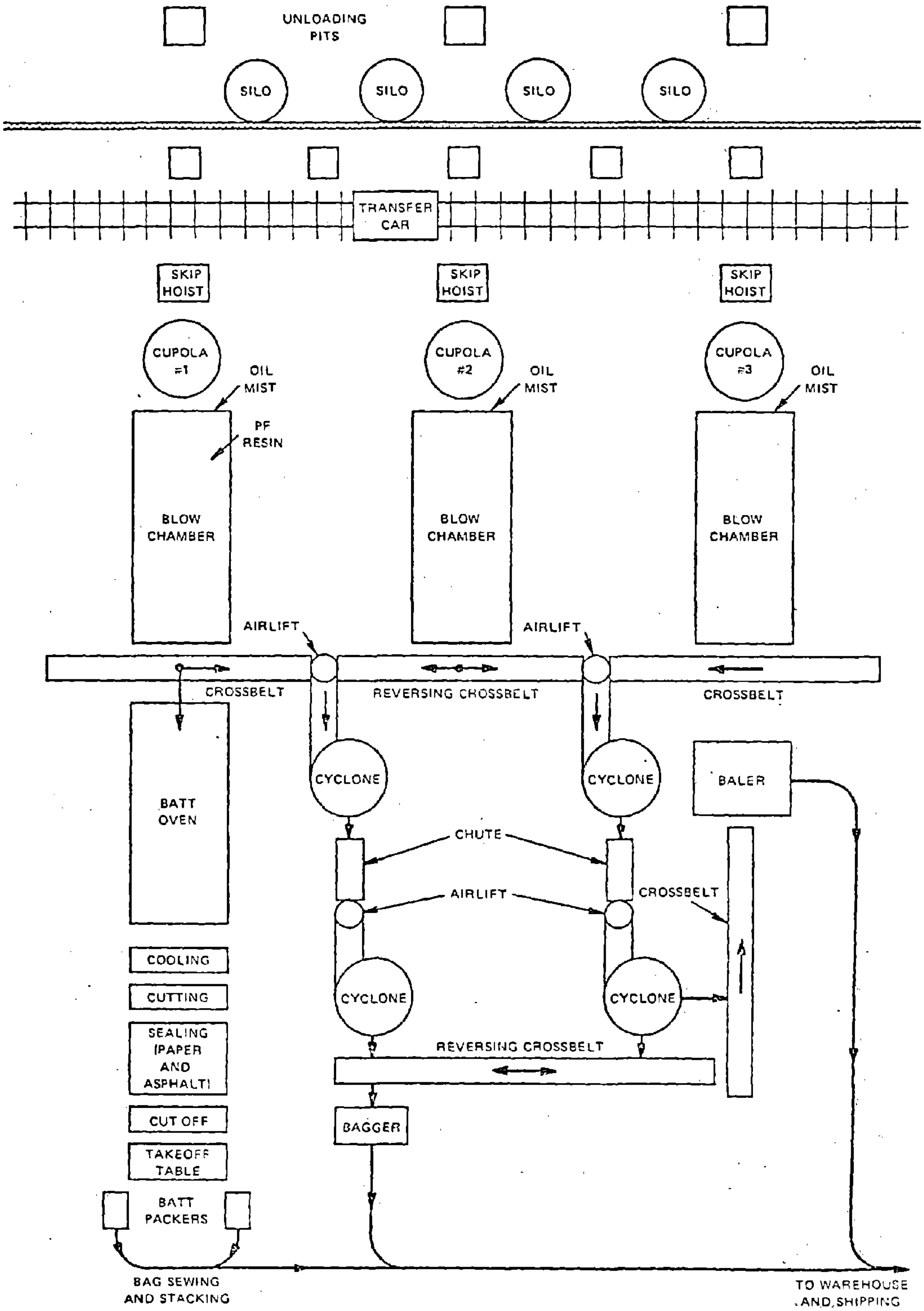


FIGURE 1 U.S. GYPSUM-BIRMINGHAM PLANT PROCESS FLOW DIAGRAM (Not to Scale)

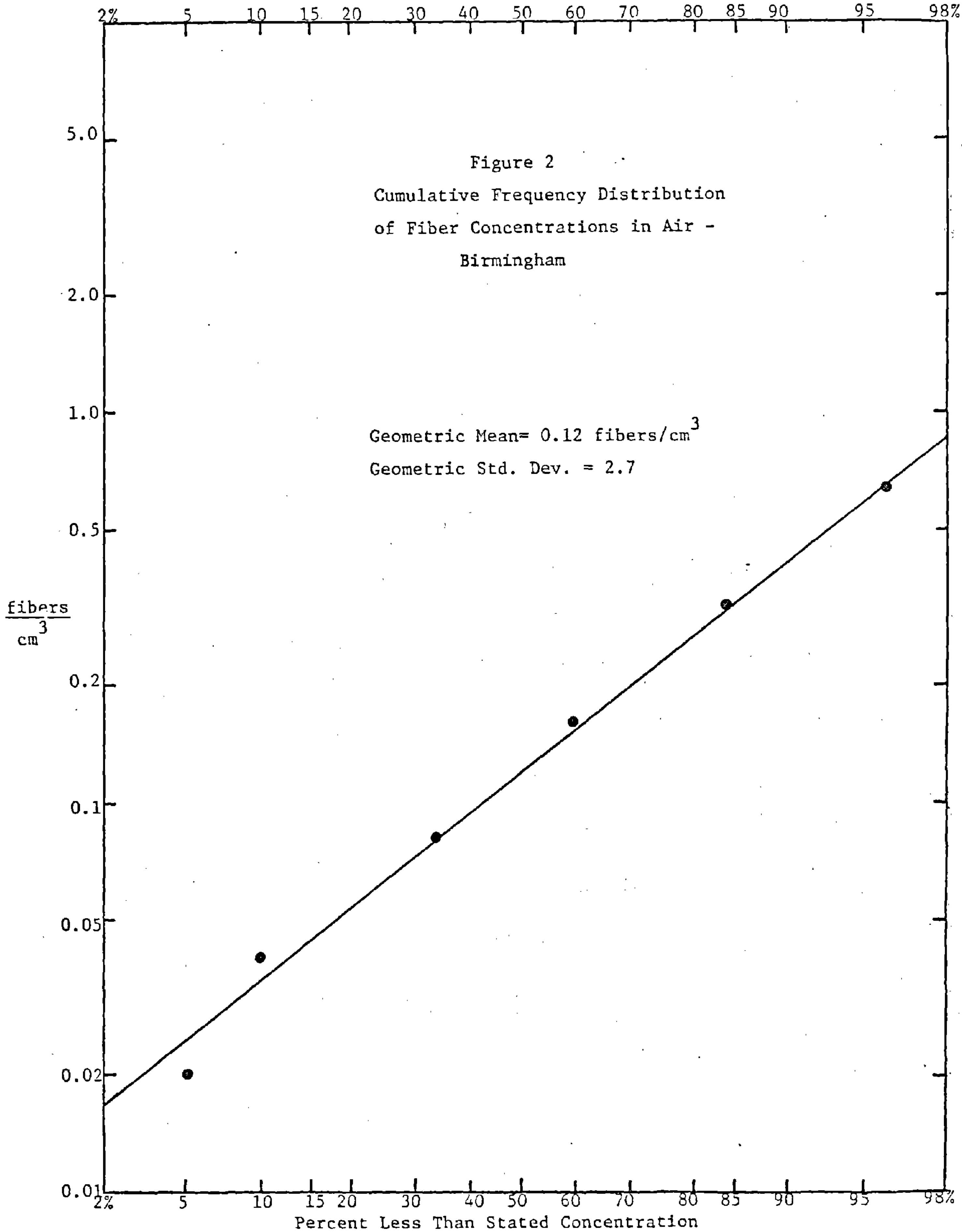
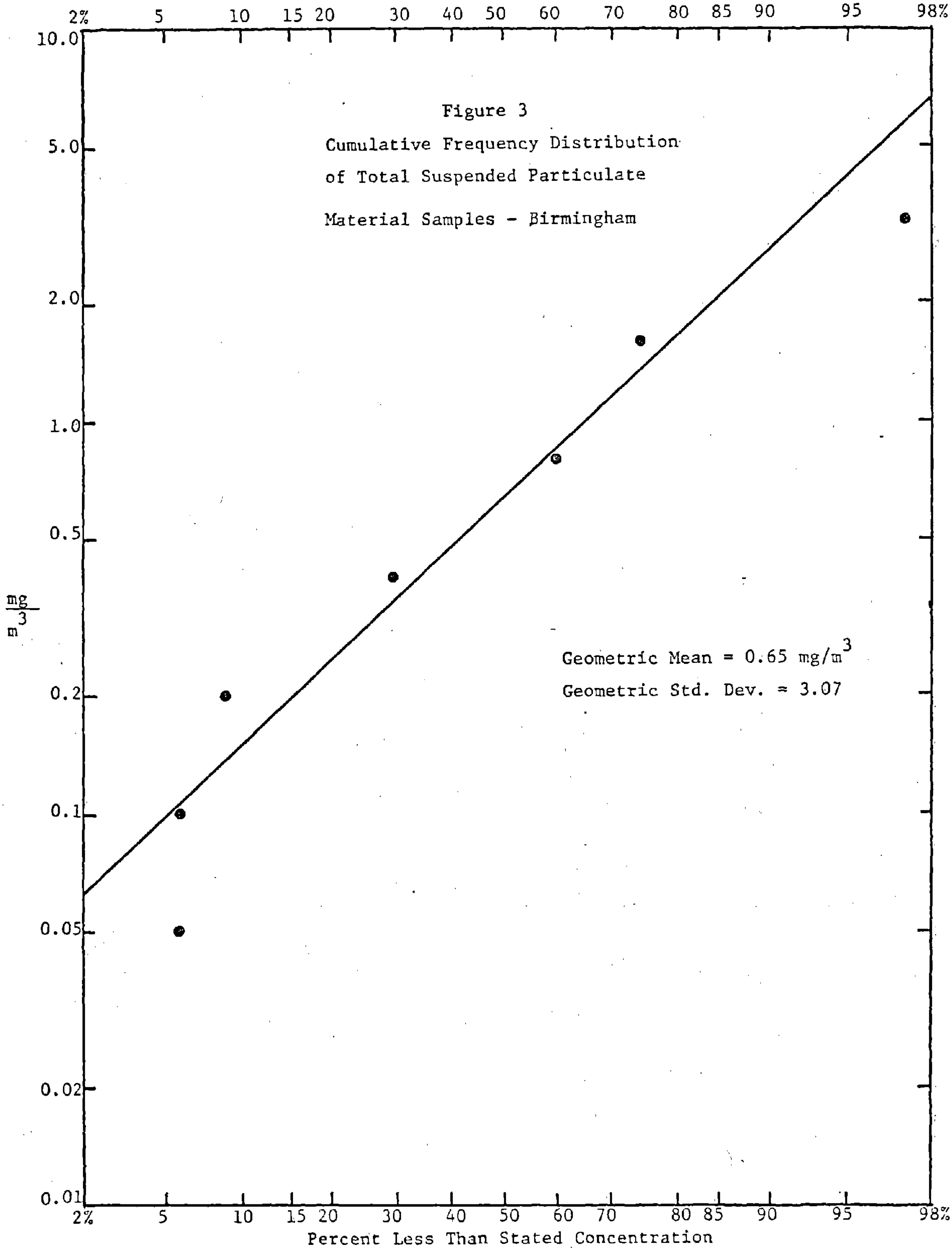


Figure 2
Cumulative Frequency Distribution
of Fiber Concentrations in Air -
Birmingham
Geometric Mean= 0.12 fibers/cm3
Geometric Std. Dev. = 2.7
fibers
cm3
5.0
2.0
1.0
0.5
0.2
0.1
0.05
0.02
0.01
2%
5
10
15
20
30
40
50
60
70
80
85
90
95
98%
Percent Less Than Stated Concentration


2%
5
10
15
20
30
40
50
60
70
80
85
90
95
98%
10.0
5.0
2.0
1.0
0.5
0.2
0.1
0.05
0.02
0.01
mg/m3
Figure 3
Cumulative Frequency Distribution
of Total Suspended Particulate
Material Samples - Birmingham
Geometric Mean = 0.65 mg/m3
Geometric Std. Dev. = 3.07
Percent Less Than Stated Concentration

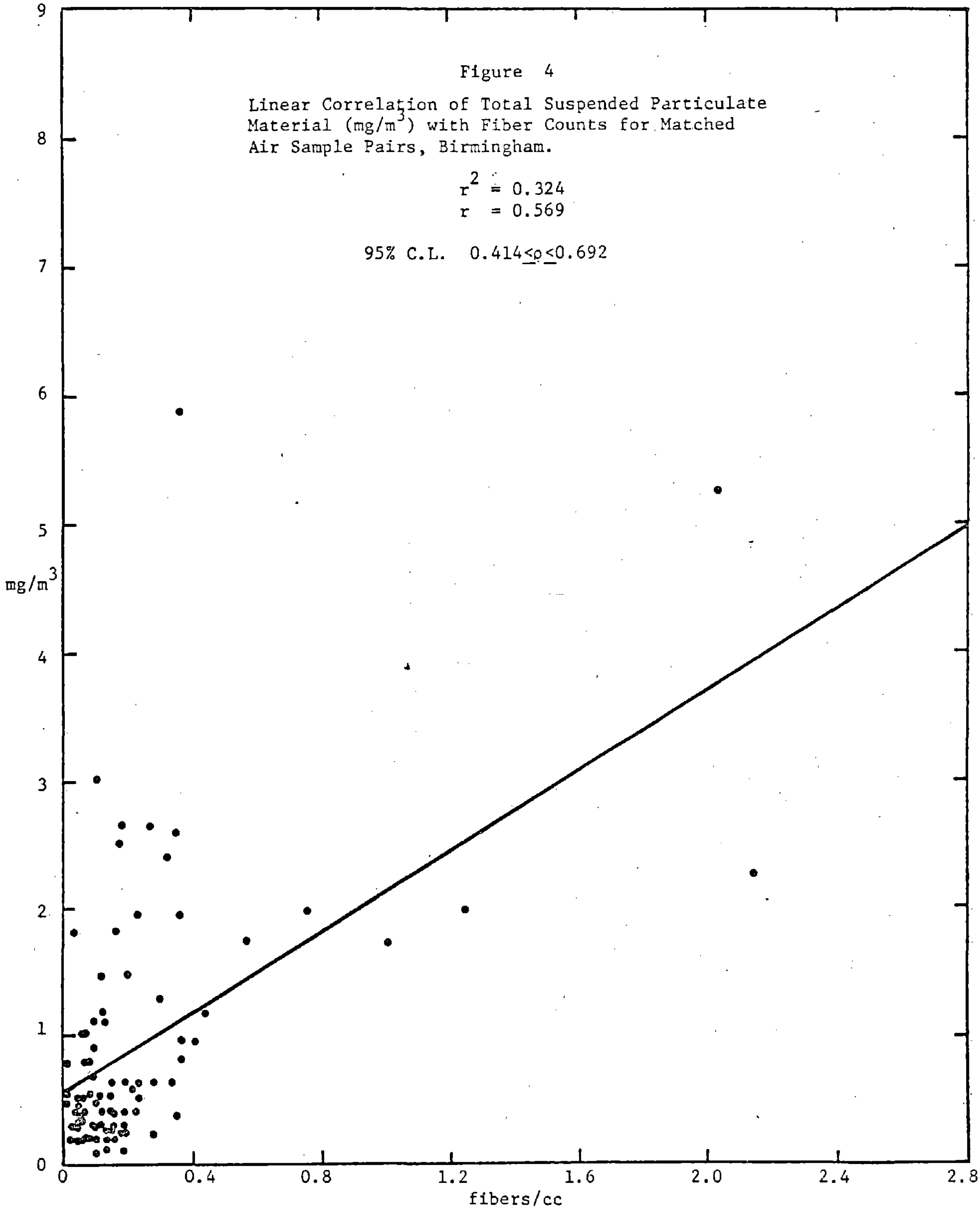


Figure 4
Linear Correlation of Total Suspended Particulate Material (mg/m3) with Fiber Counts for Matched Air Sample Pairs, Birmingham.
r2 = 0.324
r = 0.569
95% C.L. 0.414≤ρ≤0.692
mg/m3
fibers/cc
0
1
2
3
4
5
6
7
8
9
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8

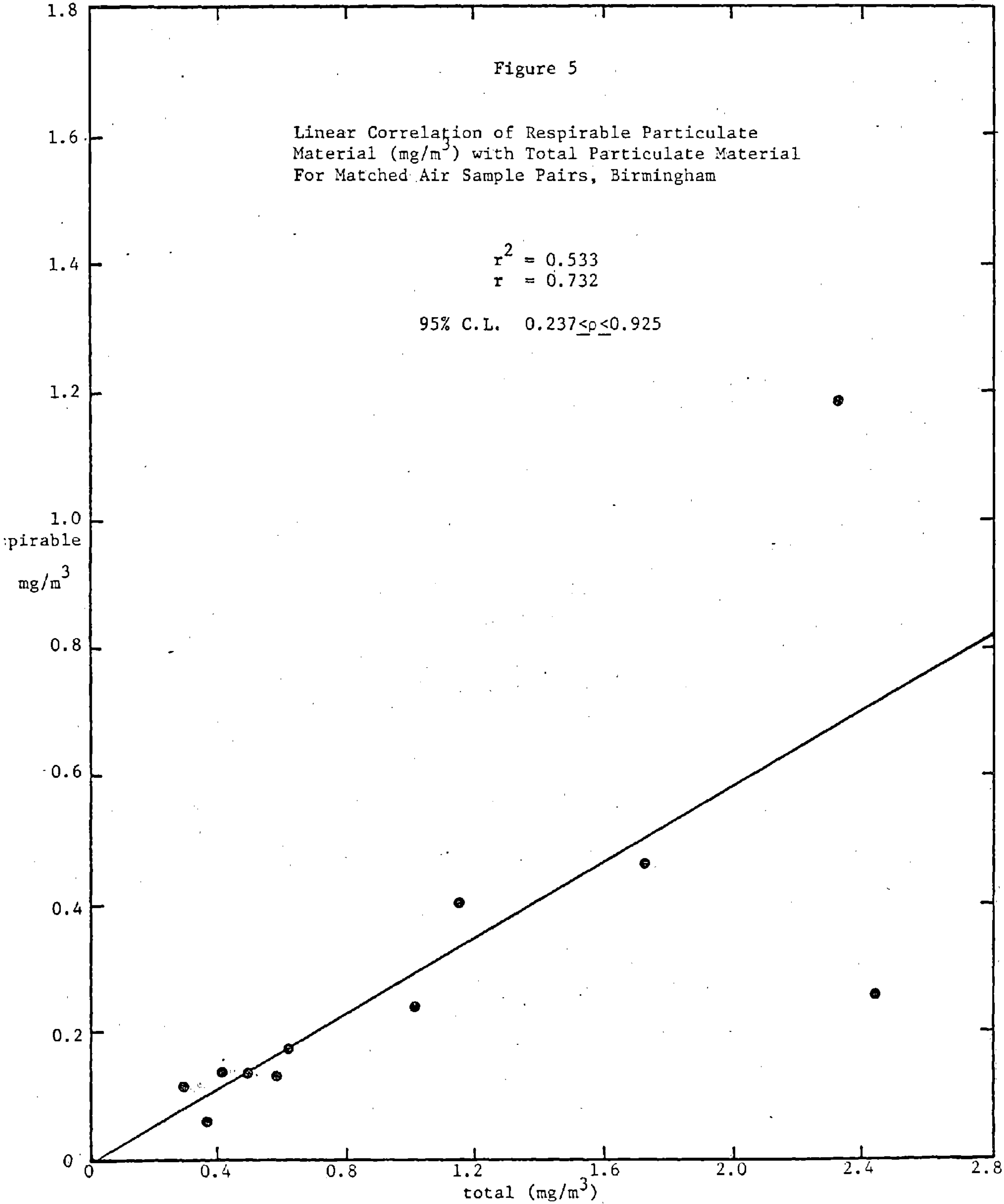


Figure 5
Linear Correlation of Respirable Particulate Material (mg/m³) with Total Particulate Material For Matched Air Sample Pairs, Birmingham
$r^2 = 0.533$
$r = 0.732$
95% C.L. $0.237 \leq \rho \leq 0.925$
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
:pirable
mg/m³
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
total (mg/m³)

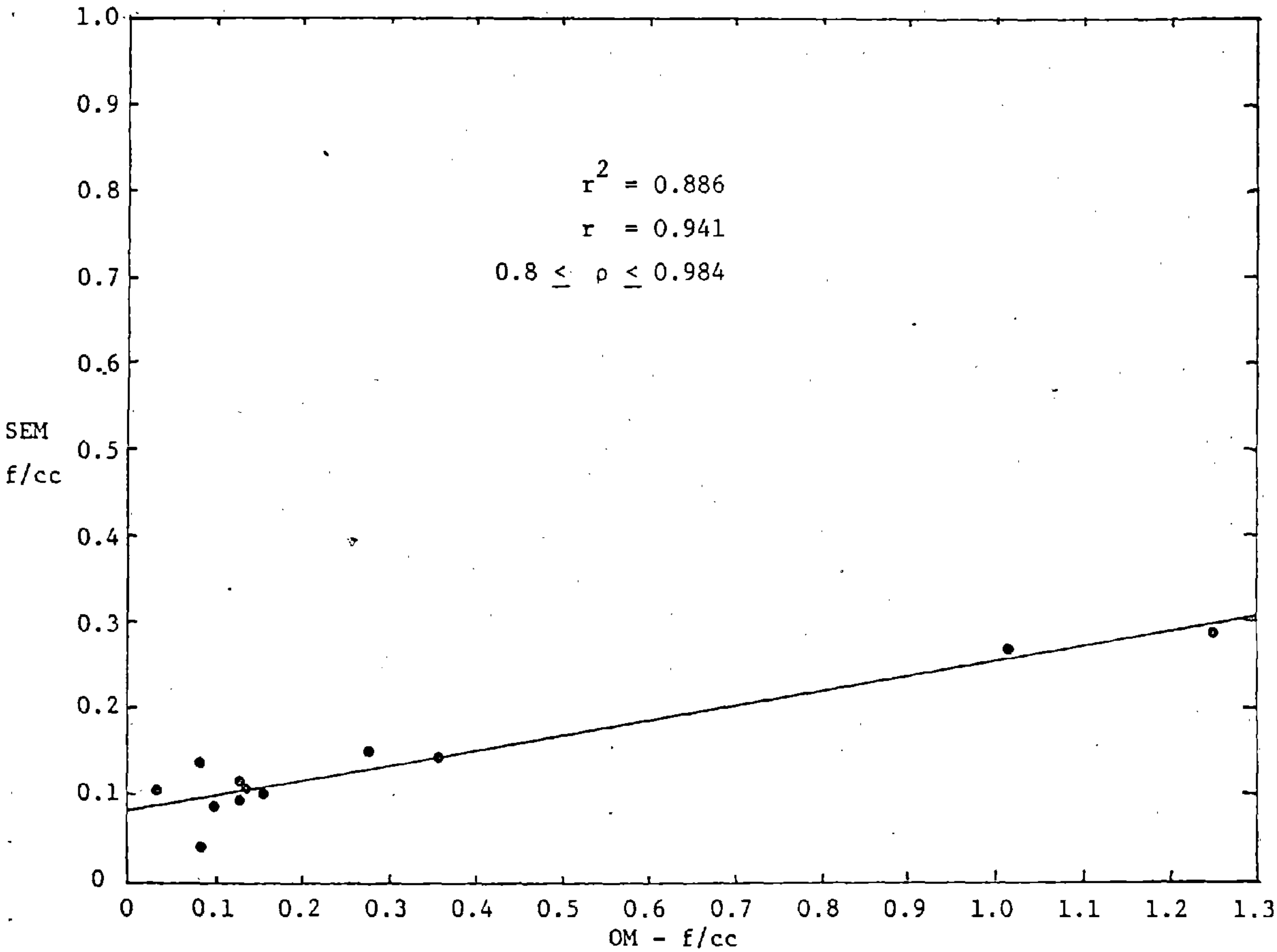


Figure 6

Linear Correlation of Fiber Concentrations by Scanning Electron Microscopy (SEM) and Optical Microscopy (OM)

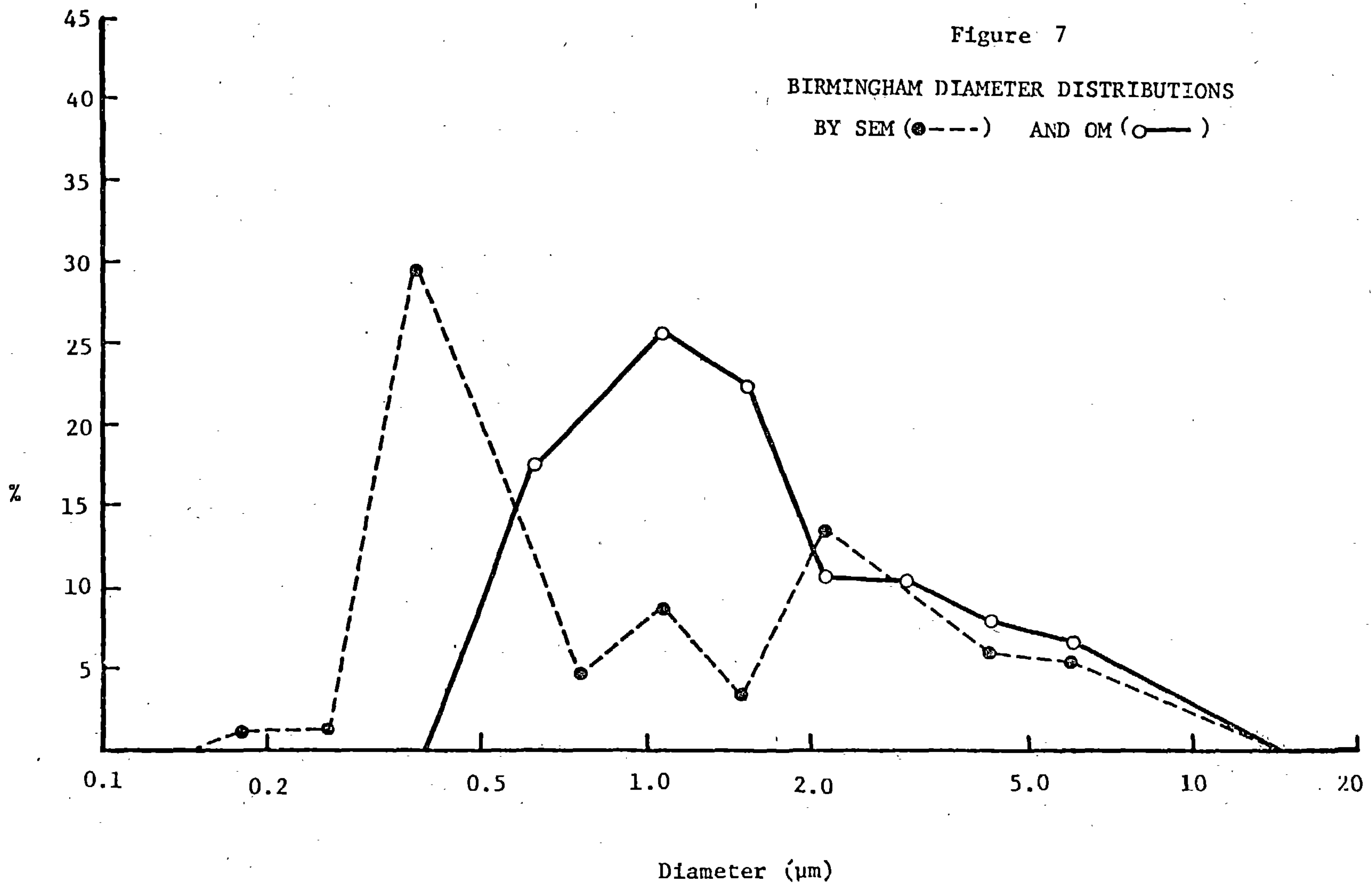


Figure 7

BIRMINGHAM DIAMETER DISTRIBUTIONS

BY SEM (●----) AND OM (○——)

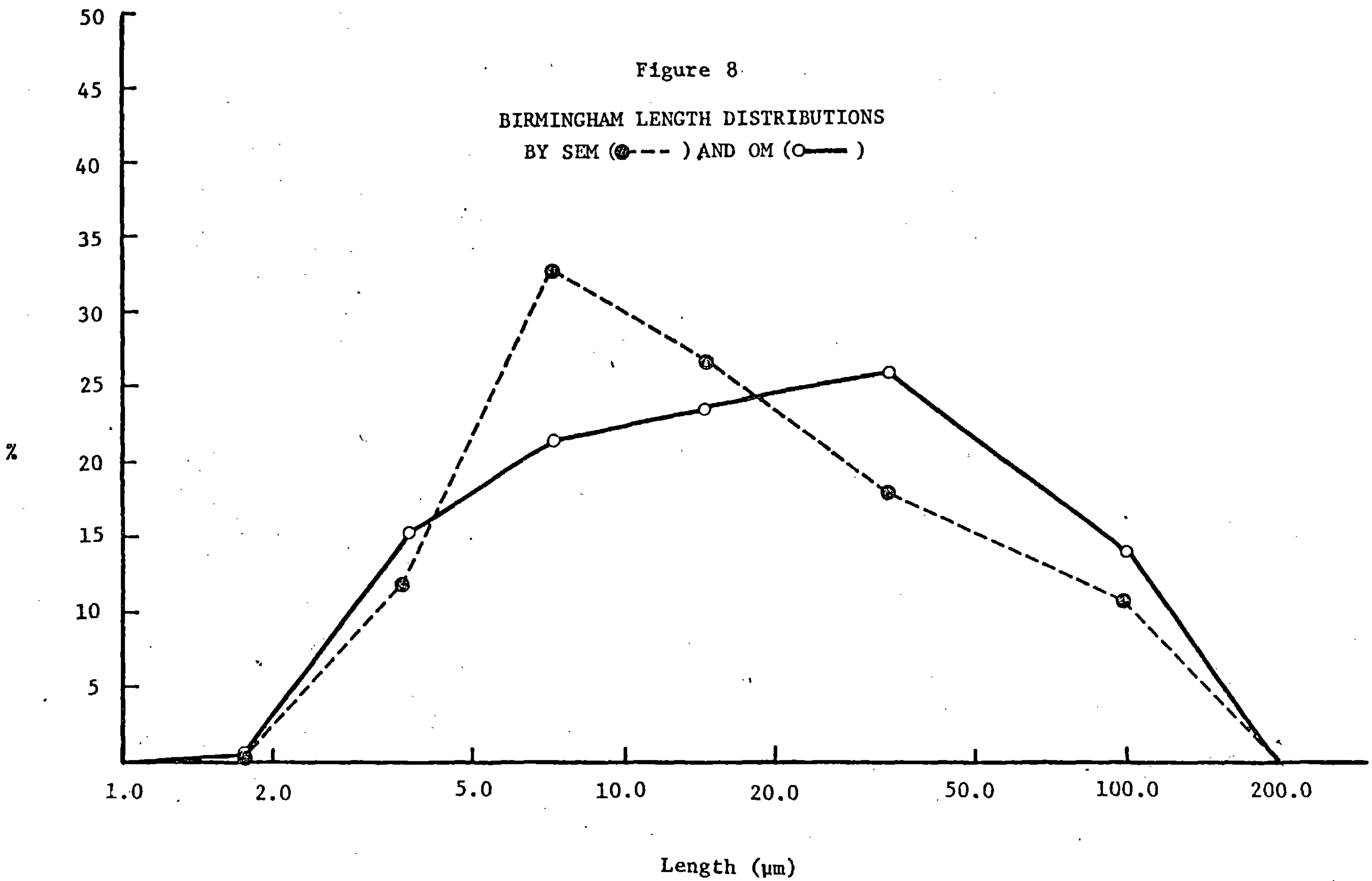


Figure 8

BIRMINGHAM LENGTH DISTRIBUTIONS
BY SEM (●---) AND OM (○—)

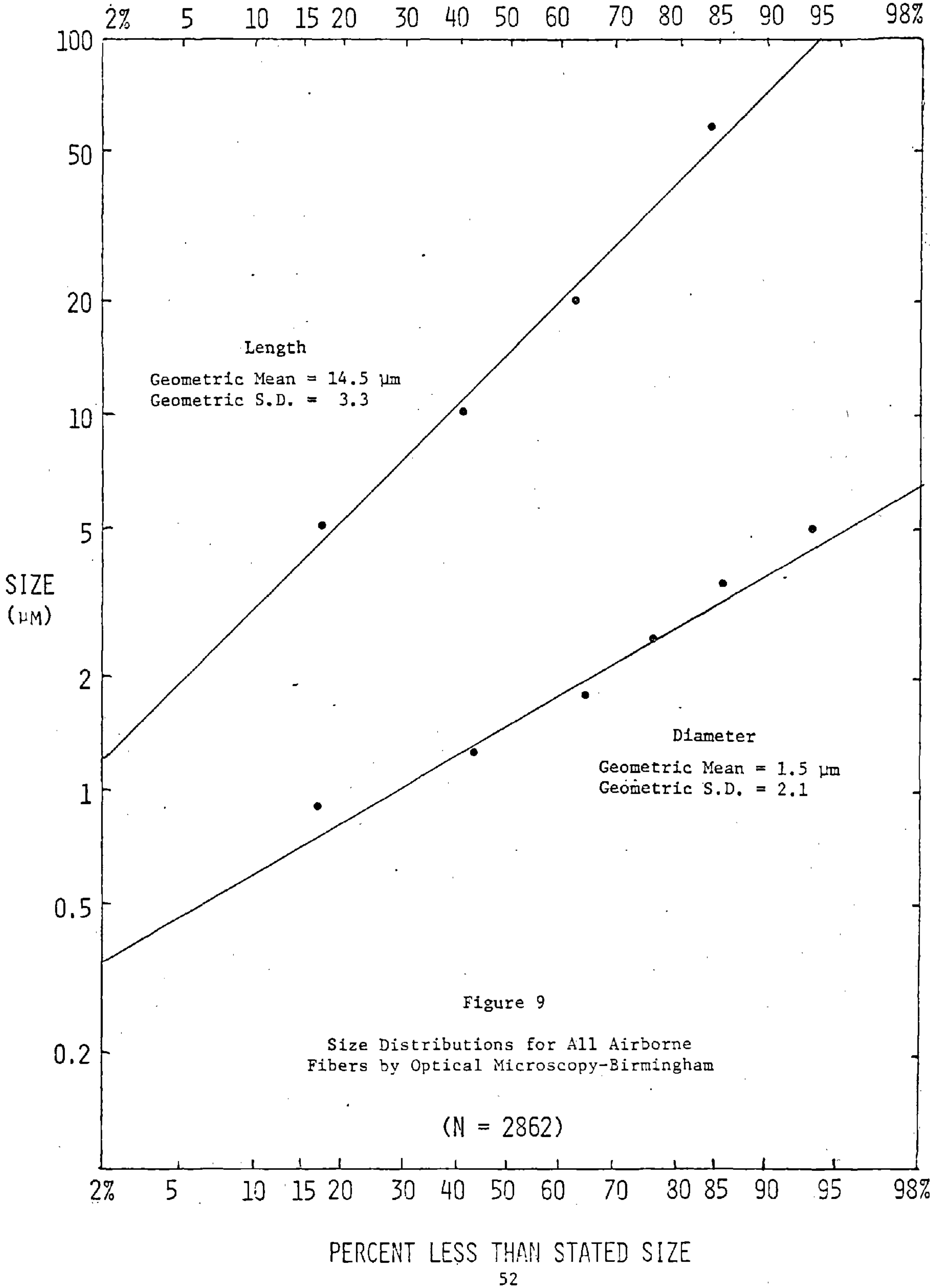


Figure 9

Size Distributions for All Airborne Fibers by Optical Microscopy-Birmingham

(N = 2862)

APPENDIX

A

BULK SAMPLE ANALYSES - U.S.G. BIRMINGHAM

The following samples of bulk material from the Birmingham plant were examined:

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

The analyses applied to these samples have been described previously, in the "Survey Methods" section of the main body of the report.

TABLE A - 1

BULK SAMPLES FROM BIRMINGHAM 10/76 (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
BB1	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		
BB2*	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			
BB3	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	
BB4	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					
BB5	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
BB7*	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			
BB8	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		
BB9	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			

†VP = Variable Particle; not a fiber

*No fibers >10μ in diameter

TABLE A – 2

BULK SAMPLES FROM BIRMINGHAM 10/76 (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
BB1	VP			0.8	3.4	0.1		0.1	<0.1			0.1					
BB2	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	
BB3	VP	0.2			3.5		0.1	0.1				0.1		0.1	0.2		
BB5	VP				3.2		0.1			<0.1		<0.1					
BB6	VP				0.7		0.1	<0.1	0.2	?<0.1		<0.1			0.1	<0.1	
BB7	VP	0.1			3.4												
BB1	shot			0.2	0.6		0.1	3.5				0.3		<0.1			
BB2	shot			0.4	1.1	<0.1	0.2	3.5	<0.1			0.2		<0.1		<0.1	
BB3	shot			0.5	1.5			2.7	0.1			0.3		<0.1			
BB4	shot		0.4	0.9	2.2	0.1	0.1	3.2		0.1		0.3					
BB5	shot			0.5	1.6		0.1	3.6	<0.1		<0.1	0.2		<0.1			
BB6	shot		0.4	0.6	1.8	0.1	0.1	3.4	<0.1	0.1		0.2					
BB7	shot				1.1	<0.1	0.1	3.4	0.1			0.2		<0.1			
BB8	shot			1.0	2.5	<0.1	0.1	3.2	<0.1	0.1		0.2			<0.1		
BB9	shot				1.0	<0.1	0.1	3.3			<0.1	0.2		<0.1			
BB1	small		?0.2	2.3	3.0		0.2	3.6	0.1			0.2		0.1			
BB2	small			3.3	1.3		0.2		<0.1			<0.1		0.2			
BB3	small			3.8	2.3	0.2		2.1	0.1			0.4	? 0.1	0.1	<0.1		
BB4	small			2.1	2.9	0.1	<0.1	3.1	0.1	0.1		0.4		<0.1			
BB5	small			3.4	0.4			0.1				0.1	?<0.1	<0.1			
BB6	small			3.0	2.5	<0.1	0.1	2.1	0.1	<0.1		0.2		0.1	<0.1	<0.1	
BB7	small	0.1		2.3	1.8		<0.1	1.1	<0.1	0.1		0.1		0.1			
BB8	small			1.4	1.5			1.3	<0.1	0.1		0.1		<0.1		<0.1	
BB9	small			1.5	2.1	0.1	<0.1	2.5		0.1		0.2		<0.1		<0.1	
BB1	medium		0.2	0.6	2.6		0.1	3.4				0.2		?<0.1			
BB2	medium			2.4	3.0	<0.1	<0.1	0.6	0.2			<0.1	<0.1	0.1			
BB3	medium			1.1	2.4	0.2	0.1	3.4	0.1			0.5		<0.1			
BB4	medium		0.3	0.9	1.8	0.1	0.1	3.3	<0.1	0.1		0.4	0.1	0.1			
BB5	medium			3.4	3.0		<0.1	0.4	0.2			0.2		0.2			<0.1
BB6	medium			1.1	2.5	0.1	0.1	3.3	0.1	<0.1		0.2		<0.1	0.1		
BB7	medium			1.3	2.6	0.1	0.1	3.3	0.1	<0.1	<0.1	0.2		?<0.1			
BB8	medium			0.8	2.2	<0.1	0.1	3.3	0.1		0.1	0.2					
BB9	medium				1.9	<0.1	<0.1	3.4				0.2		<0.1		<0.1	
BB1	large		0.2	0.7	2.6	<0.1	<0.1	3.4		<0.1		0.2			<0.1		
BB3	large			0.8	1.8	<0.1		3.3	0.1			0.2				<0.1	
BB4	large		0.5	1.2	2.8	0.1	0.1	3.2	0.1	<0.1	<0.1	0.4					
BB5	large			1.5	3.4	0.1	0.4	3.1	0.1	<0.1		0.3					<0.1
BB6	large			0.9	2.1	0.1	0.1	3.4	<0.1		<0.1	0.1					
BB8	large				2.9			3.2	<0.1	<0.1		0.2		<0.1	<0.1		
BB9	large			1.4	2.2			3.2				0.2		<0.1			

TABLE A - 3

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

Birmingham-(μg/gram)

Element	BB-1		BB-2		BB-3		BB-4		BB-5		BB-6			BB-7		BB-8		BB-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 A-4

Bulk Sample Fiber Diameters by
Optical Microscopy - Birmingham

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

Portion Category	Diameter (μm)	Samples (#fibers)									Total #fibers
		BB-1	BB-2	BB-3	BB-4	BB-5	BB-6	BB-7	BB-8	BB-9	
< 1	<0.91	6	14	11	7	11	1	3	8	10	71
1 ≤ 2	0.91-1.28	4	36	6	4	6	4	12	8	15	95
2 ≤ 3	1.28-1.81	15	38	25	14	15	9	13	14	16	159
3 ≤ 4	1.81-2.56	15	46	17	8	17	8	13	19	20	163
4 ≤ 5	2.56-3.62	21	55	13	8	15	18	15	12	20	177
5 ≤ 6	3.62-5.12	32	103	29	19	22	11	21	15	38	290
6 ≤ 7	5.12-7.24	12	102	12	15	23	13	17	15	32	241
7 ≤ 8	7.24-10.24	7	88	13	17	22	27	10	13	20	217
8 ≤ 9	10.24-14.48	4	26	2	5	7	13	3	2	8	70
9 ≤ 10	14.48-20.48	1	4	1	1	4	3	2	2	3	21
10 ≤ 11	20.48-28.96	0	2	0	2	0	0	0	0	0	4
11 ≤ 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
$P < 0.005$

Table A-5

Fe/Mn Ratio Distributions
Birmingham

Sample #	Fe/Mn Ratio	log Fe/Mn Ratio
BB-1	17.06	1.23
BB-2	10.50	1.02
BB-3	23.53	1.37
BB-4	18.33	1.26
BB-5	23.00	1.36
BB-6	5.42	0.73
BB-7	7.39	0.87
BB-8	9.00	0.95
BB-9	15.26	1.18
Mean	14.39	1.11
Standard Deviation	6.66	0.23
Geometric Mean	12.88	-
Geometric Standard Deviation	1.68	-

χ^2 test for Normal Distribution

Range	Observed		Expected	
0 - 5.00	0	3	0.64	2.05
5.01 - 10.00	3		1.41	
10.01 - 15.00	1	1	2.83	2.83
15.01 - 20.00	3	5	2.66	4.12
20.01 - 25.00	2		1.46	

$\chi^2 = 1.81$
$\chi^2_{.05}$ (2d.f.) = 5.99
P∿0.68 that $\chi^2 \geq 1.81$ obtained by chance

χ^2 Test for Log-Normal Distribution

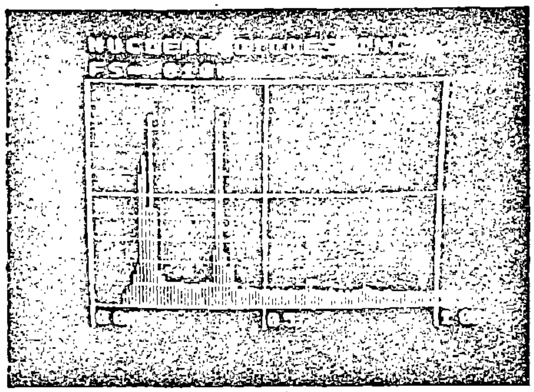
Range (log Fe/Mn)	Observed	Expected
0.700 - 0.933	2	3.27
0.934 - 1.166	2	3.28
1.167 - 1.400	5	2.45

$\chi^2 = 3.64$
χ^2 .05(2d.f.) = 5.99
P∿0.125 that $\chi^2 \geq 3.64$ obtained by chance

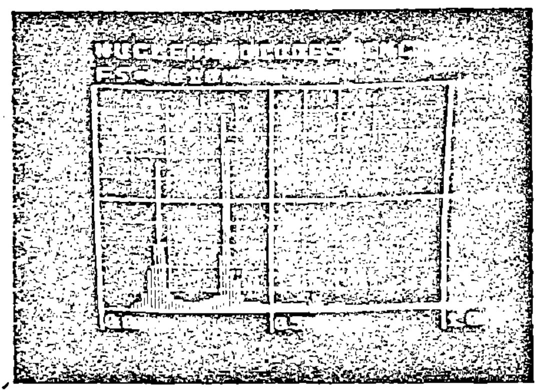
Figure A-1

BIRMINGHAM SEM MICROPROBE
Sample BB-1

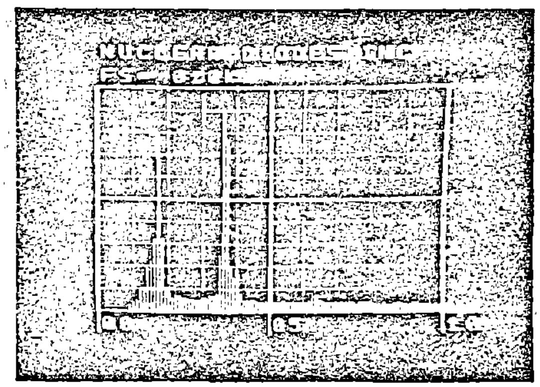
Small



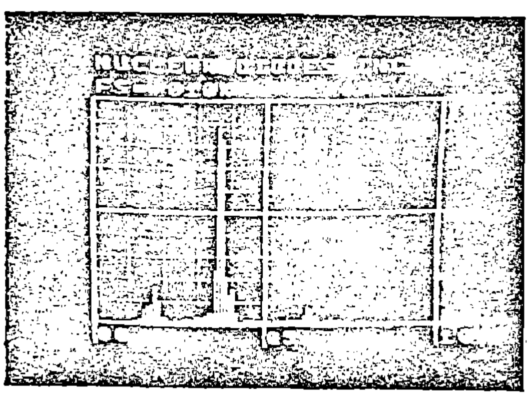
Medium



Large



Shot



Variable Particle

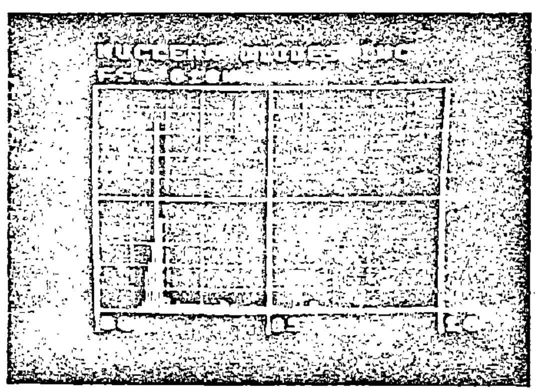
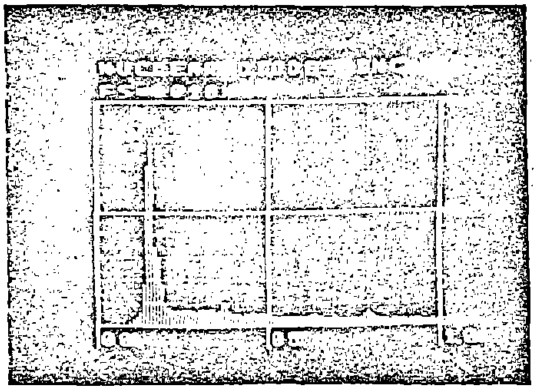


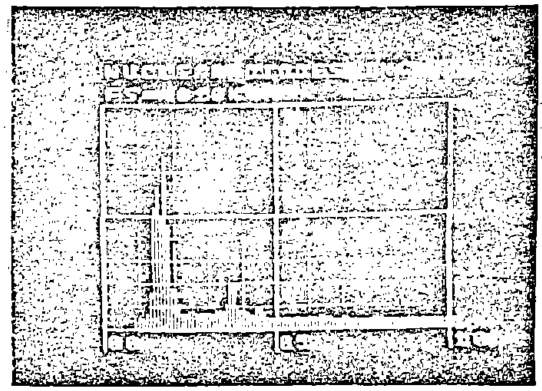
Figure A-2

BIRMINGHAM SEM MICROPROBE
Sample BB-2
(no large fibers in sample)

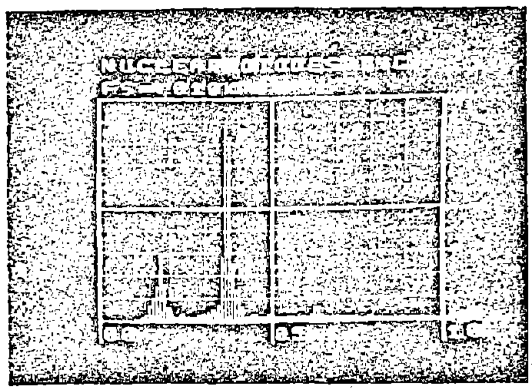
Small



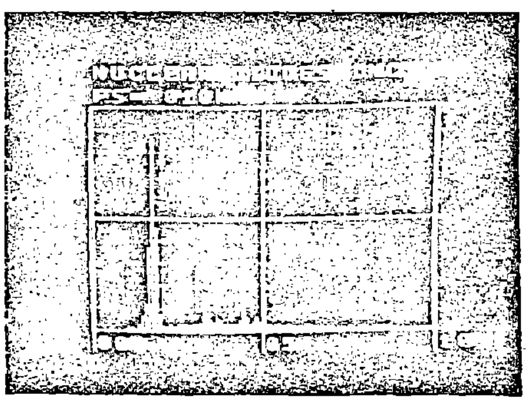
Medium



Shot



Variable Particle



Variable Particle

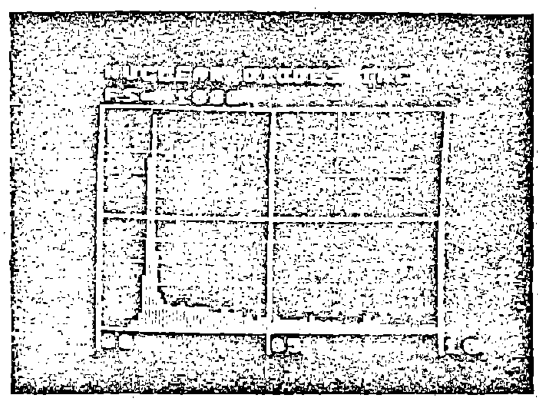
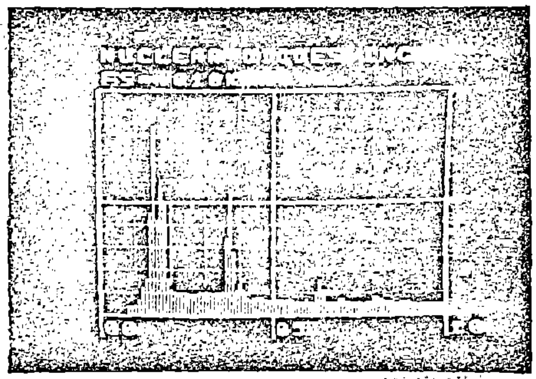


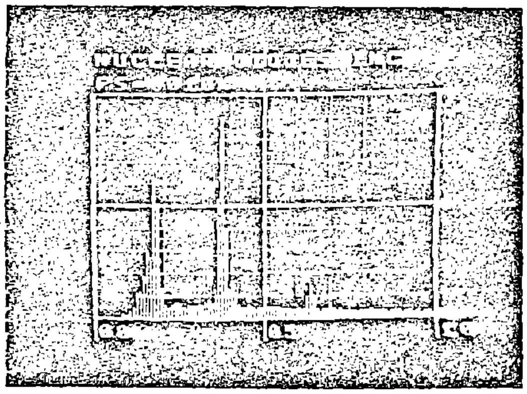
Figure A-3

BIRMINGHAM SEM MICROPROBE
Sample BB-3

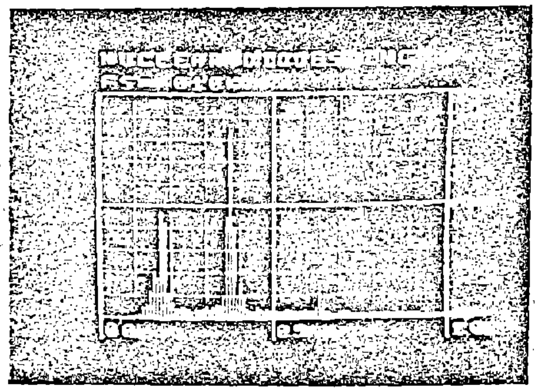
Small



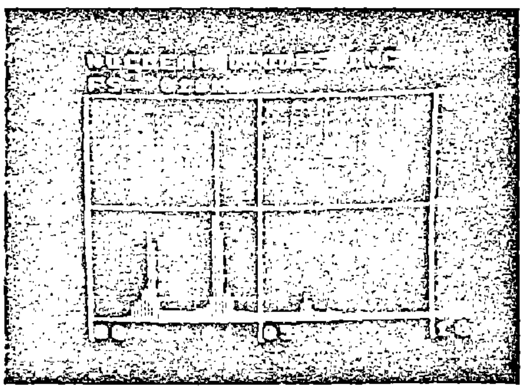
Medium



Large



Shot



Variable Particle

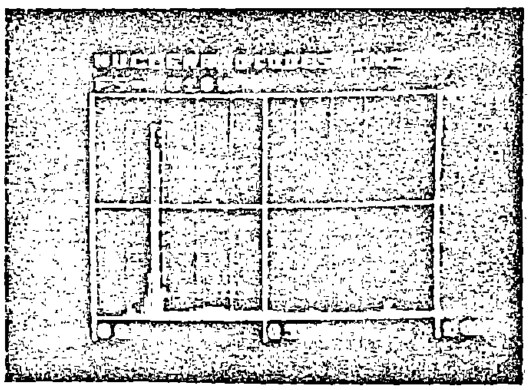
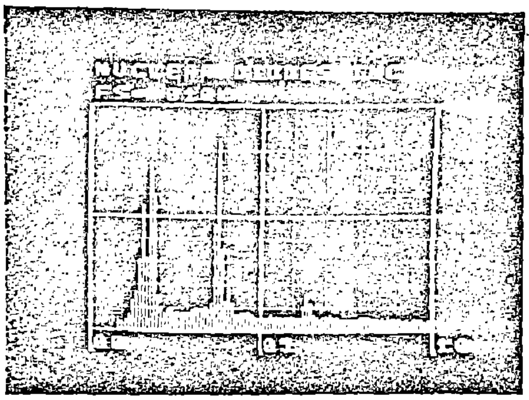


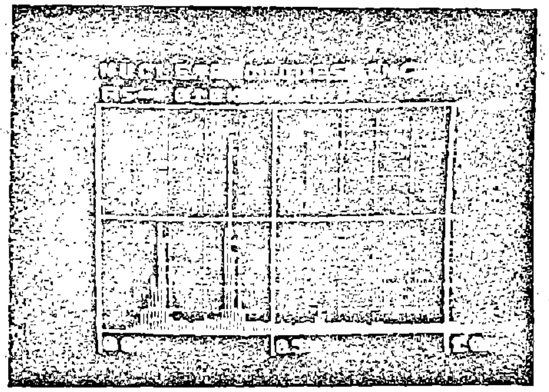
Figure A-4

BIRMINGHAM SEM MICROPROBE
Sample BB-4

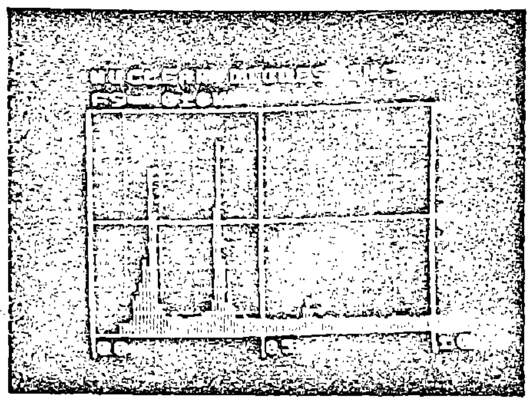
Small



Medium



Large



Shot

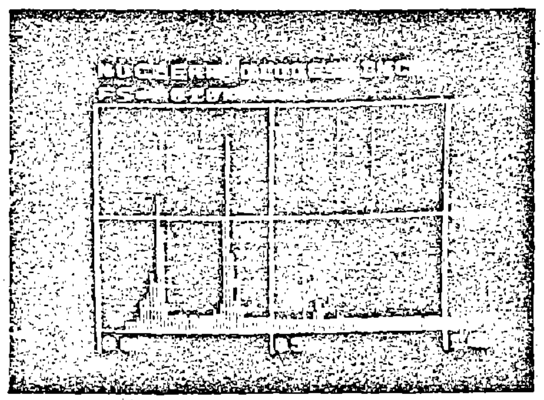
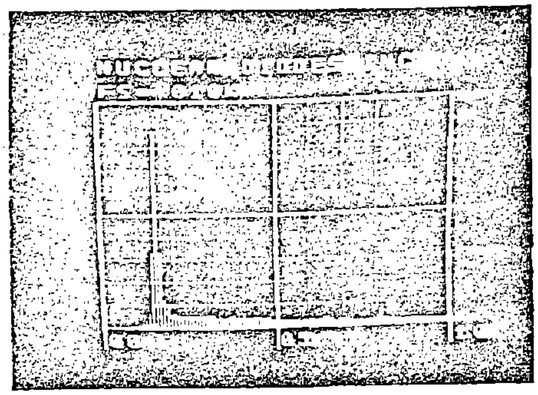


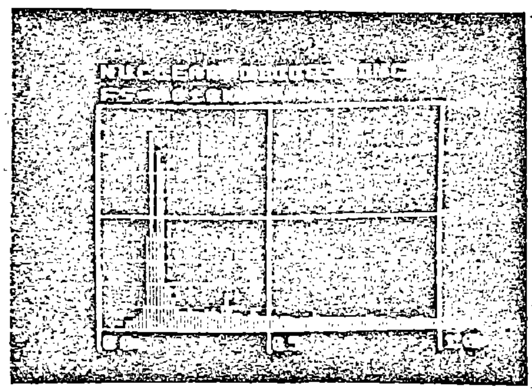
Figure A-5

BIRMINGHAM SEM MICROPROBE
Sample BB-5

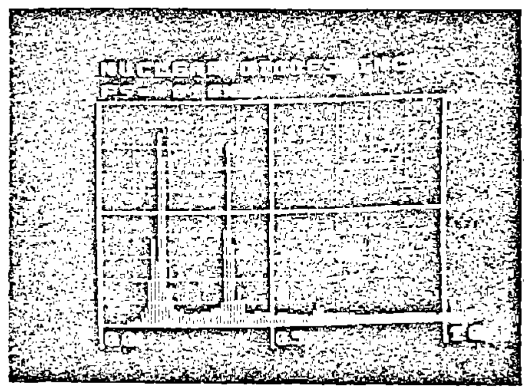
Small



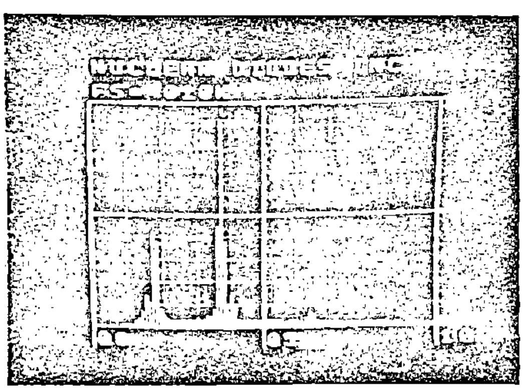
Medium



Large



Shot



Variable Particle

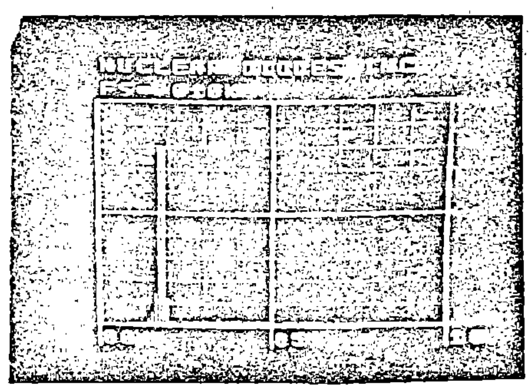
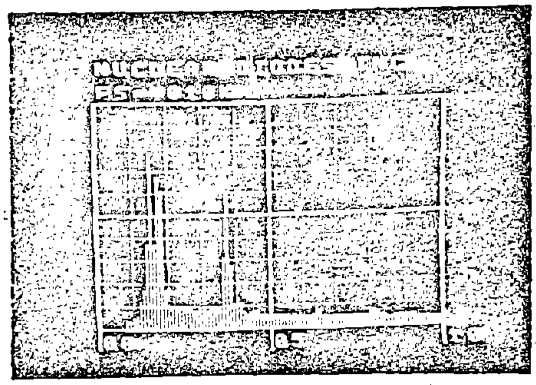


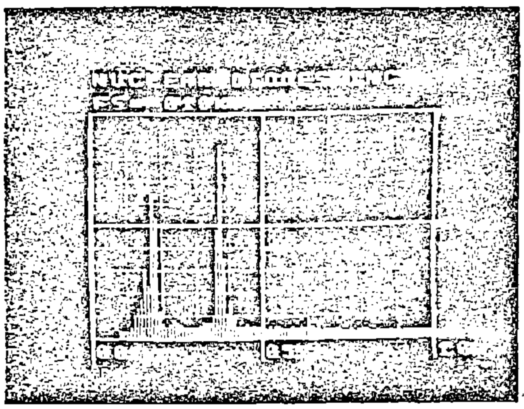
Figure A-6

BIRMINGHAM SEM MICROPROBE
Sample BB-6

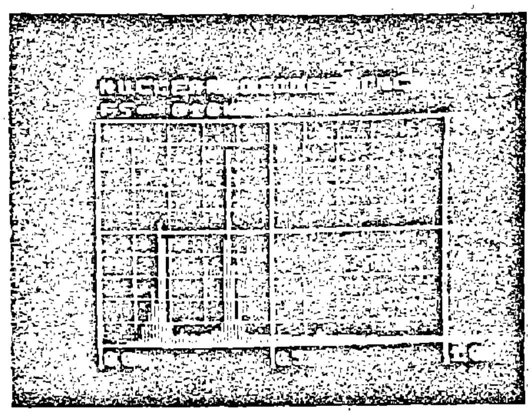
Small



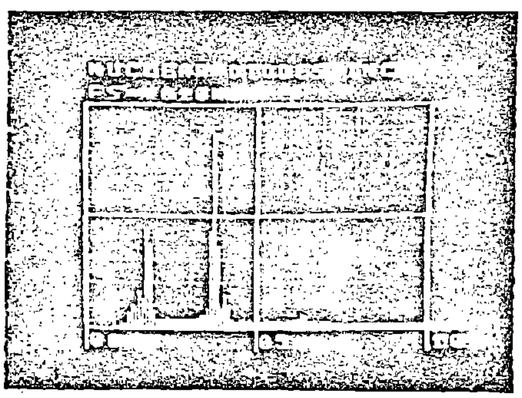
Medium



Large



Shot



Variable Particle

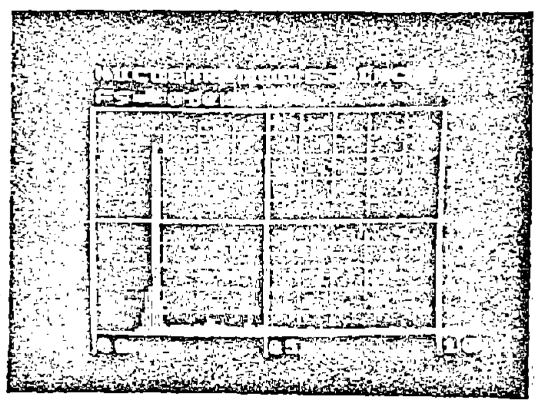
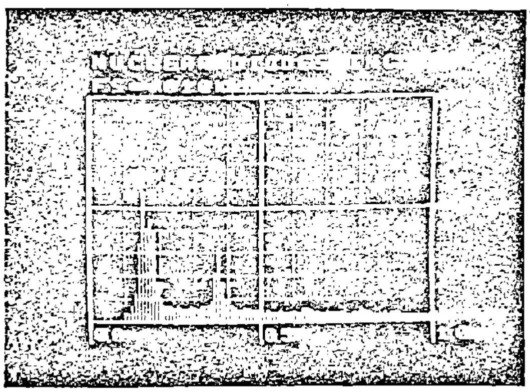


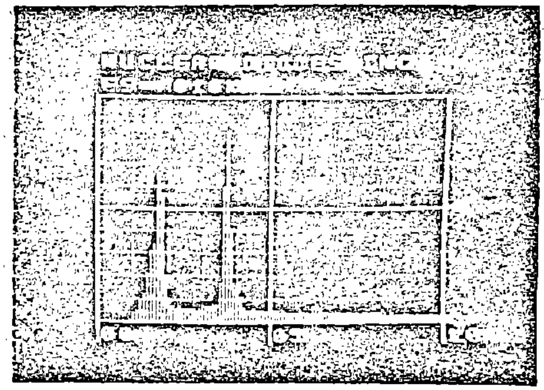
Figure A-7

BIRMINGHAM SEM MICROPROBE
Sample BB-7
(no large fibers)

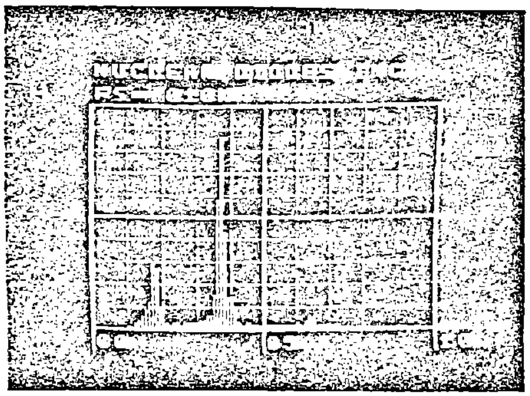
Small



Medium



Shot



Variable Particle

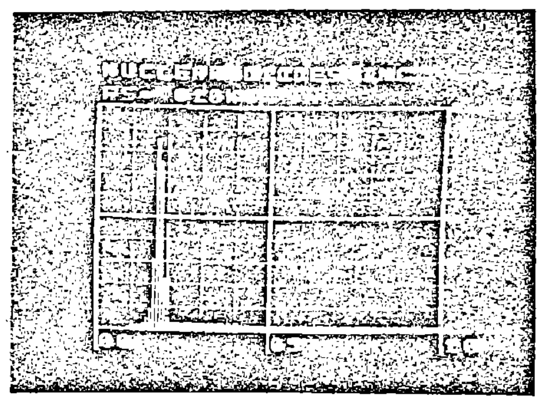
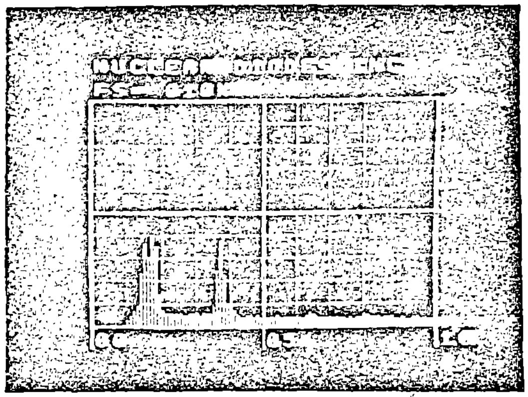


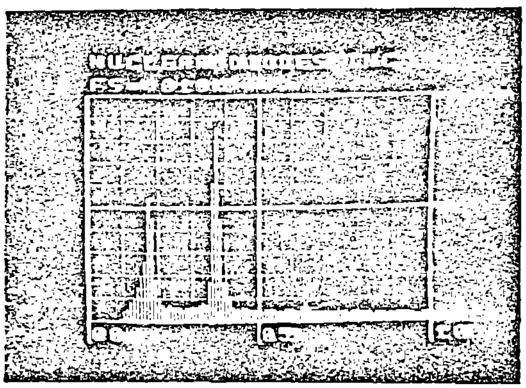
Figure A-8

BIRMINGHAM SEM MICROPROBE
Sample BB-8

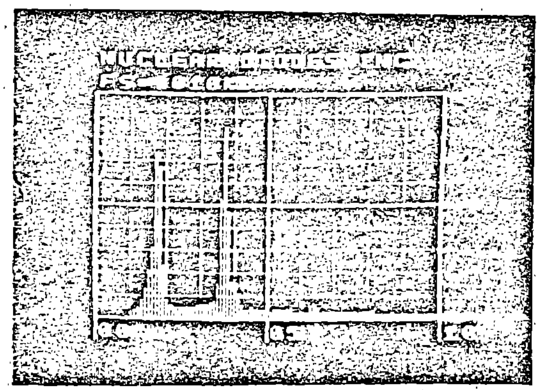
Small



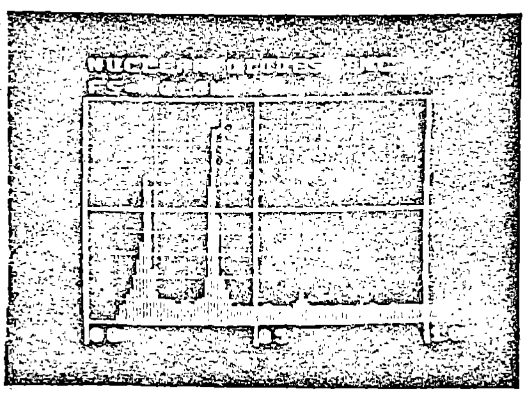
Medium



Large



Shot



Variable Particle

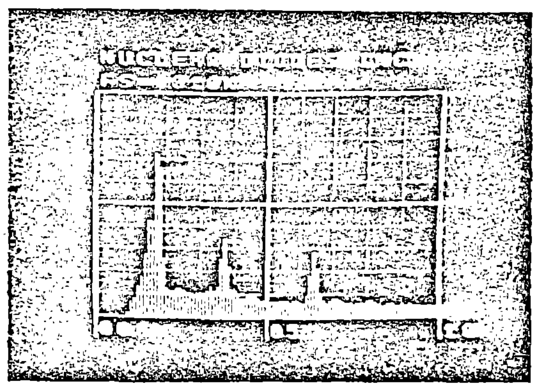
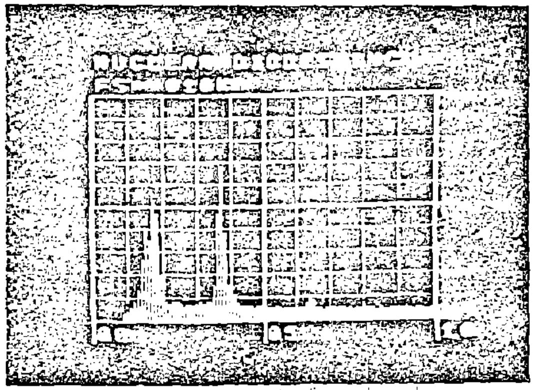


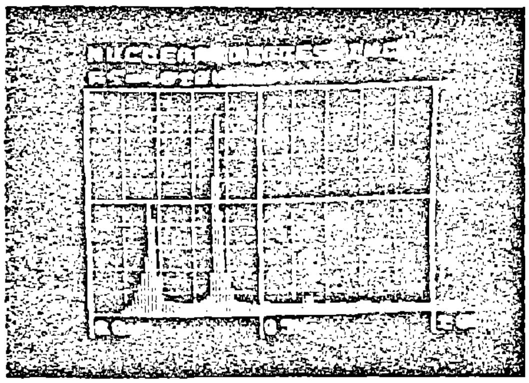
Figure A-9

BIRMINGHAM SEM MICROPROBE
Sample BB-9

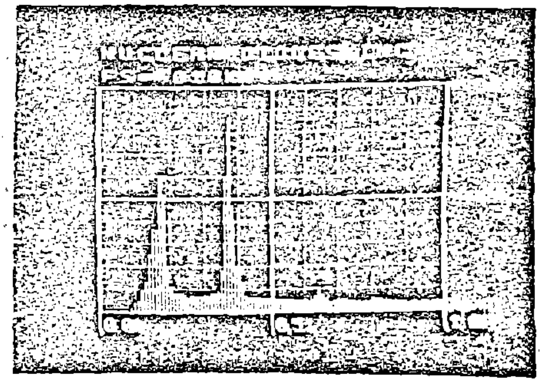
Small



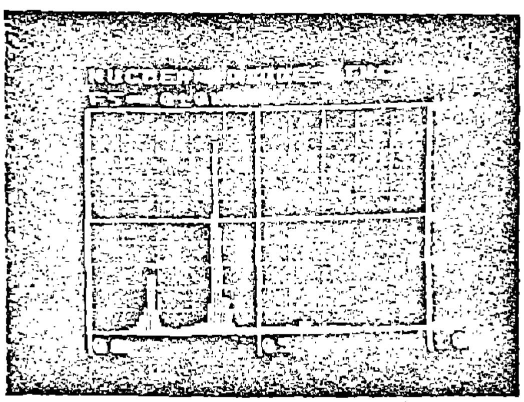
Medium



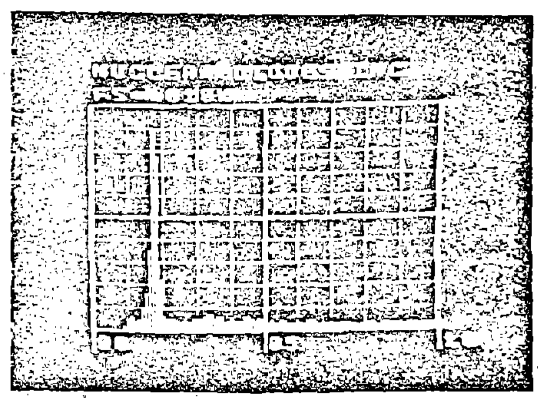
Large



Shot



Variable Particle



APPENDIX B

The following observations were made during the survey, but are included here, since they are peripheral to the main subject of the survey.

PHYSICAL AGENTS AND GENERAL POTENTIAL SAFETY HAZARDS

The cupola area had very high noise levels, as well as potential 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 operiods, especially by maintenance personnel. Welding was carried out in open areas without inadequate 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.