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Industrial Hygiene Survey Report

CELOTEX CORPORATION
PITTSTON, PENNSYLVANIA

Prepared For:

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

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INDUSTRIAL HYGIENE SURVEY REPORT

Pittston Plant of the Celotex Corporation
(A Division of the Jim Walter Corporation)

INTRODUCTION

As part of SRI International's performance of NIOSH Contract #210-76-0120, the Pittston, Pennsylvania ceiling tile plant of the Celotex Corporation was surveyed in the week of December 14-17, 1976 by Douglas P. Fowler, Mary A. Zerwas, Russell Tanita, and Stan K. Futagaki. Celotex personnel contacted included: Mr. R. Krablin, Technical Supervisor; Mr. R.H. Enslen, Plant Manager; Mr. R.R. Hergan, Employee Relations Supervisor; Mr. M. Mackachinis, President, Local 8672, Oil, Chemical and Atomic Workers Union.

Air samples were taken to evaluate workers' exposure to mineral wool fibers, total suspended particulate material, and respirable particulate material. Limited noise and ventilation surveys were also carried out, as well as detector tube sampling for CO, H_2S, and SO_2. This report contains a description of the plant medical, industrial hygiene, and safety programs; as well as a description of the methods and results of the survey.

DESCRIPTION OF THE FACILITY

This plant was constructed in 1956, and production began in 1957. The principal product (mineral wool fiber based acoustical ceiling tile) has been produced here since 1957, with additional products (discussed under Past Processes) on occasion. The plant layout is shown in Figure 1.

Celotex is a relatively recent acquisition of Jim Walter Corporation, but continues to operate (technically) very much as it did before the acquisition. There are approximately 80 hourly employees at this plant, which operates on a five day per week, three shift per day basis for wool and board production and on a one shift basis (days only) for tile production, depending on demand. (See Process Descriptions Below)

The only product in production at the time of the survey was ceiling tile. Production workers are organized under Local #8672 of the Oil, Chemical and Atomic Workers (OCAW); Mike Mackachinis, Local President.

Medical, Industrial Hygiene and Safety Programs

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

Industrial hygiene at the plant is the responsibility of the Employee Relations Supervisor, with assistance from corporate staff in Tampa. A recent industrial hygiene survey (approximately four years ago) was done for determination of total dust levels in the plant. This survey was done by the Engineering Department of the Zurich American Insurance Company.

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

PRESENT OPERATION

The process flow sheet for this plant is shown in Figure 2. The raw materials used here are quartzite, dolomite, metallurgical coke, and slag. The slag is obtained by mining an old (approximately one hundred years) bank of iron furnace slag near Allentown, Pennsylvania. This material is also used by local plants of U.S. Gypsum and U.S. Mineral Products. As with other typical mineral wool plants, there is layer charging of a single cupola. There is a single, centrifugal spinner, with steam attenuation of the partially fiberized material. The steam attenuated fibers are conveyed to the blowing chamber, with addition of oil for lubrication. The fibers then go by conveyor to a granulator/separator and from here are conveyed into a wool bin for in-plant storage. The wool is then taken from the wool bin by conveyor belt/skip loader and added to the next step, the formulation of the board mixture. As shown on the flow sheet (Figure 2) the wool is added to the tile mixture at an intermediate point, just before pouring into the boards. All the wool produced here at this plant, is used internally with none being sold. Following preparation of the mix of starch, clay, old tile dust, wax, guar gum and sodium hexametaphosphate, which is cooked to a gell, the wool is added and the mixture is mixed thoroughly. The colloidal dispersion resulting, is dropped onto 2' x 6' wire mesh trays, and the top scraped (for the characteristic texture of these boards) by a rapidly reciprocating bar as the tray goes to the board drying oven. The dried board goes to a cooling conveyor and is then stacked for storage until it goes to the tile line. The board is planed on one or both sides (face and/or back) and sanded on the face. The length of the 2' x 6' board is then trimmed longitudinally to an exact 2' width, and then cut across to produce a square panel 2' x 2'. This panel is then rabbeted with an edge mill (listed on the flow sheet as the beveler) and is now ready for the final stages of sizing, painting and packing. The sizing is a starch spray applied to the back of the tile. The face of the tile is sprayed with paint, which is then dried in a radiant heat dryer. The sized, painted, and dryed tile next goes for sorting and inspection, packaging, storage, and final shipment.

PAST OPERATIONS

The production of the acoustical tiles has been the same since the plant's start in 1957, but the characteristics of the fibers produced have changed slightly. Until 1961, the fiber diameter was usually slightly more than 7μm, with design specifications of 7-11 μm. From 1961 to 1966, the mean fiber diameter was stated to be approximately 6.8 to 6.9 μm, while since 1966 the production specifications, and examined records of mean fiber diameter indicate a mean diameter of 6.7 to 6.8 μm. These fiber size determinations have been made with a light field microprojector, calibrated with a stage micrometer. The total magnification on the screen of the microprojector appears to be about 1,000.* Figure 3 shows the counting form used for these calculations. Figure 4 shows the chemical analysis of a sample of slag, and two samples of wool submitted from this plant for analysis in 1971.

For a period of a few years, in the mid-1960's, a ceramic product ("core board") was produced at this plant. Production was intermittent, and it was an experiment that was not commercially successful. This was apparently a baked, brittle, ceramic material produced from clay and some silica. This was a somewhat dusty operation, although the equipment

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

used was new and from observation of the equipment formerly used in this operation, it appears that exhaust ventilation was provided at appropriate points.

A potentially more serious exposure occurred also in the mid-1960's, when it was attempted to add asbestos to the currently produced mineral acoustic tile. The asbestos was injected into the blow chamber, following production of the mineral wool and mixed with the wool at that time. It was stated that this asbestos was a brownish material, and it was probably amosite. It was stated that a Mr. Jones of the Celotex Corporation ordered the halt of the use of asbestos as soon as he found that it was being so used. No vestiges of this operation currently are evident, and it apparently was carried out only for a very few months.

It was stated by both management and by workers that the past conditions in this plant were significantly dustier than is currently the case. Recent enclosure of the planing, sanding and milling machines in the tile department for noise and dust control, were particularly mentioned as being beneficial to current conditions.

SPECIFIC JOB CATEGORIES

Table 3 lists the job classifications in use at the plant at the time of our survey.

Specific Job Responsibilities

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

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

Charger - The charger works in a separate building from all other workers, in the building designated as bulk material storage on the plant layout sketch (Figure 1). He loads a weighing hopper from the silos holding the individual raw materials, and transfers the contents of the hopper to a conveyor, from which they are delivered to the cupola, on demand. He is exposed to dust from the coke, slag, and rock. He is also exposed to intermittent high noise levels, (from delivery of the coke, slag and rock into the hopper), and occasional extremes of cold in the winter. The charger may relieve the cupola operator, on rare occasions.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

INSPECTION OF THE PLANT

Physical Agents and General Safety Hazards

High noise levels were noted in the cupola, and tile line areas. In addition, the area surrounding the spinner in the cupola was inadequately protected by barriers, leading to occasional spurts of molten slag onto the floor and in the general direction of the cupola operator. Although most of the process equipment appeared to be well guarded, open chains were noted at a few process points. Relatively large chips of the board material were ejected at several points, most notably at the cutoff saws and the edge milling machines. These were ejected with sufficient velocity to cause eye injury if they should happen to lodge in a workers eye. Intermittent high noise levels were noted during the use of air line for cleaning processing equipment.

Housekeeping

Housekeeping appeared to be generally adequate in this plant throughout the time of the survey. Piles of waste material were noted around those process points mentioned, and relatively large amounts of settled dust were seen in the wool room in the area surrounding the blow chamber and the storage bin. The necessity for storing fairly large amounts of boards, and broken waste tile while awaiting transportation to the tile line, made for occasional near blockages of passageways and aisles. In the warehouse, and in the area where bulk raw materials were stored inside the plant near the stock mix preparation area, broken bags of clay, and starch were seen on occasion. The lunchroom and locker room appeared to be relatively neat and clean, with provision of adequate sanitary facilities.

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

Engineering Controls

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

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

Potential Exposures

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

1. Mineral wool fibers.
2. Smoke, metal fume, and combustion gases in the cupola area.
3. Clays in all areas of the plant, but especially in the board slurry mixing area, and at the station of the paint operator and paint technician.
4. Organic chemical additives to the board and to the paint.

Survey Procedures

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

Survey Equipment

- Bendix BDX-44, portable battery-powered air sampling pumps.
- Bendix 10 mm (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 (5.0 μm mean pore size) 37mm diameter polyvinyl chloride membrane filters
- Millipore 2-piece and 3-piece polystyrene filter holders.
- Drager and MSA detector tubes and pumps
- Alnor Jr. Velometer

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") 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 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 these 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(in all job categories substantially exposed to mineral wool)sufficient to characterize each category's peak and time-weighted average (TWA) exposures to mineral wool fibers, total suspended particulate material (TSP) and respirable particulate (RP) material. To attain this goal, an effort was made to take samples in the breathing zones of all production and maintenance workers with probable substantial exposures.

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 matter, in most cases. For approximately 10% of the workers, total and respirable particulate matter samples were taken. Bendix cyclones (10mm Dorr-Oliver nylon type) were used as pre-selectors 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 periods for each worker were typically 6-7 hours, beginning shortly after the start of a shift and continuing until shortly before the end of the shift. The TSP and RP filter samples were left throughout the sampling period to accumulate as heavy loading as possible for the gravimetric and trace element measurements. The fiber counting filters were usually changed at about the mid-point of the shift, or as needed to present obscuration of the collected fibers by other particulate material.

The samples being taken were monitored at intervals throughout the sampling period, and air flow rates were adjusted back to the 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.

Analytical Procedures

Filter Handling

Each Gelman PVC filter was weighed ($\pm$ 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. Upon return of the filters to the laboratory, the Gelman PVC filters were reweighed ($\pm$ 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.

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 4 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 5) 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

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

put in place, it was tapped lightly with tweezers. Any air that remained entrapped was eliminated by pushing on the cover slip with a pencil eraser.

For counting and sizing a Leitz Ortholux II Pol-BK microscope with 40X, 0.65 NA phase objective, a 10X Periplan GF eyepiece, and Kohler illumination was used. A standard Porton reticle (100L = 64 µm) was placed at the focal point of the eyepiece and used as the counting field area (4.096×10^{-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.

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.

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 3 x 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 1.011 μm (± 0.005 μm) polystyrene latex balls (Duke Scientific Corp.) was added to one corner of the Nuclpore 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 30K^V 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 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 were 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:

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

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 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 (~1 um diameter)
- medium fibers (~4-5 um diameter)
- large fibers (~≥ 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:

$$\text{Fiber Concentration} \quad (f/cc) = \frac{\text{Fibers} \times R}{\text{Fields} \times \text{Volume}}$$

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)

Fiber Counts by Scanning Electron Microscopy

The fiber count in fibers/cc is equal to:

$$\text{fibers/cc} = \frac{\text{Fibers x R}}{\text{fields x volume x F}}$$

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.

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

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

RESULTS

The results from this survey are shown in Tables 6-20, and Figures 4-27. The results for air samples for fiber counting, total suspended particulate (TSP) material, and respirable particulate material are shown in Table 6. Table 7 and Figure 4 are displays of the cummulative frequency distribution of TSP samples, and the airborne fiber concentrations are shown in Table 8 and Figure 5.

The time-weighted averages (TWAs) for the job categories (payroll titles) in the plant for both TSP and fiber counts are shown in Table 9. Table 10 is a tabulation of the geometric means and upper and lower 95% confidence limits on the means for the job categories. The means and confidence limits on the means for the major areas in the plant are given in Table 11. Figure 6 is a graphical display of the individual category confidence limits, means and TWAs for the fiber counts, and Figure 7 is a display of the information from Table 11.

In Figure 8 and 9 are shown the logarithmic linear regression relationships of the fiber count samples to the TSP samples. Figure 10 is a representation of the log-linear regression relationships between TSP and respirable samples.

The optical microscopic fiber sizing data are shown in Tables 12-15 and Figures 11 and 12. In Tables 12 and 13 are shown the distributions for individual fiber diameter and length; they are graphically portrayed in Figure 11. Tables 14 and 15 are tabulations of the count median (geometric mean) lengths and diameters for the sample data from Table 6. Figure 12 is a representation of those data.

In Table 16 are shown the comparative results for scanning electron microscopy (SEM) and optical microscopy (OM) fiber counts. Those comparative values are also shown in Figure 13, with the log-linear regression coefficients. Figures 14 and 15 are representations of the cumulative frequency distributions of the fiber sizes in the air samples examined both by SEM and OM.

In Figure 16 are shown the ventilation survey measurements made in the cupola area. In addition to those ventilation measurements, a few detector tube measurements were made in the cupola area for combustion gases (CO, H_2S, and SO_2). These measurements, made during tapping and non-tapping periods, were low in all cases. CO was 5-7 ppm, SO_2 less than 1 ppm, and H_2S less than 5 ppm (parts per million).

Noise levels in the cupola were relatively high. The overall noise levels in the major portion of the cupola room were approximately 100-105 dB(A); near the spinner, the levels were 110-115 dB(A). The cupola operator spends approximately 10% of his time in this latter area. Noise levels in the tile production area were also occasionally excessive, tending to center around 90dB(A), with levels slightly above and below this value in various areas.

The optical microscopic diameter sizing results for the bulk samples taken during the survey are given in Tables 17 and 18. Tables 19 and 20 are the X-Ray Fluoresence analysis results for those same bulk samples. Figures 17-26 are elemental spectra for individual fibers and shot in the bulk samples. Spectra are shown for typical "large" fibers (approximately 10 μm diameter), "medium" fibers (4-5 μm), "small" fibers (approximately 1 μm), and shot particles.

In addition to the mineral wool samples, samples were taken of the clays and other materials used in the process. Only one of these, (wollastonite, used as a filler in the paint) had an appreciable number of fibers. Figure 27 shows the fiber size data for the wollastonite sample by SEM and OM.

DISCUSSION OF RESULTS

There are three sets of standards applicable to the results of this survey. The first of these are the Federal legal limits upon occupational environmental air concentrations for "Toxic and Hazardous Substances" found in 29 CFR, part 1910.1000, and enforced by the Occupational Safety and Health Administraion (OSHA). These are listed below as "OSHA". A well accepted set of voluntary standards are prepared by the American Conference of Governmental Industrial Hygienists (ACGIH).* The National Institute for Occupational Safety and Health (NIOSH) prepares recommendations for OSHA, when changes are needed in the OSHA standards. These recommendations are supported by "Criteria Documents" which explain the background and rationale for the recommended changes.

Mineral wool is not considered specifically in the OSHA standards, but has been generally considered to be an inert or "nuisance" dust, with an applicable workplace concentration limit of 5 mg/m^3 for the respirable fraction and 15 mg/m^3 for the total dust sample, as weights in sampled air. ACGIH has set a specific limit of 10 mg/m^3 for the total mineral wool dust level. NIOSH has recently prepared a criteria document on fibrous glass, which is to apply to mineral wool and other "man-made mineral fibers" until more information is available. This document calls for occupational exposures to be held to less than

*Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment, ACGIH, P.O. Box 1937, Cincinnati, OH 45201

3 fibers per milliliter of air, for fibers less than 3.5 μm diameter, and with length greater than 10 μm. (Fibers/milliliter = fibers/cc = f/cc)

The maximum gravimetric result (total suspended particulate material) was 11.573 mg/m^3, found in a single sample for the wool utility worker. The next highest single sample result was 10.280 mg/m^3 for the line attendant, and third highest was 10.177 mg/m^3 for the wool and board inspector. Thus none of the workers were exposed to total particulate material levels above the current Federal OSHA limit, even if single samples are considered alone, and only three values exceeded the ACGIH voluntary standard for mineral wool fibers. If time-weighted averages for job categories are considered, as they are in Table 9, then only the line attendant's exposure is excessive by ACGIH standards.

The highest respirable particulate value found was 1.661 mg/m^3, for the charger. All respirable samples were thus below the appropriate OSHA limits.

The highest single sample value fiber count found in this survey was 6.911 fibers/cc, for the board utility worker, during a 28 minute period when he was sweeping up and shoveling broken boards into a hopper for return to the process and discard. The second highest fiber count recorded was 5.859 f/cc,for the oven operator, over a 3 hour period. The third highest value found was 4.888 f/cc, for a 26 minute sample during the period when the tile line setup worker was blowing off settled dust from equipment, using a compressed air line. The TWA exposure values for the separate job categories were all below the NIOSH recommended limit of 3 f/cc (see table 9), as were the calculated TWAs for individual workers. In addition, the restriction on fiber size that is imposed by the NIOSH limit, means that the exposures to fibers within those size restrictions only, would be even lower. If Figure 11 is examined, it can be seen that approximately 45% of the fibers were longer than 10 μm, and that approximately 90% were less than 3.5 μm in diameter. Thus, the fibers that fell within the NIOSH limits were less than half of those counted in the total fiber count.

Elemental concentrations are also the subject of regulation. In this survey, concentrations of seven elements were measured. The ACGIH, NIOSH and OSHA TWA exposure limits on those elements are:

	ACGIH	OSHA	NIOSH
Zn (ZnO)	5.0 mg/m^3	5.0 mg/m^3	
Pb	0.15 mg/m^3	0.2 mg/m^3	0.05 mg/m^3 **
Mn	5.0 mg/m^3	5.0 mg/m^3	
Cr (metal)	1.0 mg/m^3	1.0 mg/m^3	0.025 mg/m^3***
Co	0.1 (0.05)*	0.1 mg/m^3	
Ni (metal)	1.0 mg/m^3	1.0 mg/m^3	0.005 mg/m^3
Cd	0.05 mg/m^3	0.2 mg/m^3	0.04 mg/m^3

*Intended Change
**Less than 0.15 mg/m^3, but not less than 0.05
*** For non-carcinogenic Cr(VI) compounds

The maximum concentrations found for any of these samples were:

Element	Maximum Concentration	Job Category
Zinc (Zn)	10.7 $\mu g/m^3$	Wool Utility
Lead (Pb)	3.8 $\mu g/m^3$	Shift Mech. (elec.)
Manganese (Mn)	15 $\mu g/m^3$	Wool Utility
Chromium	<1.3 $\mu g/m^3$	Line Attendant
Cobalt	<4.0 $\mu g/m^3$	Wool & Board Insp.
Nickel	<2.0 $\mu g/m^3$	Stock Preparer
Cadmium	<0.8 $\mu g/m^3$	Stock Preparer

It should be noted that these maximum concentrations were, in four of seven cases, below the detection limits of the atomic absorption spectroscopic method used; in no case did the maxima approach either the OSHA or ACGIH limits.

If Table 7 and Figure 4 are examined, the total suspended particulate material concentrations are seen to be approximately log-normally distributed, with a median (geometric mean) concentration of 1.5 mg/m^3. The 95% confidence limits for the true mean (using Students t-distribution, Snedecor and Cochran, op cit, p. 61, and assuming log-normality) are 1.175 mg/m^3 and 1.952 mg/m^3.

The fiber count data in Table 8 and Figure 5 have been similarly treated. The geometric mean fiber concentration for all samples was 0.53 fibers/cc. The 95% confidence limits on that mean are 0.66 and 0.43 fibers/cc.

These can be compared with the confidence intervals for job categories (payroll titles) and major plant areas in Figures 6 and 7 and Tables 10 and 11. In only one case do the fiber count or TSP confidence limits for these subdivisions not overlap the confidence intervals for the total plant. That is the major area of the "Board Department dry operations", which was the accumulated samples from the oven operator, dry helper, humidifier operator and board utility workers. Fiber exposure for that group of workers thus appears to be higher than for the workers in the rest of the plant.

The log linear regression plots (Figures 8, 9 and 10) show some interesting relationships, but with relatively poor correlations. In all three cases the confidence intervals of the correlation coefficients included zero; in all three cases the observed relationships cannot be said to have arisen other than by chance. Thus, it is not possible to predict fiber count from knowledge of TSP level; nor is it possible to predict respirable particulate levels from TSP.

The fiber size data in Tables 12-15 and Figures 11 and 12 are interesting, although somewhat confusing.

The diameter data in Figure 11 are of particular interest. The observed fit of the fiber diameters to the (assumed) log-normal distribution appears to be relatively poor. The fit was tested (using chi-square) and found to be poor, with a probability of less than 0.001 that a fit as poor or poorer could arise solely from chance. Tests of skewness and kurtosis were also performed; in both cases there were statistically significant ($p<0.01$) departures from log-normality. This failure to fit a log-normal distribution has limited practical importance, except as it limits the use of the fiber size data for conclusions on respirability or compliance with the afore-mentioned NIOSH exposure limits. Because the departure from log-normality (although statistically highly significant) is rather small in absolute terms at any one point, it was ignored. The plotted line of Figure 11 was used to estimate the fraction of fibers that are respirable. The upper limit criteria for respirability reported by Dement ("Environmental Aspects of Fibrous Glass Production and Utilization", Environmental Research 9:295-312, 1975) were 3.5 μm for diameter and 50 μm for length. That is, fibers thicker and longer than this will probably not be inhaled into the lungs. Ninety-one percent of the fibers are less than 50 μm long and about 85-87% are less than 3.5 μm in diameter. The fraction of fibers that are respirable is thus probably about 80-90%.

The results of the optical microscopic sizing of the bulk material samples, in Tables 17 and 18, reveal that the current mineral wool produced at the plant is relatively uniform in geometric mean diameter (approximately 3-4 μm), but that the material produced in 1957 was significantly larger. The comparison of samples CB-5 and CB-7 in Table 17 is illustrative of this. CB-5, produced in 1957, has a geometric mean fiber diameter of 5.1 μm (95% confidence interval 4.4 to 5.9 μm). The tile produced in 1962 (Sample CB-7) contains significantly smaller fibers, with a geometric mean of 3.2 μm (3.0 - 3.4). The respirable fraction in 1957 would have been about 30%, while in 1962 it was near 55%.

Another significant point from these bulk samples can be seen by examination of Figure 27, the presentation of the fiber diameters in the Wollastonite sample. The fibers found in this material are substantially smaller than the mineral wool fibers in the other samples.

Figure 14 shows the optical vs. electron microscopic size comparisons for all of the air samples examined by both methods. It can be concluded that a significant difference exists in the fibers seen by the two methods; that both length and diameter of the fibers seen by SEM are smaller than those seen by optical microscopy. Nearly all of the fibers seen by SEM are respirable (<50 μm length, <3.5 μm diameter). In Table 16, it is shown that the fiber counts by SEM are generally higher than by OM, although some are lower. This is consistent with the differences in size shown in Figure 14; the SEM enables visualization of fibers smaller than those seen by OM.

Figure 15 is a display of the fiber diameter sizing data by SEM and OM for sample C876. This sample, taken in the breathing zone of the paint operator, would be expected to display the most marked difference between the SEM and OM measurements, because of his potential exposure to the fibrous wollastonite in the paint. Indeed this is true; the difference shown in Figure 15 is marked, and suggests that the exposure of this worker is qualitatively different than others. It is most probable that the source of the difference is the presence of fibrous wollastonite in his breathing zone. Although a fiber counting sample was inadvertantly not taken on the paint technician, it is probable that he shares this exposure with the paint operator. Peak fiber exposures during mixing may be relatively high for him.

The ventilation survey in the cupola (Figure 16) disclosed a relatively uneven pattern of air circulation. It is believed that some modest redesign of the cupola enclosure would reduce cupola operator and wool utility worker TSP exposure levels, and prevent any (probable but unobserved) exposures to smoke, fume, or other airborne particulate materials in this area.

Figures 17 through 26, the elemental spectra of the individual fibers and shot in the samples, indicate no apparent differences in the elemental composition of the fibers and shot.

SUMMARY AND CONCLUSIONS

Throughout this survey, excellent cooperation was obtained from both management and labor. There was concern for any potential health effects on the part of all those contacted. It is believed that correction of the few adverse conditions discovered in this plant will receive the team effort needed for their successful alleviation.

The levels of total suspended particulate material were occasionally in excess of recommended values, but no levels of any air contaminant measured were above current OSHA standards.

Noise levels in the cupola and tile production areas were above 90 dB(A) at times.

The exhaust ventilation system in the tile production area was often compromised in its function, because of inproper connection of dust connectors. The use of personal safety eye protection by workers was also sporadic, even for those exposed to potentially hazardous flying debris.

Use of wollastonite in the paint mix led to exposure to respirable fibers for at least two workers.

The levels of airborne mineral wool fibers found in this survey cannot be judged to be either hazardous or non-hazardous. Too little is

Table 1

Components of Ceiling Tile
Celotex, Pittston

(In order of relative composition.)

Solids

Mineral Wool (approximately 2/3)

Clay

Starch

Dust and "Broke" (broken pieces of ceiling tile)

Wax

Guar Gum

Sodium Hexametaphosphate

Moisture (before drying)

Approximately 2/3

Table 2

Past Chemical Analysis of Slag and Wool

Celotex, Pittston

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

Analysis by: General Testing Laboratories, Inc.
241 South Jefferson Street
Allentown, Pennsylvania 18102

(Method of Analysis unknown)

Table 3

Employee Categories

Celotex, Pittston

Department (Area)	Job Title	Total # Employees	Shifts Worked
Wool	Cupola Operator	3	All
	Wool Utility	3	All
	Charger	3	All
Board	Texture Control	3	All
	Board Utility	3	All
	Stock Preparer	3	All
	Stockmix Operator	3	All
	Oven Operator	3	All
	Oven Loader	3	All
	Humidifier Operator	3	All
	Dry Helper	3	All
Tile	Line Operator	1	Day
	Line Setup	1	Evening
	Tile Utility	1	Day
	Paint Operator	1	Day
	Sorter Packer	5	Day
	Utility Set-up	2	Evening
	Stacker	1	Day
	Line Attendant	1	Day
Traffic	Warehouse Leader	1	Day
	Warehouse Worker	3	Day
	Warehouse Worker (Truckdriver)	1	Day
Technical	Paint Technician	1	Day
	Laboratory Technician	1	Day
	Wool and Board Inspector	3	All
	Tile Inspector	1	Day
Maintenance	Shift Mechanic - Electrical	3	All
	Shift Mechanic	4	Day(2), Eve.(1), Night(1)
	Utility Mechanic	4	Day(2), Eve.(1), Night(1)
General Plant	Storeroom Attendant	1	Day
	Janitor	1	Day

TABLE 4

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 5

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 6
AIR SAMPLING RESULTS
PITTSON

Area	Payroll Title	Fiber Counting: Sample No.	Flow (m^3)	f/cc	N	Count Median Length (SD)	Diam. (SD)	Total Airborne Particulate Material: Sample No.	Flow (m^3)	Total mg/m^3	Elemental Concentration ($\mu g/m^3$): Zn	Pb	Mn	Cr	Co	Ni	Cd	Respirable Particulate Material: Sample No.	Flow (m^3)	Total mg/m^3
Wool Dept.	Charger	C975	0.382	*	28	15.5 (2.8)	2.3 (1.9)	A447	0.829	2.245	2.0	<1.6	0.6	<0.9	<0.8	<1.2	<0.5			
		C856	0.201	0.139																
		C853	0.211	0.121																
	Charger	C941	0.411	0.456	98	8.9 (2.3)	1.7 (1.6)	A472	0.802	7.329	4.1	<1.6	12	<0.9	<0.9	<1.2	<0.5			
		C939	0.412	*																
	Charger							A478	0.824	4.056	0.9	<1.6	1.6	<0.9	<0.8	<1.2	<0.5	W043	0.722	1.661
	Cupola Oper.							A483	0.824	0.254	0.6	<1.6	0.8	<0.9	<0.8	<1.2	<0.5	W42	0.700	0.490
	Cupola Oper.	C917	0.404	0.284	123	10.8 (2.8)	1.7 (1.6)	A480	0.805	1.091	1.5	<1.6	0.8	<0.9	<0.9	<1.2	<0.5			
		C942	0.376	0.326																
	Cupola Oper.	C871	0.200	0.390	40	13.2 (3.3)	1.5 (1.8)	A442	0.867	1.103	1.9	<1.5	<0.5	<0.8	<0.3	<0.8	<0.4			
		C869	0.434	*																
	Wool Utility	C903	0.422	2.035	212	24.0 (2.5)	1.6 (2.0)	A477	0.716	11.573	1.2	<1.8	15	<1.0	<1.0	<1.4	<0.6			
		C915	0.418	*																
	Wool Utility	C960	0.192	0.332	33	21.6 (2.2)	1.9 (2.2)	A443	0.785	2.913	10.7	<1.6	2.0	<0.9	<0.9	<1.2	<0.5			
		C854	0.461	*																
	Wool Utility							A467	0.743	5.332	4.7	<1.7	4.6	<1.0	<0.9	<1.4	<0.6	W64	0.678	0.515
Board Dept.	Stock Preparer	C873	0.160	0.320	52	26.4 (2.8)	2.4 (2.1)	A445	0.791	1.846	1.3	<1.6	<0.5	<0.9	<0.9	<1.2	<0.5			
		C858	0.499	0.100																
	Stock Preparer	C929	0.342	0.750	285	17.3 (2.7)	2.2 (1.7)	A482	0.784	4.046	0.5	<1.6	1.3	<0.9	<0.9	<1.2	<0.5			
		C902	0.394	1.070																
	Stock Preparer	C921	0.106	2.393	302	15.6 (2.9)	1.7 (1.8)	A484	0.532	4.919	1.5	<2.4	<0.8	<1.4	<1.3	<2	<0.8			
		C916	0.314	1.529																

*Fibers obscured by overlying non-fibrous particles.

Air Sampling Results - Pittson
Page 2

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

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		Fiber Counting						Total Airborne Particulate Material										Respirable Particulate Material		
						Count Median					Elemental Concentration (μg/m3)									
Area	Payroll Title	Sample No.	Flow (m^3)	f/cc	N	Length (SD)	Diam. (SD)	Sample No.	Flow (m^3)	Total mg/m3	Zn	Pb	Mn	Cr	Co	Ni	Cd	Sample No.	Flow (m^3)	Total mg/m3
	Dry Helper	C838	0.236	2.499	270	5.5	1.4	A469	0.824	1.252	0.7	<1.5	<0.5	<0.9	<0.8	<1.2	<0.5			
		C972	0.387	0.892		(2.0)	(1.4)													
	Dry Helper	C969	0.452	0.431	139	24.7	2.8	A454	0.778	1.213	2.2	<1.7	<0.5	<0.9	<0.9	<1.2	<0.5			
		C870	0.301	0.245		(2.3)	(1.8)													
	Humidifier Oper.	C919	0.453	0.848	216	12.2	1.7	A453	0.785	2.339	1.3	<1.6	0.7	<0.9	<0.9	<1.2	<0.5			
		C918	0.426	0.504		(2.9)	(2.1)													
	Humidifier Oper.	C905	0.394	1.666	481	5.7	1.5	A476	0.691	0.566	1.3	<1.9	<0.6	<1.0	<1.0	<1.4	<0.6			
		C908	0.330	3.626		(2.1)	(1.5)													
	Humidifier Oper.	C866	0.666	0.833	275	4.6	1.3	A437	0.772	0.350	1.5	<1.7	<0.5	<0.9	<0.9	<1.2	<0.5			
		C857	0.405	1.198		(1.8)	(1.4)													
	Board Utility	C909	0.368	1.303	146	22.5	2.4	A471	0.804	8.479	0.5	<1.6	5.6	<0.9	<0.9	<1.2	<0.5			
		C928	0.443	0.324		(2.7)	(1.8)													
	Board Utility (Ceiling)	C882	0.056	6.911	107	21.5	2.6													
						(2.1)	(1.7)													
	Board Utility							A455	0.652	0.626	1.7	<2.0	<0.6	<1.0	<1.1	<1.7	<0.6	W050	0.683	0.126
	Board Utility	C0913	0.389	0.441	198	15.8	1.3	A473	0.762	1.079	0.2	<1.7	<0.4	<0.9	<0.9	<1.2	<0.5			
		C0904	0.344	0.623		(3.1)	(1.9)													
Tile Dept.	Line Setup (Ceiling)	C932	0.052	4.888	295	15.9	2.1	A463b	0.844	(negl.)	0.3	<1.5	<0.5	<0.9	<0.8	<0.8	<0.4			
		C906	0.179	2.439		(2.5)	(1.8)													
		C963	0.254	0.325																
	Utility Setup	C933	0.054	3.946	268	12.9	1.9	A470	0.882	6.900	0.6	<1.5	5.0	<0.8	<0.8	<1.1	<0.5			
		C830	0.372	0.587		(2.3)	(1.8)													
		C958	0.415	0.234																

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Area	Payroll Title	Fiber Counting Sample No.	Fiber Counting Flow (m^3)	Fiber Counting f/cc	Fiber Counting N	Fiber Counting Count Median Length (SD)	Fiber Counting Count Median Diam. (SD)	Total Airborne Particulate Material Sample No.	Total Airborne Particulate Material Flow (m^3)	Total Airborne Particulate Material Total mg/m^3	Elemental Concentration (μg/m3) Zn	Pb	Mn	Cr	Co	Ni	Cd	Respirable Particulate Material Sample No.	Respirable Particulate Material Flow (m^3)	Respirable Particulate Material Total mg/m3
Tile Dept.	Utility Setup	C920 C957	0.286 0.435	0.556 0.201	129	12.2 (2.9)	1.4 (2.1)	A466	0.780	1.637	0.6	<1.6	<0.5	<0.9	<0.9	<1.2	<0.5			
	Line Operator							A446	0.780	2.364	1.3	<1.7	<0.5	<0.9	<0.9	<1.2	<0.5	W47	0.641	0.275
	Line Attendant							A395	0.536	10.280	0.4	<2.4	2.1	<1.3	<1.3	<2	<0.7	W48	0.431	0.752
	Paint Operator	C971 C876	0.405 0.313	1.053 0.898	303	12.9 (2.4)	2.0 (1.6)	A452	0.749	6.740	0.8	<1.7	3.0	<1.0	<0.9	<1.4	<0.6			
	Sorter Packer	C974 C860	0.401 0.362	1.043 0.597	238	14.2 (2.5)	2.0 (1.7)	A436	0.751	3.928	0.7	1.7	1.9	<1.0	<0.9	<1.4	<0.5			
	Sorter Packer	C967 C874	0.392 0.368	0.782 0.519	260	10.6 (2.6)	2.2 (1.7)	A458	0.766	2.027	0.3	<1.7	<0.5	<0.9	<0.9	<1.2	<0.6			
	Sorter Packer	C970 C865	0.430 0.362	0.476 0.695	239	18.2 (2.6)	2.3 (1.7)	A438	0.798	2.134	1.4	<1.6	<0.5	<0.9	<0.9	<1.2	<0.5			
	Sorter Packer	C964 C859	0.425 0.315	0.739 0.239	194	18.8 (2.5)	2.3 (1.8)	A439	0.737	1.818	1.1	<1.8	<0.5	<0.9	<0.9	<1.4	<0.6			
	Sorter Packer							A457	0.729	2.336	1.6	<1.8	<0.5	<1.0	<1.0	<1.4	<0.7	W63	.0667	0.223
	Tile Utility	C952 C864	0.399 0.350	1.315 1.110	311	13.1 (2.4)	2.1 (1.6)	A451	0.738	1.602	0.6	<1.8	<0.5	<1.0	<0.9	<1.4	<0.6			
	Stacker	C855	0.737	1.085	233	6.3 (2.1)	1.5 (1.4)	A390	0.753	0.610	0.9	<1.7	<0.53	<0.9	<0.9	1.4	<0.5			
Technical Dept.	Paint Technician							A419	0.805	2.466	<0.3	<1.6	<0.7	<0.9	<0.9	<1.2	<0.5	W041	0.651	0.367
	Tile Inspec.	C891	0.693	0.518	124	11.4 (2.4)	1.7 (1.6)	A391	0.692	1.785	1.0	<1.9	<0.6	<1.0	<1.0	1.4	<0.6			

Area	Payroll Title	Fiber Counting Sample No.	Fiber Counting Flow (m³)	Fiber Counting f/cc	Fiber Counting N	Count Median Length (SD)	Count Median Diam. (SD)	Total Airborne Particulate Material Sample No.	Flow (m³)	Total mg/m³	Elemental Concentration (µg/m3) Zn	Pb	Mn	Cr	Co	Ni	Cd	Respirable Particulate Material Sample No.	Flow (m³)	Total mg/m³
	Wool & Board Inspec.	C925 C956	0.193 0.466	0.484 0.503	172	17.3 (3.1)	2.0 (2.0)											W57	0.745	0.039
	Wool & Board Inspec.							A432	0.812	10.177	0.8	<1.6	2.0	<0.9	<0.9	<1.2	<0.5	W62	0.688	0.356
	Wool & Board Inspec.	C897	0.688	0.264	96	14.1 (2.5)	1.8 (1.7)	A394	0.645	1.405	0.8	<2.0	<0.6	<1.1	<4.0	<1.4	<0.6			
Maint.Dept.	Shift Mechanic	C878 C898	0.276 0.432	0.326 0.155	82	16.4 (2.7)	1.6 (1.9)	A408	0.855	1.878	2.9	2.1	1.3	0.8	0.8	<1.2	<0.5			
	Shift Mechanic	C852	0.746	0.323	125	32.7 (1.6)	2.1 (1.6)	A392	C.716	1.786	7.3	<2.3	1.0	<1.0	<1.0	1.4	<0.6			
	Shift Mechanic	C940 C959	0.585 0.256	0.434 0.184	154	7.5 (2.7)	1.6 (1.6)	A465	0.707	0.604	0.6	<1.8	<0.6	<1.0	<1.0	<1.4	<0.6			
	Shift Mech.(elec.)	C892	0.909	0.348	103	22.2 (2.0)	3.2 (1.8)	A413	0.743	1.883	0.9	<1.7	<0.5	<0.9	<0.9	<1.4	<0.5			
	Shift Mech.(elec.)	C951 C961	0.106 0.420	0.322 0.075	34	21.3 (2.5)	2.6 (1.8)	A459	0.727	0.245	1.4	<1.8	<0.6	<1.0	<1.0	<1.4	<0.5			
Maint.Dept.	Shift Mech.(elec.)	C887 C894	0.283 0.547	0.351 0.100	77	14.9 (2.9)	1.7 (2.1)	A417	0.906	1.152	4.1	3.8	0.7	<0.8	<0.8	<1.1	<0.4			
	Utility Mechanic	C962 C954	0.420 0.487	0.140 0.332	110	29.9 (2.6)	2.2 (2.0)	A462	0.577	0.740	1.9	<2.2	<0.7	<1.2	<1.2	<1.7	<0.6			
	Utility Mechanic	C886	0.725	0.164	63	10.8 (2.3)	2.4 (2.9)	A487	0.658	1.155	2.0	<2.0	1.5	<1.0	<1.1	<1.4	<0.6			
	Utility Mechanic	C888 C900	0.276 0.461	0.587 0.104	109	12.7 (2.7)	1.7 (1.8)	A397	0.860	0.735	0.5	<1.5	<0.5	<0.8	<0.8	<1.2	<0.5			

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Area	Payroll Title	Fiber Counting: Sample No.	Flow (m^3)	f/cc	N	Count Median Length (SD)	Diam. (SD)	Total Airborne Particulate Material: Sample No.	Flow (m^3)	Total mg/m^3	Elemental Concentration (µg/m^3): Zn	Pb	Mn	Cr	Co	Ni	Cd	Respirable Particulate Material: Sample No.	Flow (m^3)	Total mg/m^3
Wool Dept.	Area Sample	C935 C944	0.402 0.295	>10* >10*	*	13.9 (2.8)	1.3 (1.9)													
Board Dept.	Area Sample	C883 C887	0.248 0.283	1.666 0.362	154	13.9 (2.8)	1.3 (1.9)	A412	0.812	1.100	4.7	<1.6	<0.5	<0.9	<0.9	<1.2	<0.5			
Tile Dept.	Area Sample							A461	0.856	1.991	0.9	<1.5	<0.5	<0.8	<0.8	<1.2	<0.4	W61	0.745	0.119
Traffic Dept. (Warehouse)	Area Sample	C893	0.253	0.701	92	11.0 (2.1)	1.8 (1.6)	A486	0.263	1.510	3.0	<4.9	<1.1	<2.7	<2.3	<3.8	<1.5			
	Area Sample	C966	0.776	0.051	21	7.1 (2.3)	1.7 (1.3)	A440	0.764	0.145	1.0	<1.7	<0.5	<0.9	<0.9	<1.2	<0.5			
	Area Sample	C896	0.729	0.439	109	22.4 (2.2)	2.3 (1.7)	A441	0.727	0.618	<0.2	<1.8	<0.4	<1.0	<1.0	<1.4	<0.6			
Maint.Dept. (Storeroom)	Area Sample	C851	0.710	0.011	4	5.2 (2.0)	1.0 (1.4)													
Maint. Shop	Area Sample	C968 C953	0.230 0.442	0.233 0.061	41	10.7 (2.5)	1.7 (1.6)													
Lunch Room	Area Sample	C826	0.740	0.052	20	9.8 (2.1)	1.6 (1.7)													

*Fibers too numerous to count (>20 fibers/field)

Table 7

TOTAL SUSPENDED PARTICULATE MATERIAL

Celotex, Pittston

mg/m^3	No. Samples	Percent	Cum. %
≤ 0.05			
0.051 - 0.100			
0.101 - 0.200	1	1.6	1.6
0.201 - 0.400	4	6.6	8.2
0.401 - 0.800	12	19.7	27.9
0.801 - 1.600	14	23.0	50.8
1.601 - 3.200	18	29.5	80.3
3.201 - 6.400	6	9.8	90.2
6.401 -12.800	6	9.8	100.0
	61	100.0	

Table 8

AIRBORNE FIBER COUNTS

Celotex, Pittston

f/cc	No. Samples	Percent	Cum. %
≤ 0.05	1	1.1	1.1
0.051 - 0.100	6	6.4	7.4
0.101 - 0.200	8	8.5	16.0
0.201 - 0.400	22	23.4	39.4
0.401 - 0.800	25	26.6	66.0
0.801 - 1.600	19	20.2	86.2
1.601 - 3.200	9	9.6	95.7
3.201 - 6.400	3	3.2	98.9
6.401 -12.800	1	1.2	100.0
	94	100.0	

Table 9

TIME-WEIGHTED AVERAGES FOR SUB-CATEGORIES: PITTSTON

		T W A s			
		Fiber Counting		Total Suspended Particulate	
Area	Payroll Title	n	Fibers/cc	n	mg/m^3
Wool Dept.	Charger	3	0.293	3	4.514
	Cupola Operator	3	0.322	3	0.819
	Wool Utility	2	1.502	3	6.477
Board Dept.	Stock Preparer	6	0.834	3	3.441
	Stock Mix Oper.	4	0.965	3	2.325
	Texture Control	6	0.547	3	0.715
	Oven Loader	4	0.401	3	0.495
	Oven Operator	6	2.260	3	0.773
	Dry Helper	6	1.254	3	1.032
	Humidifier Oper.	6	1.306	3	1.111
	Board Utility	5	0.987	3	3.628
Tile Dept.	Line Setup	3	1.594	1	----- (negligible)
	Utility Setup	5	0.496	2	4.43
	Line Operator	-	-----	1	2.364
	Line Attendant	-	-----	1	10.280
	Paint Operator	2	0.985	1	6.740
	Sorter-Packer	8	0.647	5	2.472
	Tile Utility	2	1.219	1	1.602
	Stacker	1	1.085	1	0.610
Technical Dept.	Paint Tech.	-	-----	1	2.466
	Tile Inspector	1	0.518	1	1.785
	Wool & Board Insp.	3	0.378	2	6.294
Maint. Dept.	Shift Mech.	5	0.305	3	1.454
	Shift Mech. (elec.)	5	0.237	3	1.103
	Utility Mech.	5	0.232	3	0.868
Traffic Dept.	Area Sampler	3	0.305	3	0.546

Table 10

GEOMETRIC MEANS AND UPPER (UCL)

AND LOWER (LCL) 95% CONFIDENCE LIMITS

FOR PERSONAL EXPOSURES: PITTSTON

		Fiber Counting Fibers/cc				Total Suspended Particulate ng/m³			
Area	Payroll Title	n	Mean	UCL	LCL	n	Mean	UCL	LCL
Wool Dept.	Charger	3	0.197	1.112	0.035	3	4.056	54.468	0.302
	Cupola Oper.	3	0.331	0.500	0.219	3	0.674	4.571	0.099
	Wool Utility	2	0.822	$>10^5$	$<10^{-5}$	3	5.644	137.497	0.232
Board Dept.	Stock Preparer	6	0.674	2.393	0.190	3	3.324	26.541	0.416
	Stock Mix Oper.	4	0.945	2.409	0.371	3	1.978	13.924	0.281
	Texture Control	6	0.495	1.173	0.209	3	0.688	1.570	0.302
	Oven Loader	4	0.351	1.089	0.113	3	0.208	39.392	0.001
	Oven Operator	6	1.650	5.149	0.529	3	0.679	4.434	0.104
	Dry Helper	6	0.918	2.318	0.363	3	0.996	2.341	0.424
	Humidifier Oper.	6	1.171	2.573	0.533	3	0.774	9.213	0.065
	Board Utility	4	0.633	2.167	0.185	3	1.789	53.515	0.060
Tile Dept.	Line Setup	2	0.890	$>10^5$	$<10^{-5}$	1	-----	-------	-----
	Utility Setup	4	0.352	0.759	0.163	1	1.637	-------	-----
	Line Operator	-	-----	-----	-----	1	2.364	-------	-----
	Line Attendant	-	-----	-----	-----	1	10.28	-------	-----
	Paint Oper.	2	0.972	2.674	0.354	1	6.74	-------	-----
	Sorter Packer	8	0.590	0.902	0.386	5	2.353	4.709	1.176
	Stacker	1	1.085	-----	-----	1	0.610	-------	-----
Tech. Dept.	Paint Technician	-	-----	-----	-----	1	2.466	-------	-----
	Tile Inspector	1	0.518	-----	-----	1	1.785	-------	-----
	Wool & Board Insp	3	0.401	0.928	0.173	2	3.781	$>10^6$	$<10^{-5}$
Maint. Dept.	Shift Mech.	5	0.265	0.446	0.157	3	1.265	5.554	0.288
	Shift Mech. (elec.)	5	0.197	0.430	0.090	3	0.810	11.572	0.057
	Utility Mech.	5	0.216	0.518	0.090	3	0.856	1.544	0.475
Traffic Dept.	Area Sampler	3	0.250	7.634	0.008	3	0.513	10.899	0.024
All	Area Sampler	11	0.343	1.433	0.082	5	0.784	2.959	0.208

Table 11

GEOMETRIC MEANS AND UPPER (UCL)

AND LOWER (LCL) 95% CONFIDENCE

LIMITS FOR PERSONAL SAMPLES BY AREA: PITTSTON

Area	Fiber Counting				Total Susp. Particulate			
		Fibers/cc						
	n	Mean	UCL	LCL	n	Mean	UCL	LCL
Wool Dept.	8	0.342	0.771	0.152	9	2.489	6.591	0.940
Board Dept. (Wet Mix Ops.)	16	0.654	1.056	0.405	10	1.590	2.730	0.926
Board Dept. (Dry Ops)	18	1.210	1.870	0.783	9	0.805	1.307	0.496
Tile Dept. (Setup)	6	0.480	1.298	0.177	-	-----	-----	-----
Tile Dept. (Others)	13	0.746	1.016	0.548	10	2.548	4.880	1.331
All Utility Workers (Wool, Board, Tile)	8	0.794	1.348	0.468	6	2.407	7.709	0.752
All Area (Not Breathing Zone)	11	0.343	1.433	0.082	5	0.784	2.959	0.208

Table 12

DIAMETER DISTRIBUTIONS OF ALL FIBERS: CELOTEX

Porton Category	Upper Size (μm)	Number	%	Cum. %
≤ 1	0.91	572	5.5	5.5
1≤ 2	1.28	2872	27.7	33.3
2≤ 3	1.81	2740	26.5	59.7
3≤ 4	2.56	1574	15.2	74.9
4≤ 5	3.62	1057	10.2	85.1
5≤ 6	5.12	804	7.8	92.9
> 6		738	7.1	100.0
		10357		

Table 13

LENGTH DISTRIBUTIONS OF ALL FIBERS: CELOTEX

Porton Category	Upper Size (μm)	Number	%	Cum. %
≤ 4	2.56	7	0.1	0.1
4≤ 6	5.12	3401	32.8	32.9
6≤ 8	10.24	2336	22.6	55.5
8≤ 10	20.48	1873	18.1	73.5
10≤ 13	57.93	1978	19.1	92.6
> 13		762	7.4	100.0
		10357		

Table 14

FREQUENCIES OF OCCURRENCE

OF COUNT MEDIAN (GEOMETRIC MEAN) DIAMETERS: CELOTEX

Mean Diameter (μm)	Numbers of Samples	%	Cum. %
≤1.0	1	1.7	1.7
1.1 - 1.2	3	5.2	6.9
1.3 - 1.5	13	22.4	29.3
1.6 - 1.9	18	31.0	60.3
2.0 - 2.5	19	32.8	93.1
≥2.6	4	6.9	100.0
	58	100.0	

Table 15

FREQUENCIES OF OCCURRENCE

OF COUNT MEDIAN (GEOMETRIC MEAN) LENGTHS: CELOTEX

Mean Length (μm)	Numbers of Samples	%	Cum. %
≤4.9	4	6.9	6.9
5.0 - 6.9	5	8.6	15.5
7.0 -10.9	9	15.5	31.0
11.0 -16.9	22	37.9	68.9
17.0 -24.9	15	25.9	94.8
≥25.0	3	5.2	100.0
	58		

Table 16

COMPARISON OF FIBER COUNTS

BY ELECTRON (SEM) AND OPTICAL OM) MICROSCOPY

Sample #	Fibers/cc		Difference
	SEM	OM	SEM-OM
873	3.12	0.320	2.800
876	2.4	0.898	1.502
897	0.264	0.264	0.000
903	1.44	2.035	-0.595
909	1.36	1.803	-0.443
962	0.360	0.140	0.220
964	0.72	0.74	-0.020
966	0.128	0.051	0.077

Table 17

Celotone Ceiling Tile Fiber Diameters

1957 - 1976 - Celotex

Sample #	Date	Geometric Mean (μm)	Geometric S.D.	# of Fibers Sized
CB-5	July 1957	5.1	2.1	110
CB-7	April 1962	3.2	1.9	525
CB-9	April 1967	3.7	2.3	107
CB-10	Feb. 1973	3.6	1.9	119
CB-8	Dec. 1976	3.6	2.3	111

Table 18

Current Bulk Sample Fiber Diameters

Sample #	Description	Geometric Mean (μm)	Geometric S.D.	N
CB-1	"Flywool" - Rafter sample	4.1	2.3	113
CB-2	Product wool - as delivered to line	3.5	2.6	101
CB-3	Rafter sample-wool room @ head height	3.1	2.5	111
CB-4	Product wool-as delivered to line	2.9	2.3	108
CB-6	Cutting scraps near cutoff saw - tile	4.0	1.9	161

Table 19

X-Ray Fluorescence Analysis of Celotone Ceiling Tile; 1957-1976

ELEMENT	CB-5	CB-8	CB-10	CB-9	CB-7
Cr	< 90	≤ 100	< 75	< 75	< 75
Mn	.25%	.11%	950	.11%	.16%
Fe	.21%	.36%	.26%	.29%	.25%
Co	< 40	< 40	< 30	< 35	< 35
Ni	< 20	< 25	< 25	< 20	< 25
Cu	< 30	≤ 30	< 25	70	< 20
Zn	.64%	≤ 50	≤ 45	≤ 50	.48%
Hg	< 20	< 25	< 15	< 20	< 15
Pb	< 15	< 25	< 20	≤ 25	< 15
As	< 25	< 30	< 35	< 30	< 20
Se	< 10	< 15	< 15	< 10	< 10
Ag,Cd	< 75	< 110	< 100	< 105	< 80
Ti	< 140	.83%	.67%	.79%	< 300
Sn	< 210	< 150	< 200	< 200	< 150
K	.56%	.47%	.16%	≤ 550	.24%
Ca	18 %	13 %	11 %	10 %	16 %
Sr	950	< 35	115	110	260
Ba	1.9%	< 350	< 350	< 350	1.4%
Rb	< 25	< 40	< 30	< 40	< 40

*CONCENTRATIONS IN ug/gm
unless otherwise stated.

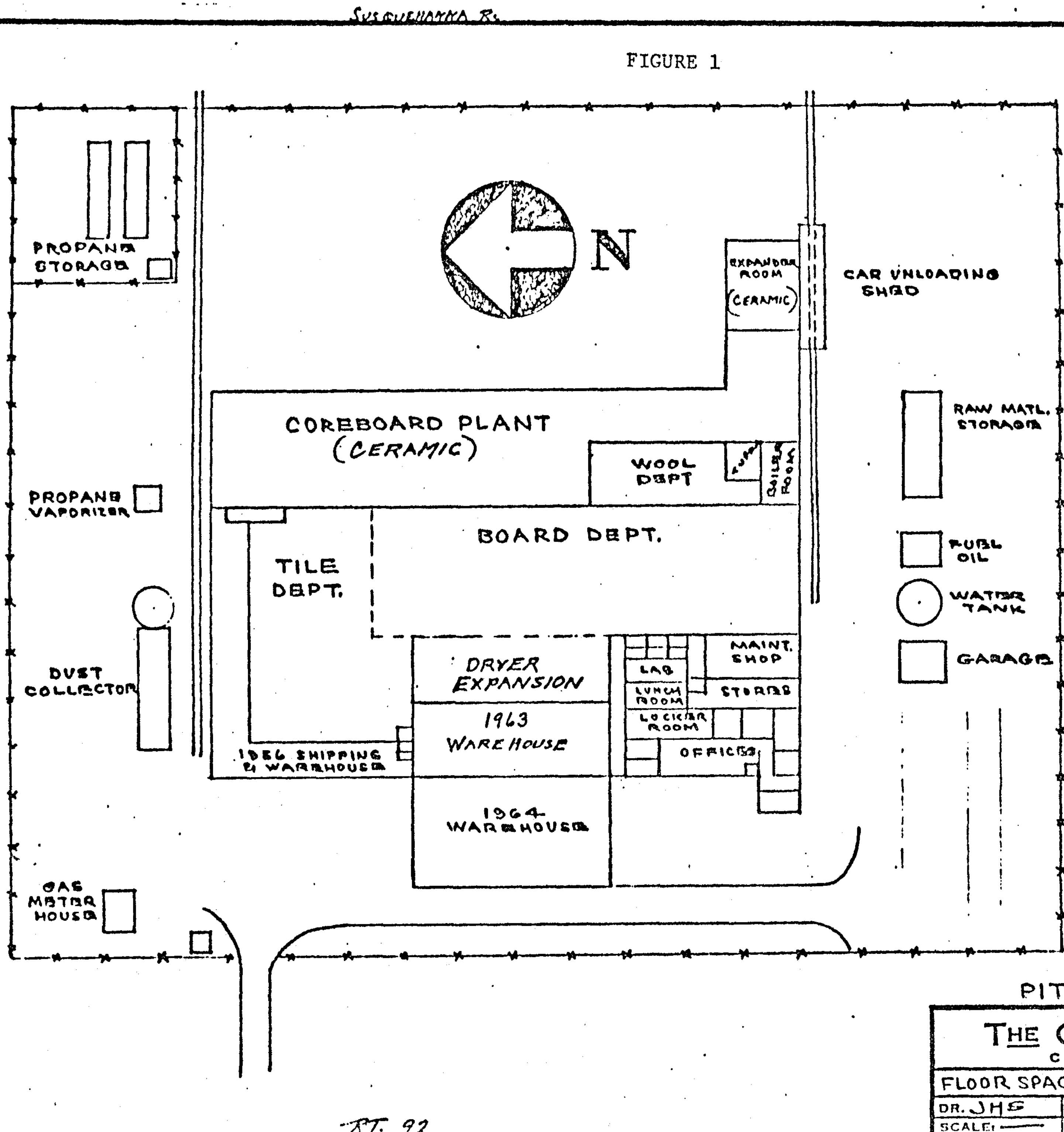
Table 20

X-Ray Fluorescence Analysis of Current Mineral Wool Fibers

ELEMENT	CB-6	CB-4	CB-2	CB-1	CB-3
Cr	< 110	< 90	< 95	< 95	< 75
Mn	.12%	.25%	.23%	.21%	.16%
Fe	.44%	.52%	.58%	.71%	.74%
Co	< 31	< 50	< 45	< 45	< 40
Ni	< 20	< 25	< 25	< 20	< 25
Cu	≤ 50	< 25	≤ 65	< 20	≤ 60
Zn	≤ 70	≤ 42	≤ 40	≤ 50	≤ 72
Hg	< 10	< 30	< 25	< 25	< 15
Pb	< 15	< 25	< 15	< 25	< 15
As	< 25	< 15	< 40	< 30	< 30
Se	< 10	< 10	< 15	< 15	< 15
Ag, Cd	< 85	< 225	< 130	< 200	< 95
Ti	.61%	.37%	.46%	.44%	.40%
Sn	< 155	< 350	< 250	< 300	< 210
K	.21%	.58%	.49%	.40%	.40%
Ca	12 %	23 %	23 %	27 %	19 %
Sr	235	290	335	380	200
Rb	< 20	< 35	< 35	< 30	< 40
Ba	< 400	< 375	< 300	≤ 570	< 350

* CONCENTRATIONS IN ug/gm
unless otherwise stated.

FIGURE 1



FLOOR SPACE
PITTSTON PLANT

WOOL DEPT.	5,800
BOARD DEPT.	27,630
TILE DEPT.	11,760
1956 WHSE.	10,200
1963 WHSE.	6,260
1964 WHSE.	10,425
STORES / LUNCH ROOM / LOCKER ROOM / OFFICES / MAINT SHOP	13,275
COREBOARD PLANT	28,000
TOTAL SQ. FT. (APPROX.)	113,350

PITTSTON PLANT

THE CELOTEX CORPORATION
CHICAGO, ILLINOIS

FLOOR SPACE - OPER. FAC. & WAREHOUSES

DR. JHS | DATE 8-25-65 | SK-P-701
SCALE: — | CK.
REV. 7-76 RR

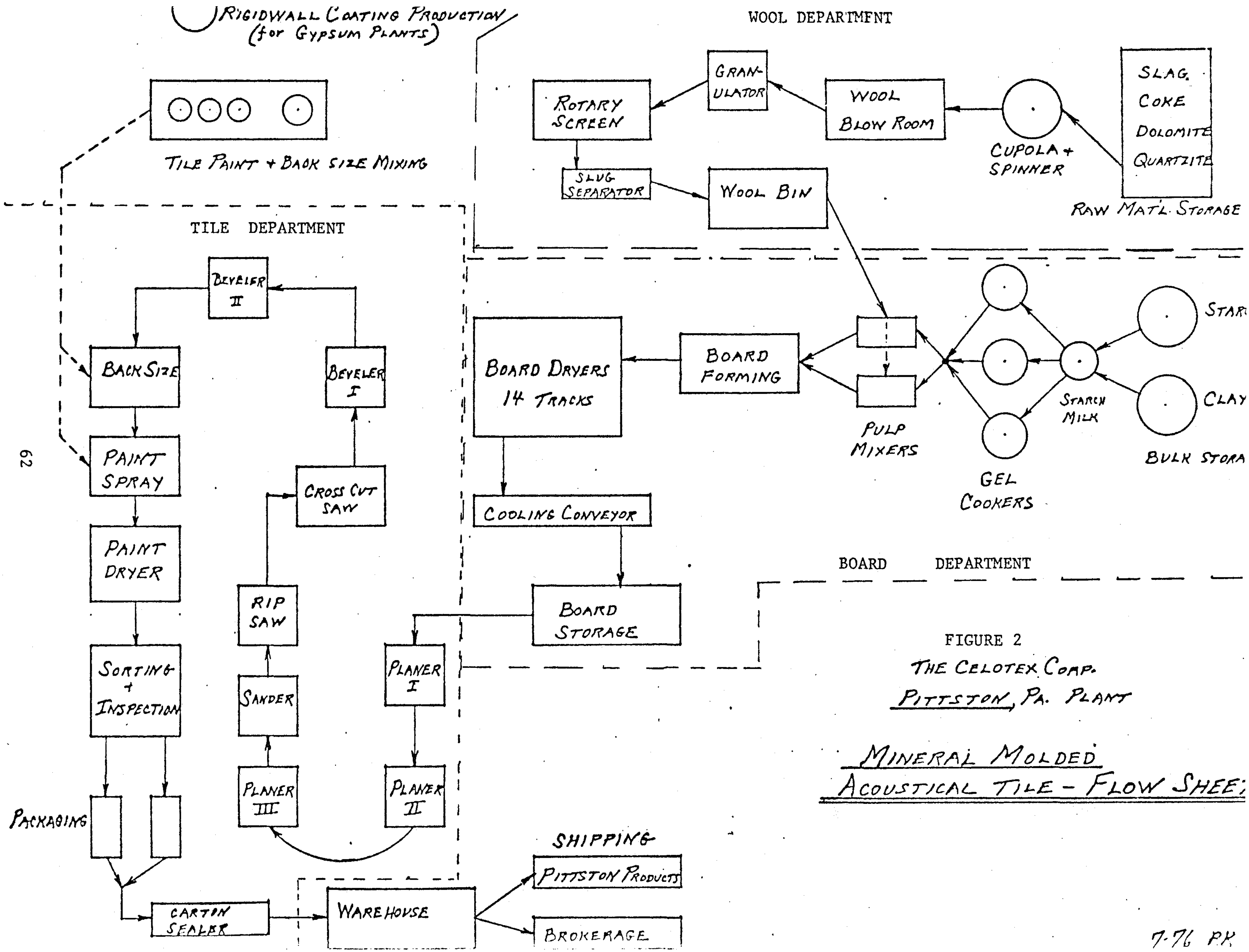


FIGURE 2
THE CELOTEX CORP.
PITTSTON, PA. PLANT

MINERAL MOLDED
ACOUSTICAL TILE - FLOW SHEE[T]

FIGURE 3

THE CELOTEX CORPORATION
PITTSTON PLANT – TECHNICAL DEPT.
FIBER DIAMETER

DATE: ______________

TIME: ______________

m MICRONS	FREQUENCY DISTRIBUTION	f	F	fm	X	
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
Totals						

CELL	F	X	$a = \frac{F}{EF}$	$b = \frac{X}{F}$	ab	ab^2	a^2	a^2b	
1-5									
6-10									
11-15									
16-20									
21-25									
TOTALS	EF								

f = Total Frequency
F = Total Cell Frequency
fm = f x Micron size
X = Total Cell fm
EF = Total Frequency of Cells

MICRON CALCULATION

Arithmetic Ave. $= \frac{\text{Sum of ab}}{100} =$ ______

Weighted Ave. $= \frac{\text{Sum of ab}^2}{\text{Sum of ab}} =$ ______

Freq. Weight.Ave. $= \frac{\text{Sum of a}^2\text{b}}{\text{Sum of a}^2} =$ ______

Signed: ______________

P-538

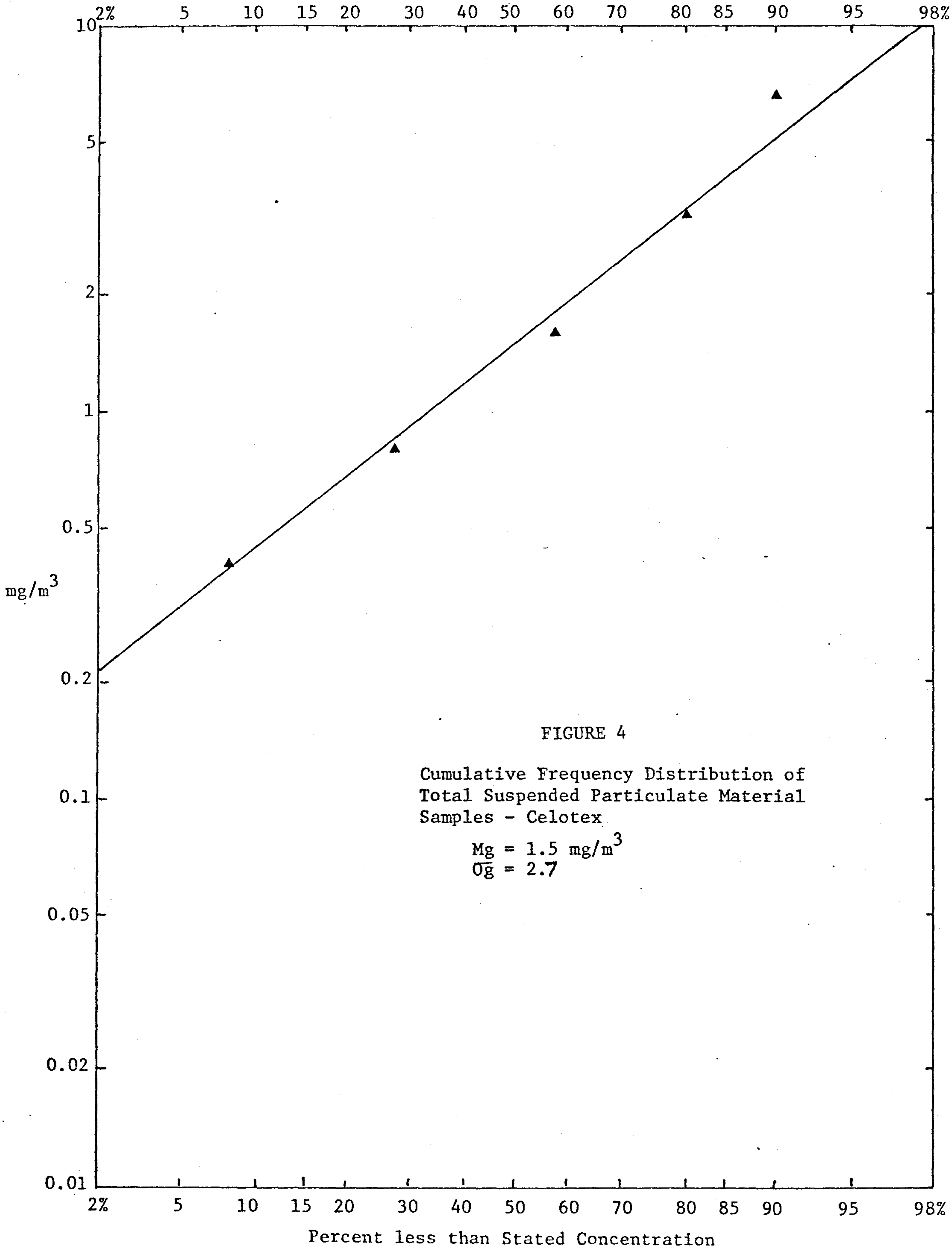


FIGURE 4

Cumulative Frequency Distribution of Total Suspended Particulate Material Samples - Celotex

M_g = 1.5 mg/m^3
σ_g = 2.7

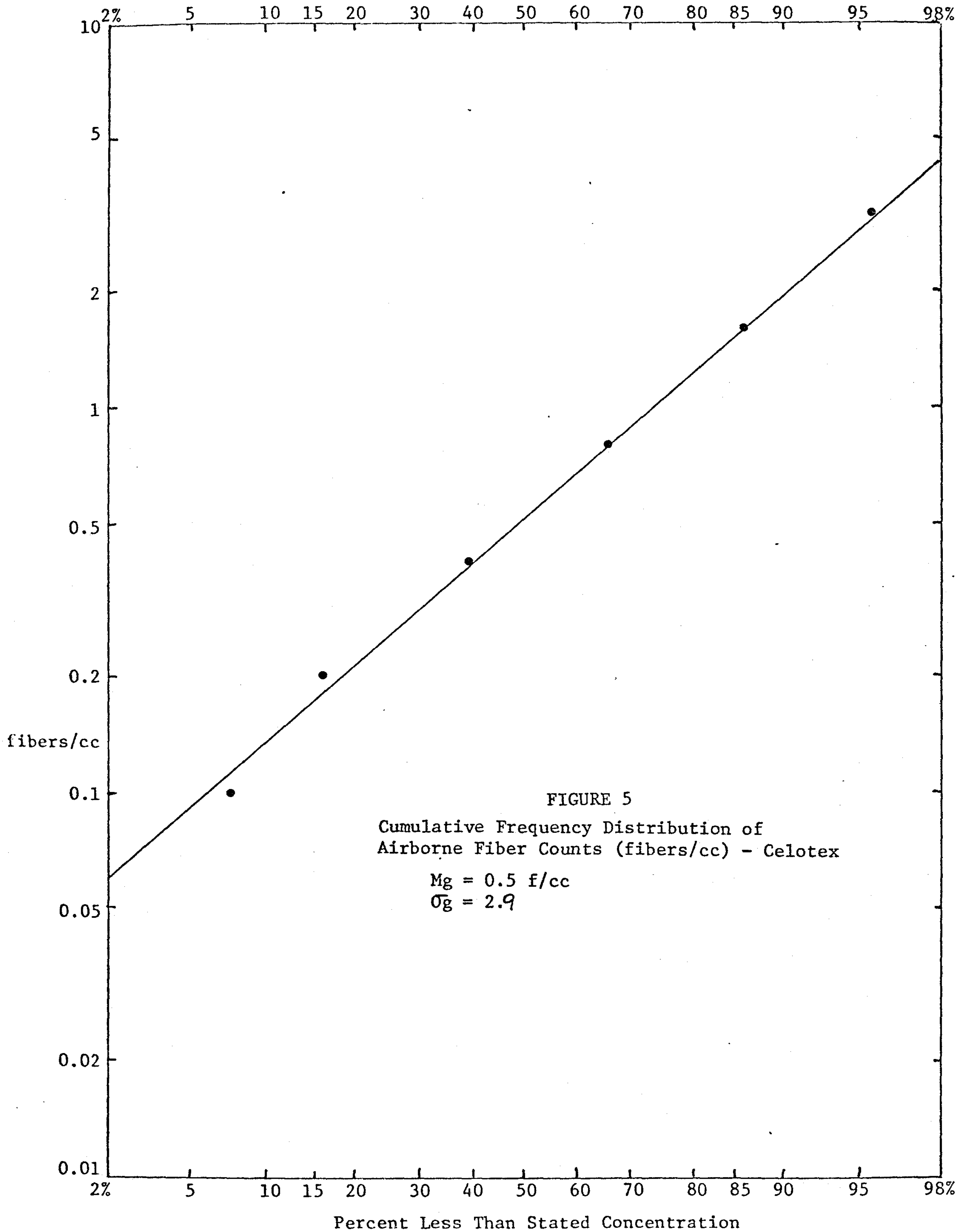


FIGURE 5

Cumulative Frequency Distribution of Airborne Fiber Counts (fibers/cc) - Celotex

$M_g = 0.5$ f/cc

$\sigma_g = 2.9$

FIGURE 6
GEOMETRIC MEANS, TWAS, AND UPPER AND LOWER CONFIDENCE LIMITS (95%) FOR
FIBER COUNTS - PITTSTON

(┼ GEOMETRIC MEAN   O TWA)

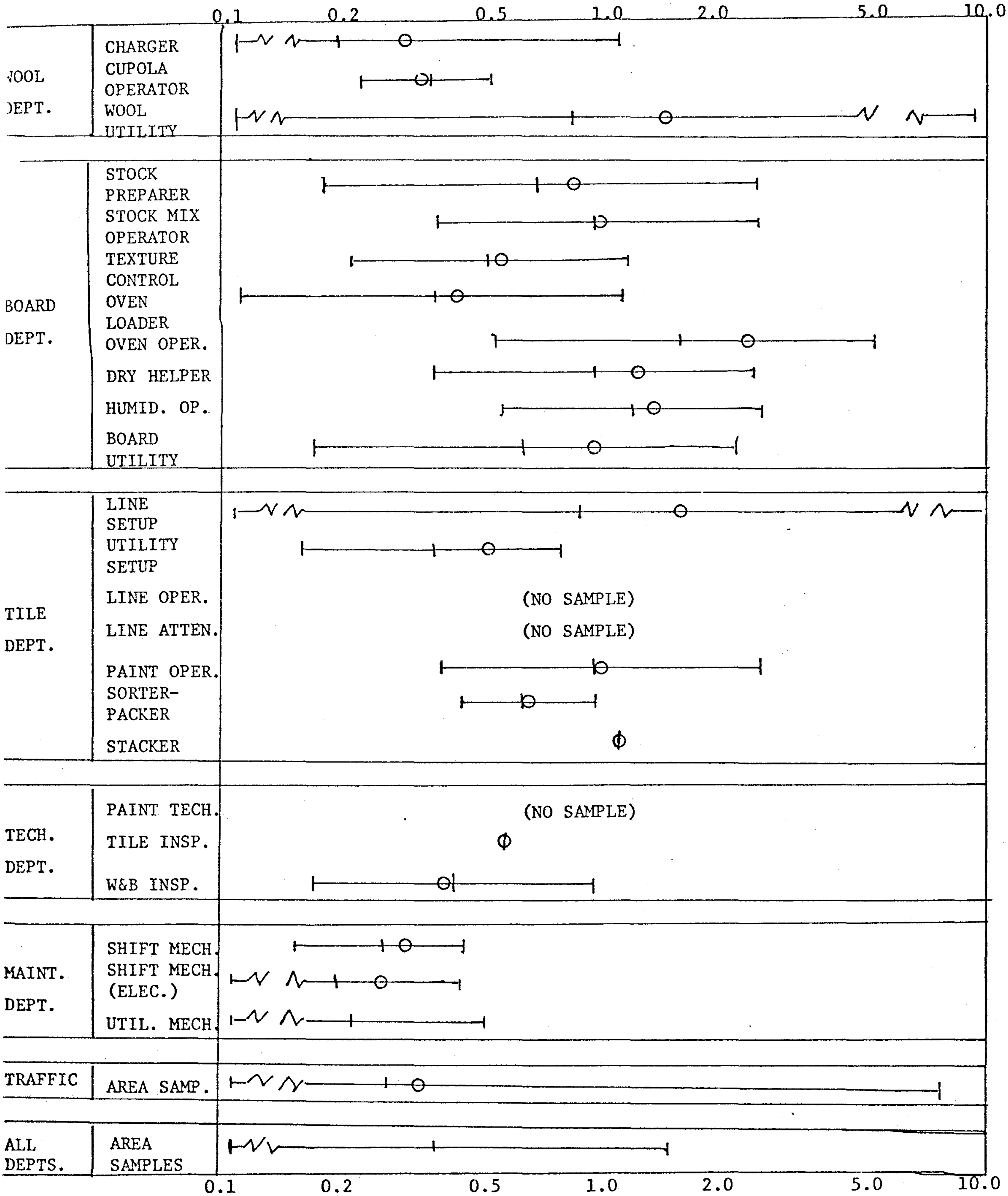


FIGURE 7
Geometric Means and 95% Confidence Limits on Means - Major Areas

Air Samples - Pittston

(Total Suspended Particulate Material = TSP)

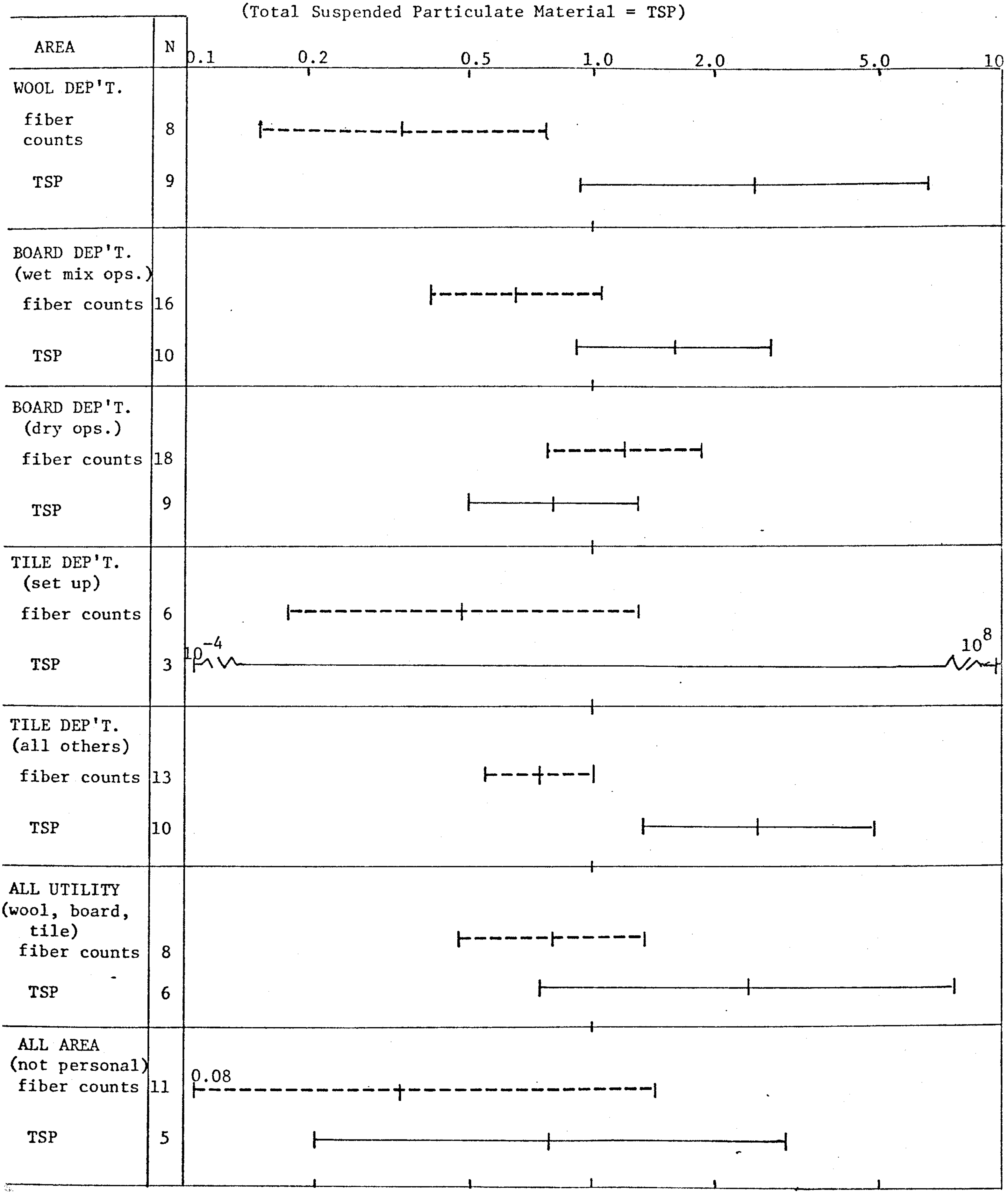


FIGURE 8

Linear Correlation of ln Total Suspended Particulate Material (mg/m^3) with fiber counts (fibers/cc) for Time-Weighted Averages for Job Categories

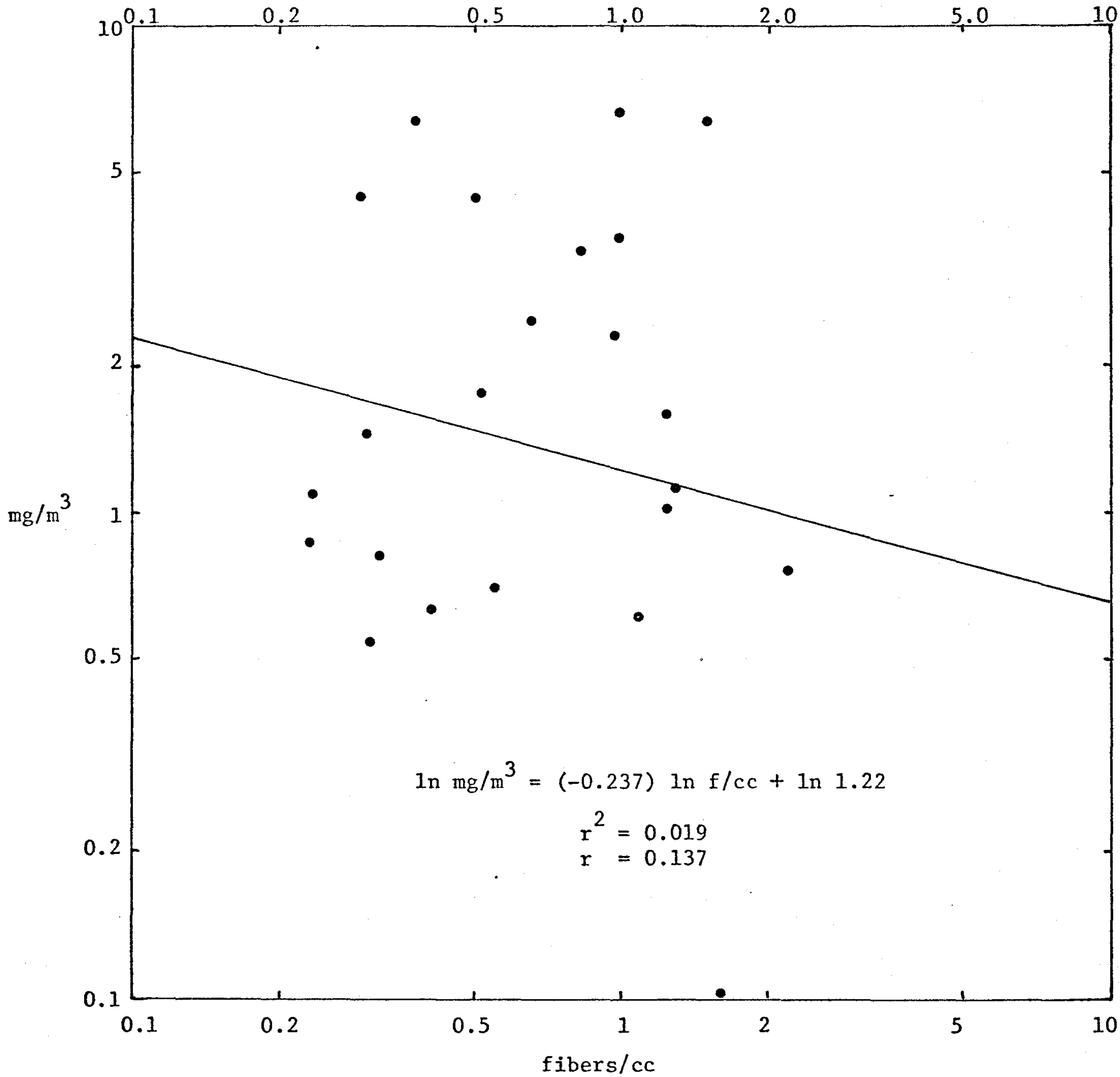


FIGURE 9

Linear Correlation of ln Fiber Counts With ln Total Suspended Particulate Material : Individual Air Samples - Pittston

$$\ln f/cc = 0.042 \ln mg/m^3 + \ln 0.564$$

$$r^2 = 0.0036$$

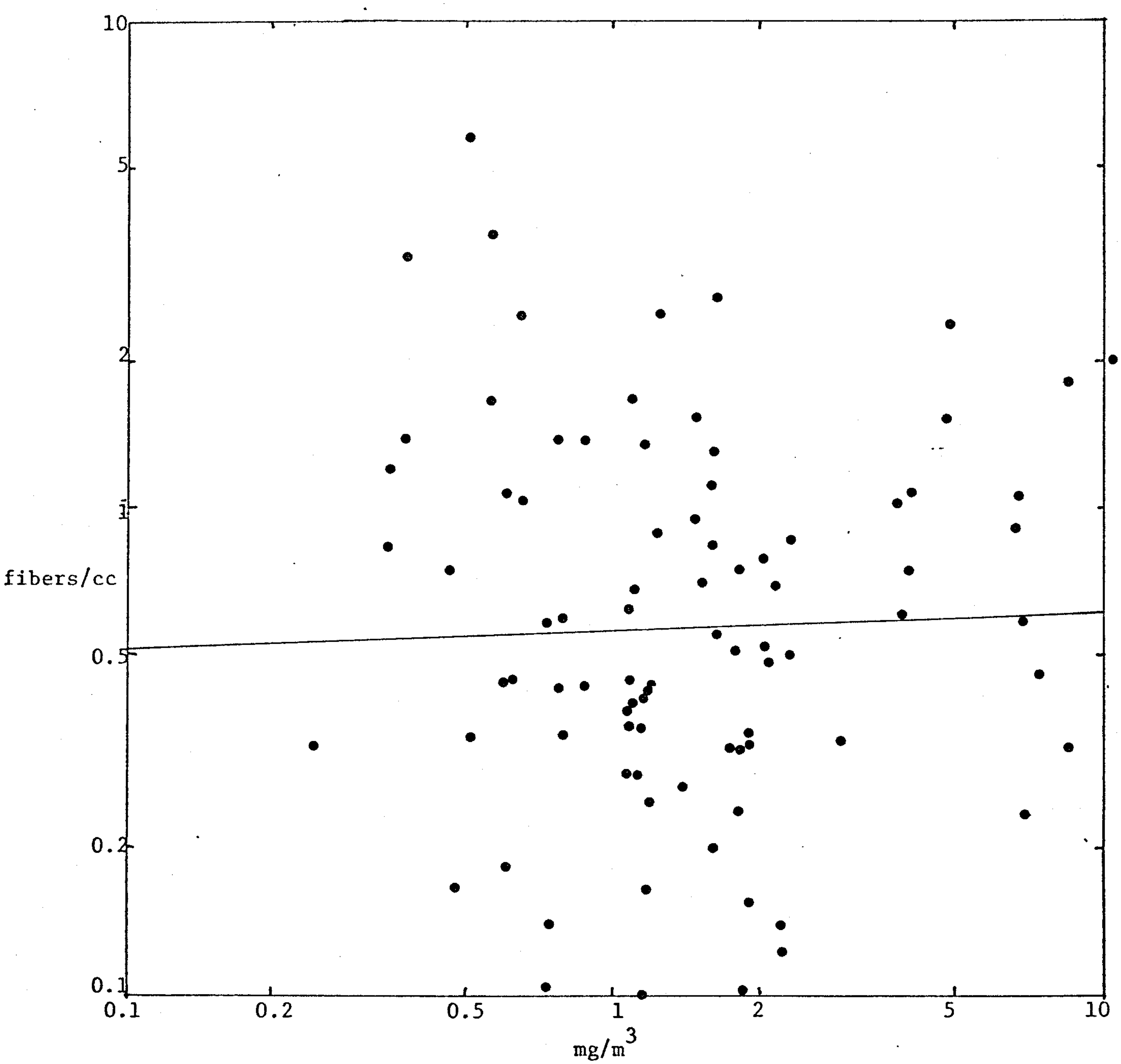


FIGURE 10

Linear Correlation of log Respirable Particulate Material (mg/m^3) With log Total Suspended Particulate Material (mg/m^3) (Pittston)

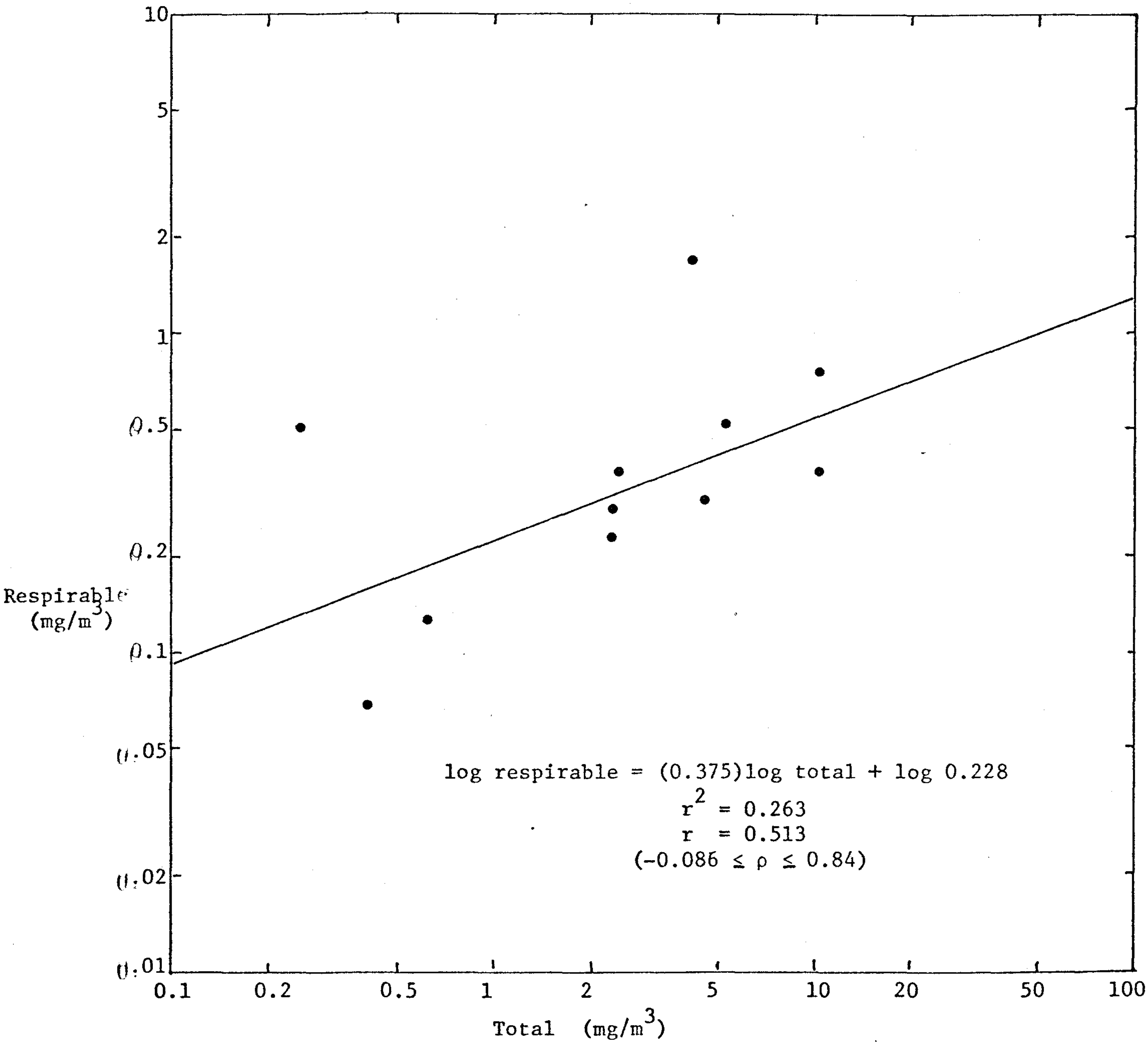
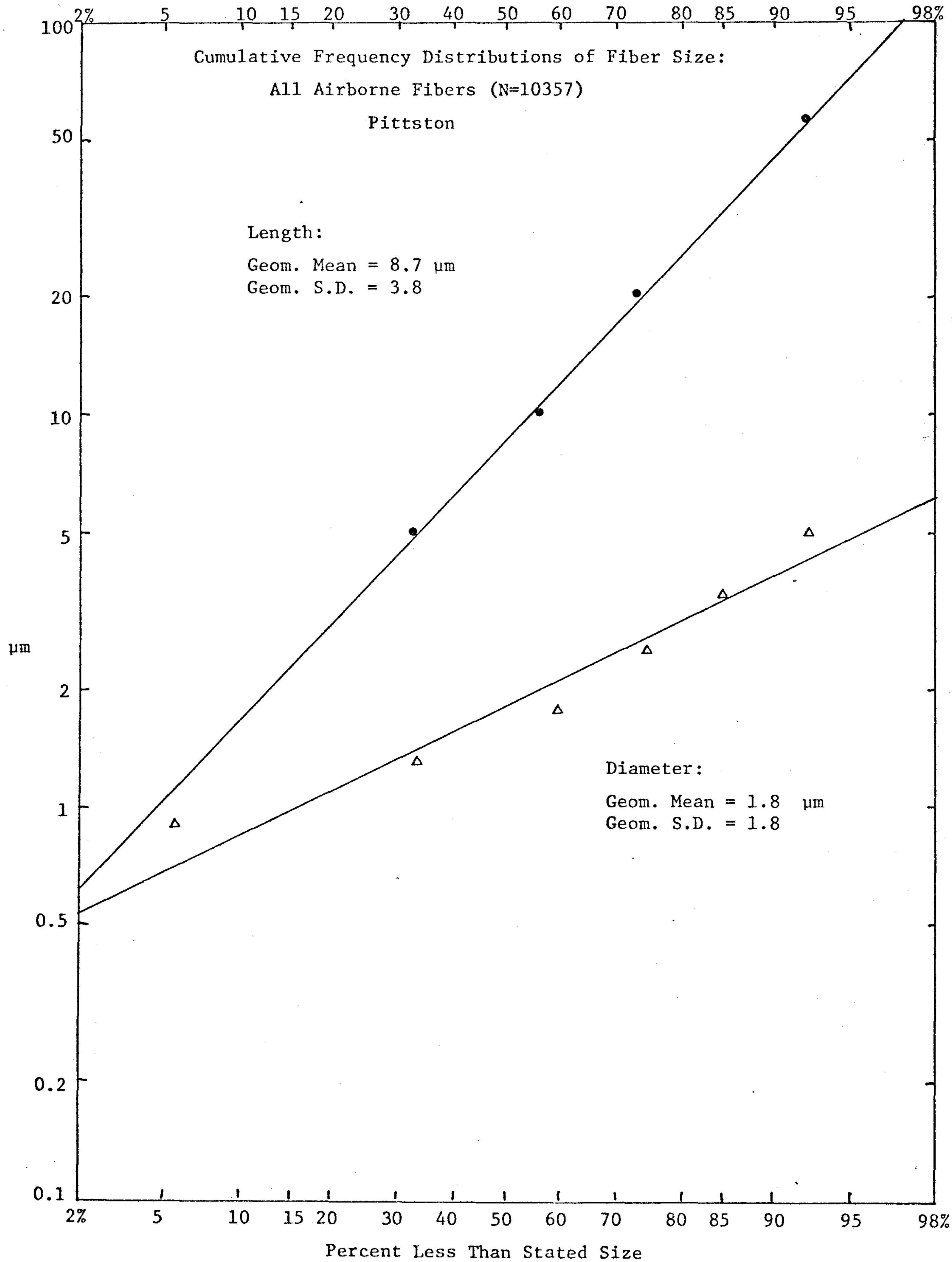


FIGURE 11


Cumulative Frequency Distributions of Fiber Size:
All Airborne Fibers (N=10357)
Pittston
Length:
Geom. Mean = 8.7 μm
Geom. S.D. = 3.8
Diameter:
Geom. Mean = 1.8 μm
Geom. S.D. = 1.8
μm
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

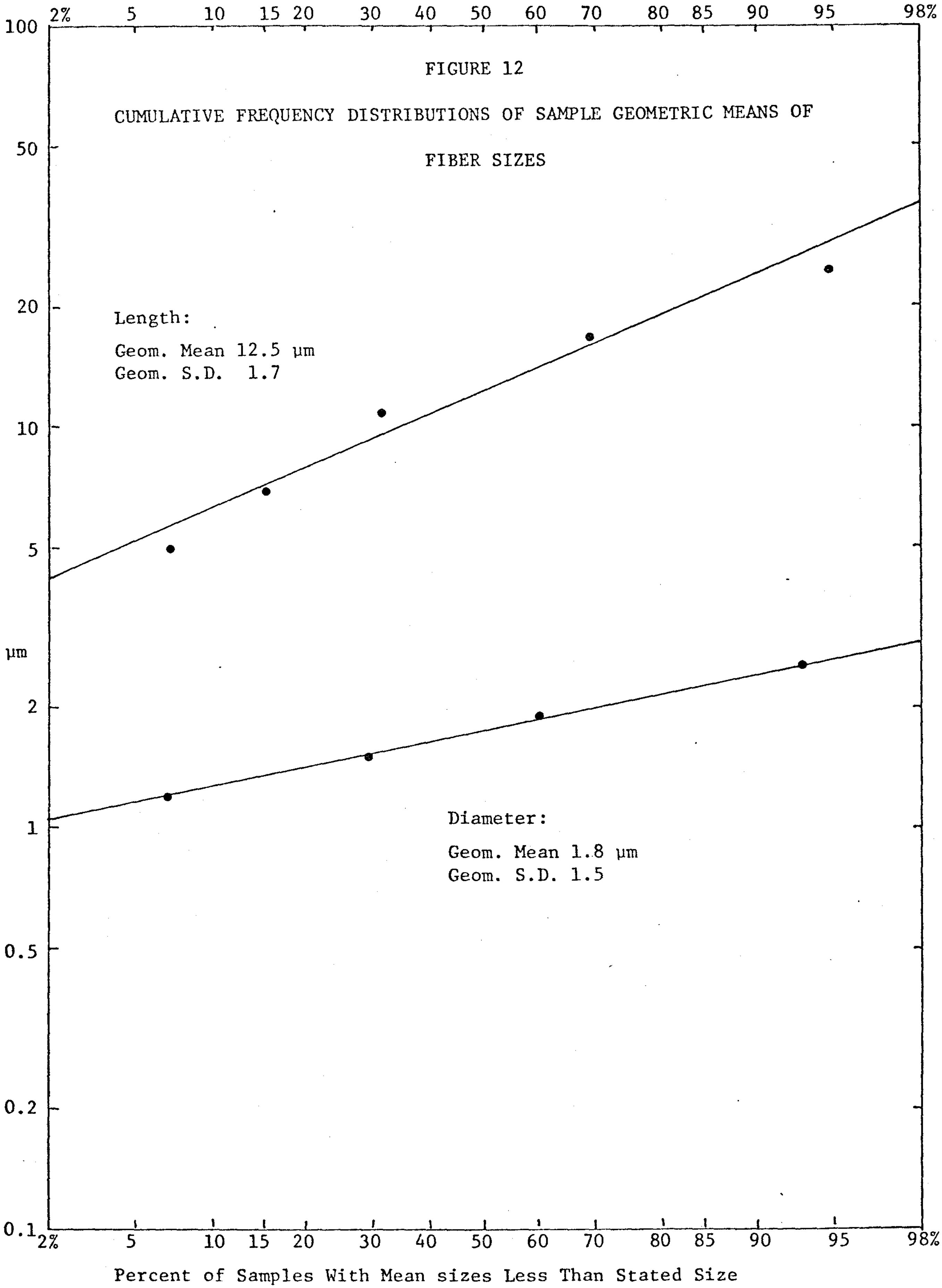
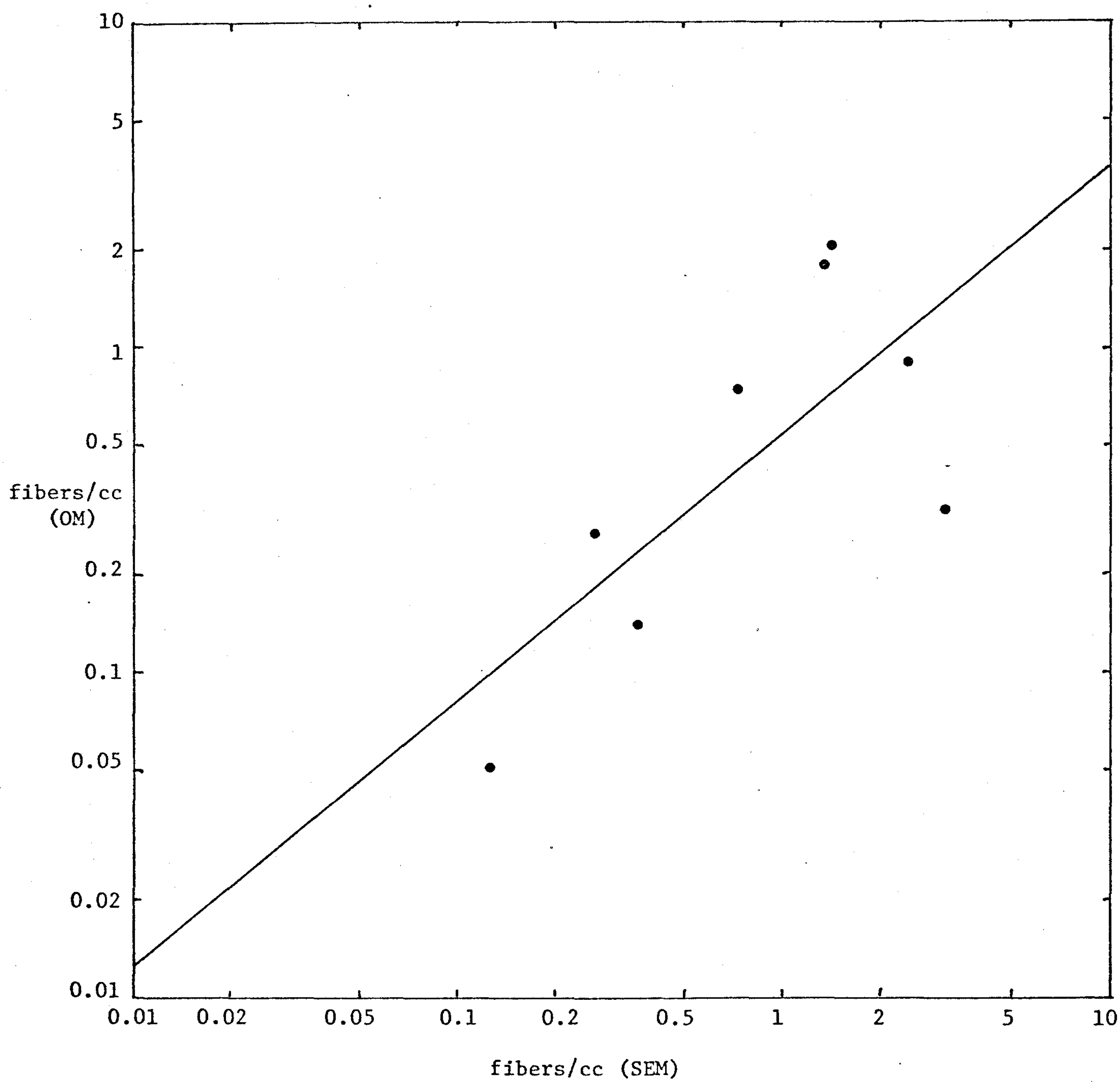


FIGURE 12
CUMULATIVE FREQUENCY DISTRIBUTIONS OF SAMPLE GEOMETRIC MEANS OF FIBER SIZES
Length:
Geom. Mean 12.5 μm
Geom. S.D. 1.7
Diameter:
Geom. Mean 1.8 μm
Geom. S.D. 1.5
μm
100
50
20
10
5
2
1
0.5
0.2
0.1
2%
5
10
15
20
30
40
50
60
70
80
85
90
95
98%
Percent of Samples With Mean sizes Less Than Stated Size

Figure 13

Linear Correlation of ln Optical Microscope (OM) Fiber Counts
With ln Scanning Electron Microscope (SEM) Fiber Counts

$r^2 = 0.539$
$r = 0.731$



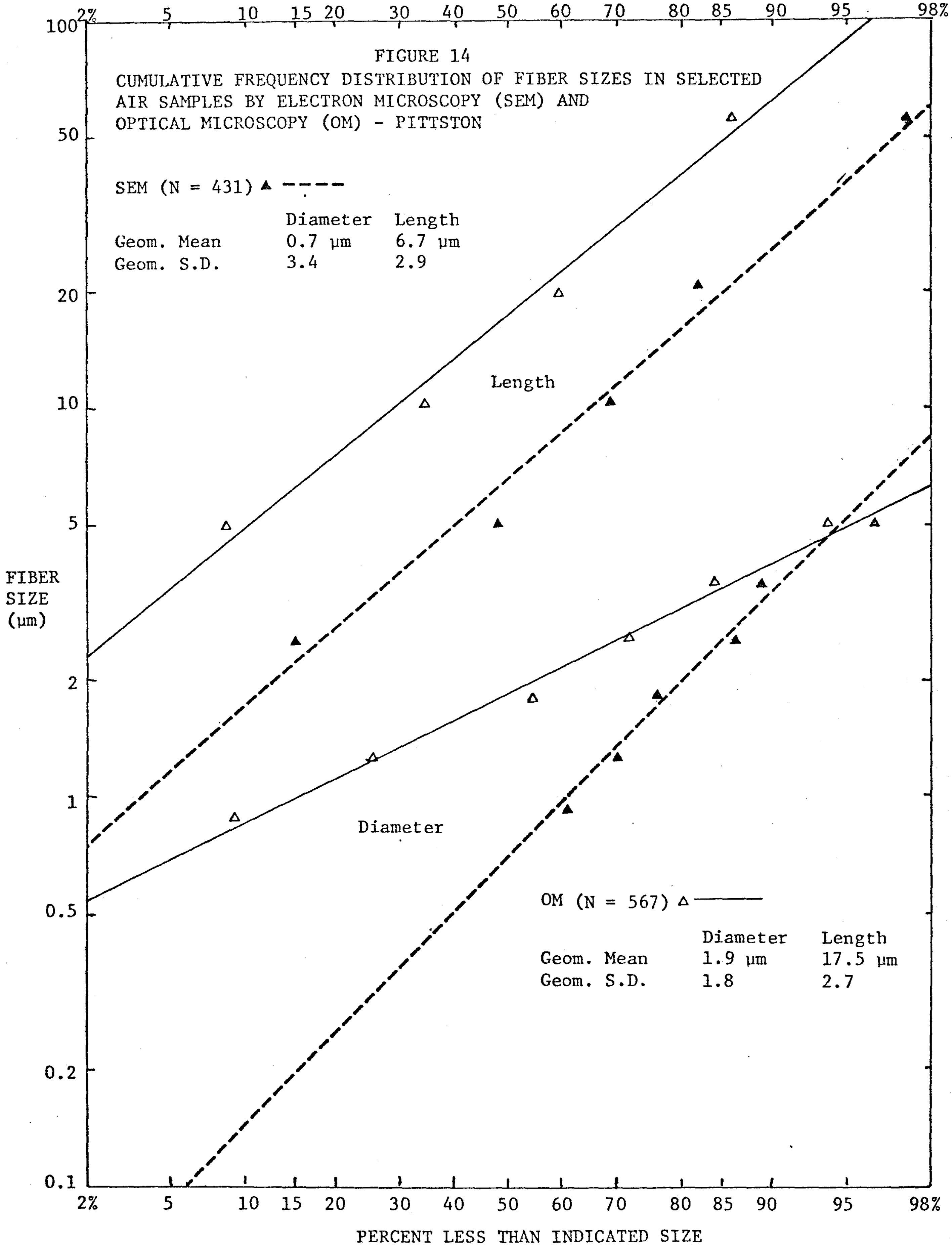
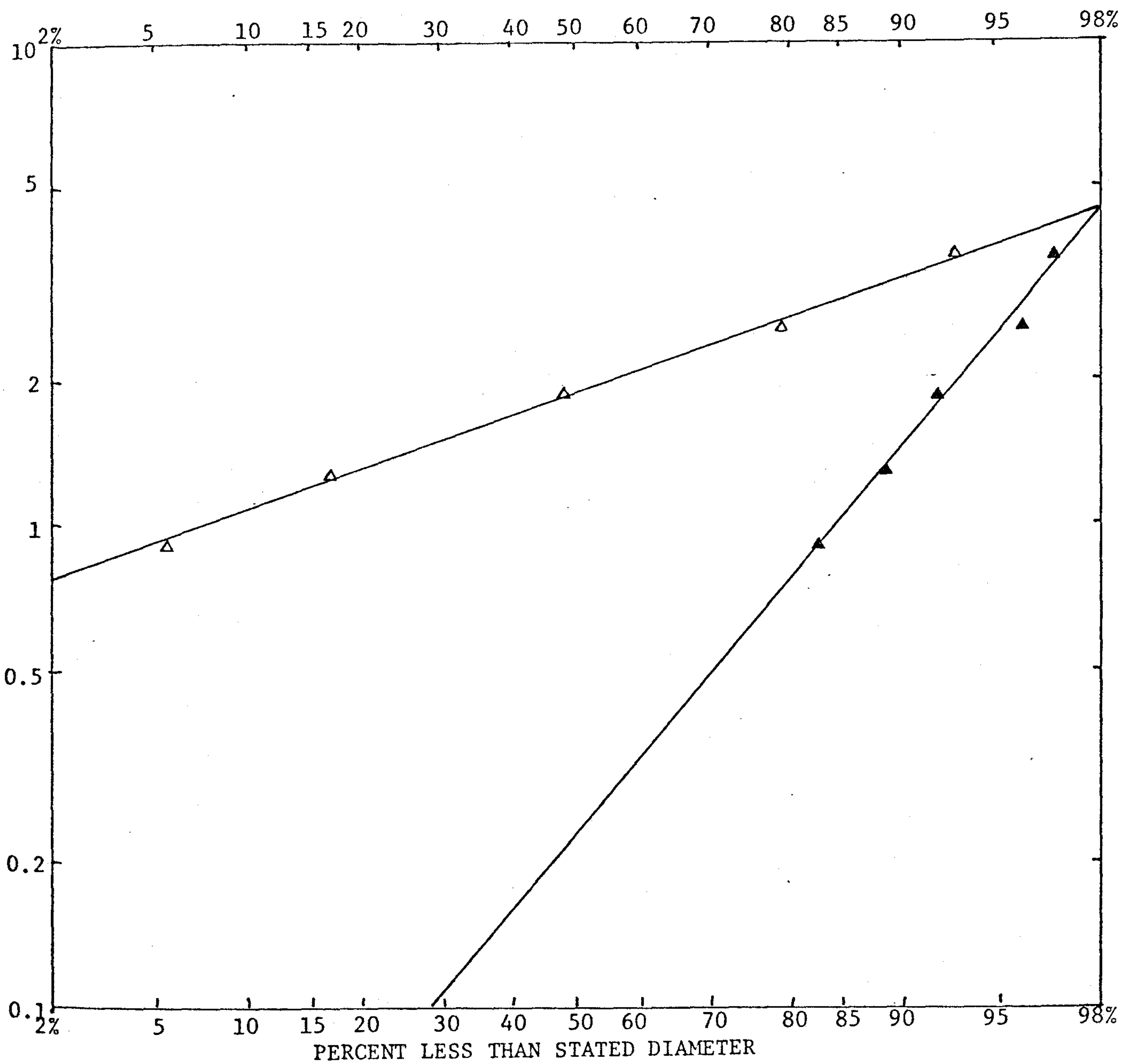


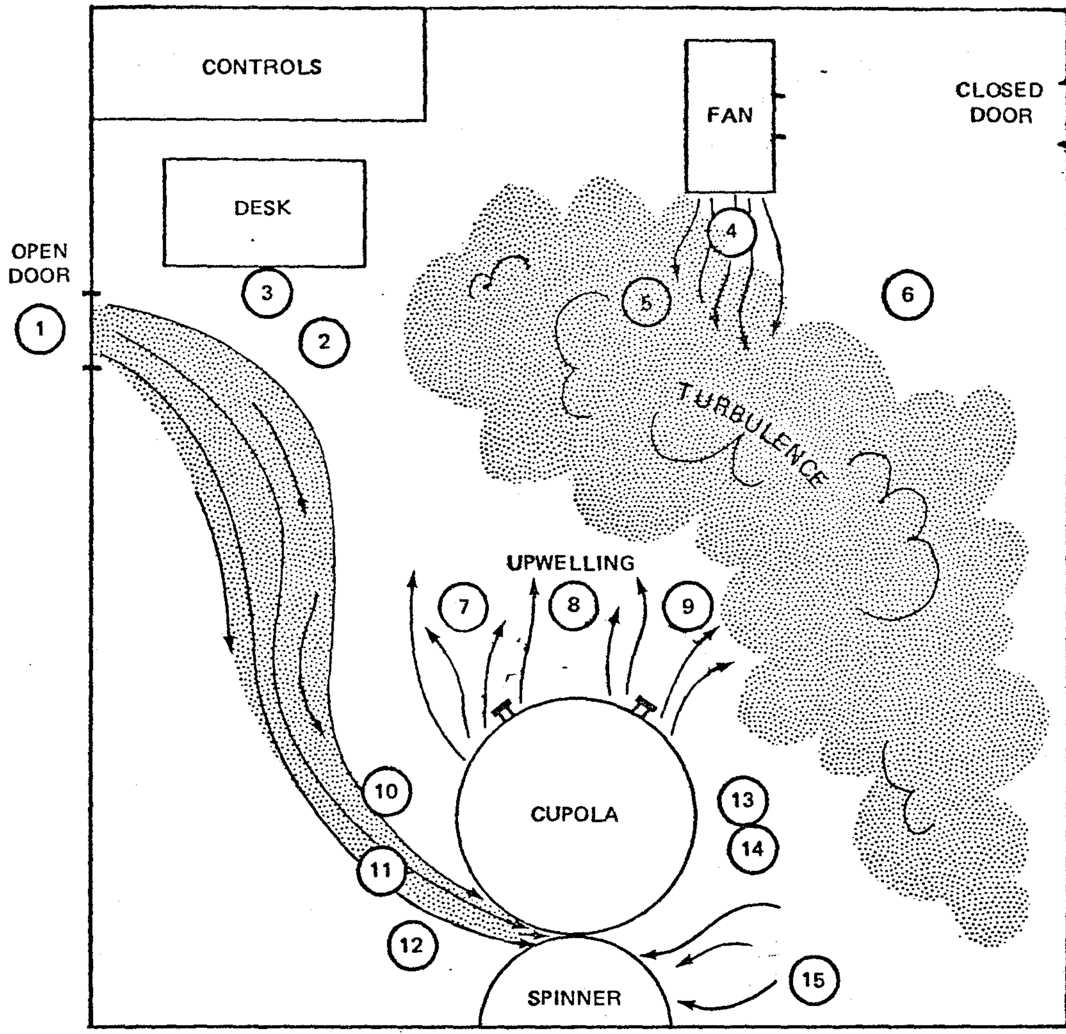
FIGURE 14
CUMULATIVE FREQUENCY DISTRIBUTION OF FIBER SIZES IN SELECTED AIR SAMPLES BY ELECTRON MICROSCOPY (SEM) AND OPTICAL MICROSCOPY (OM) - PITTSTON

FIGURE 15

CUMULATIVE FREQUENCY DISTRIBUTION OF FIBER DIAMETERS - SAMPLE C 876
BY SCANNING ELECTRON MICROSCOPY (SEM) AND OPTICAL MICROSCOPY (OM)

SEM ▲ Geom. Mean 0.23 μm, Geom. S.D. 4.1
OM △ Geom. Mean 1.9 μm, Geom. S.D. 1.5

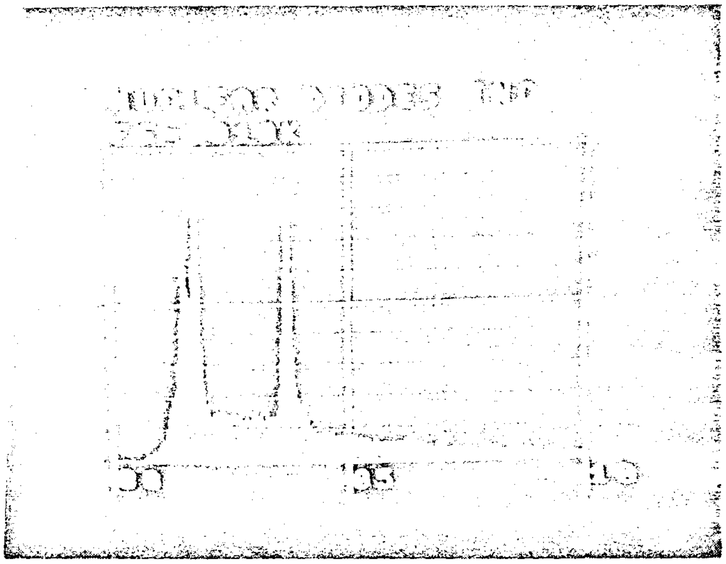




MEASUREMENTS (fpm) AT LOCATIONS ABOVE							
	HEIGHT ABOVE FLOOR				HEIGHT ABOVE FLOOR		
LOCATION	3'	5'	6.5'	LOCATION	3'	5'	6.5'
1	200	250	250	9	50	100	100
2	30 - 40	30 - 40	200	10	50	50	30
3	30	175	20	11	130	140	180
4		300		12	120	100	110
5	25	25	30	13	50	50	55
6	25	25 - 50	25	14	20	50	50
7	50 - 75	50 - 75	50 - 75	15	50	50	50
8	50	100	100				

FIGURE 16 VENTILATION MEASUREMENTS–CUPOLA AREA–PITTSTON

Figure 17 - Sample CB1



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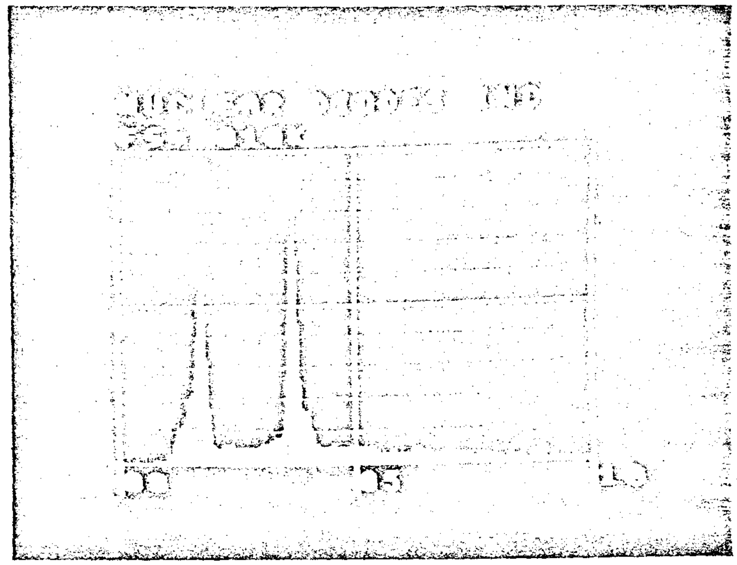

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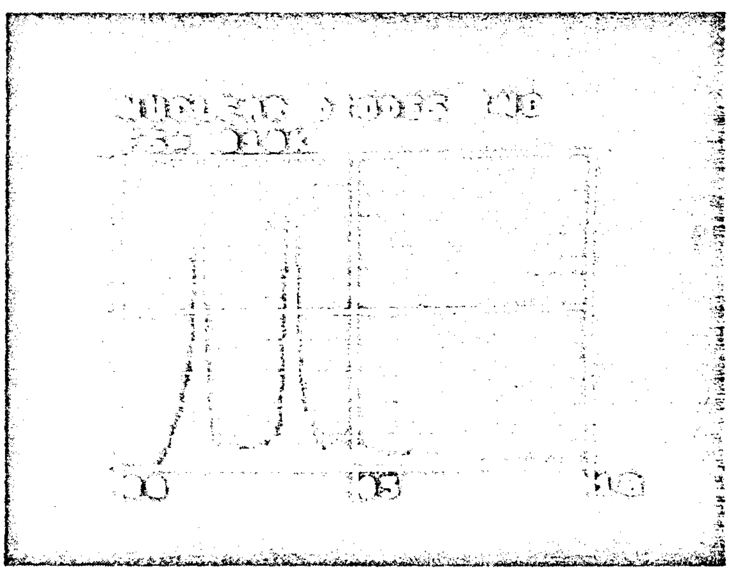

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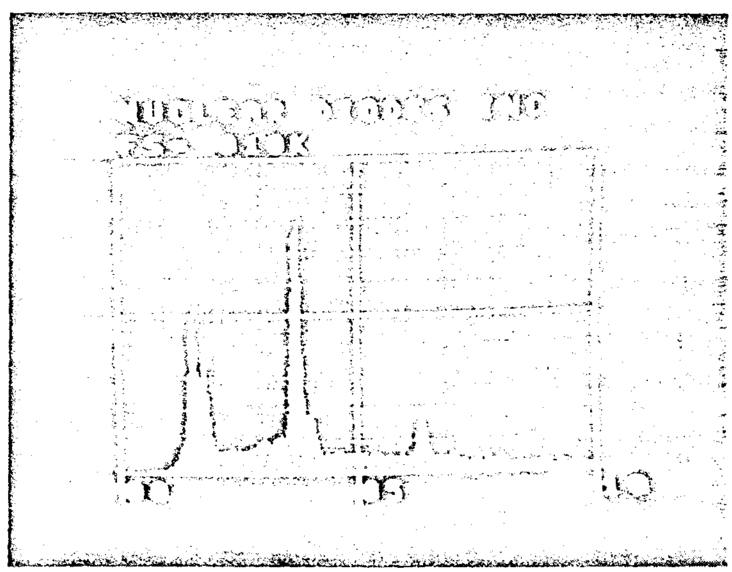
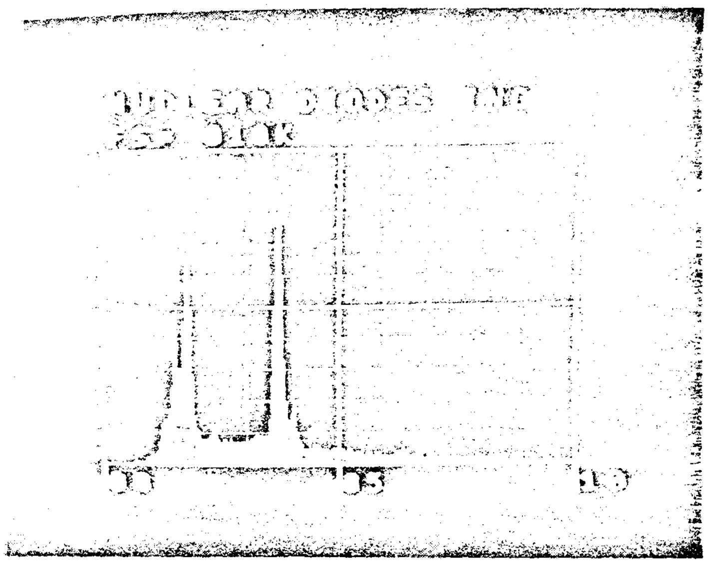


shot

Figure 18 Sample CB2



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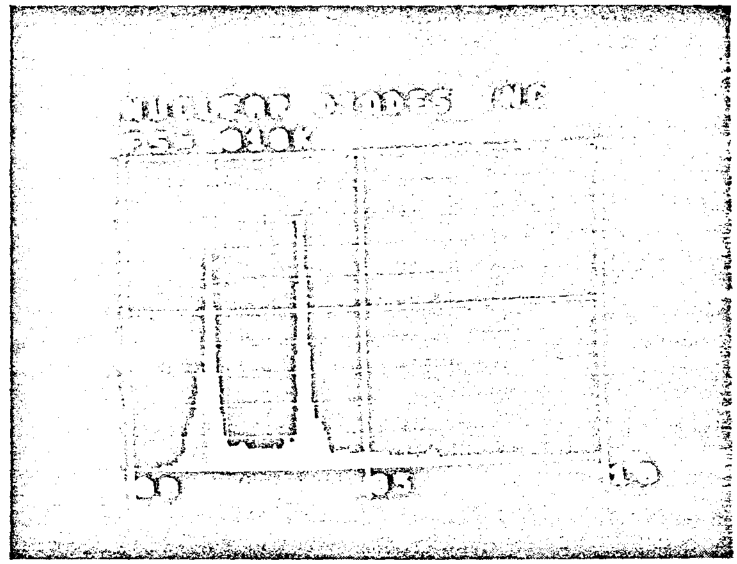

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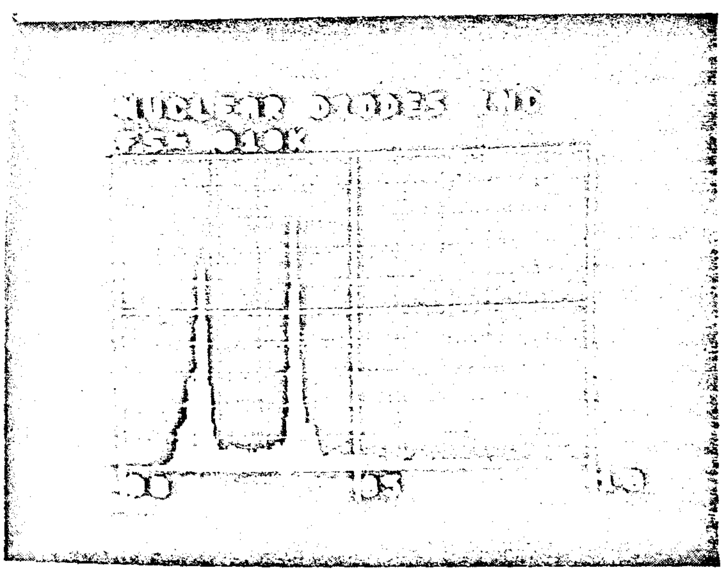

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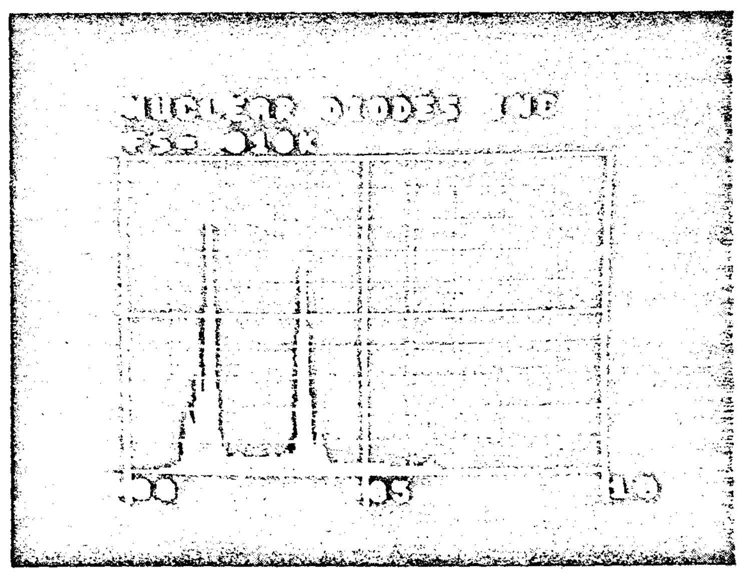
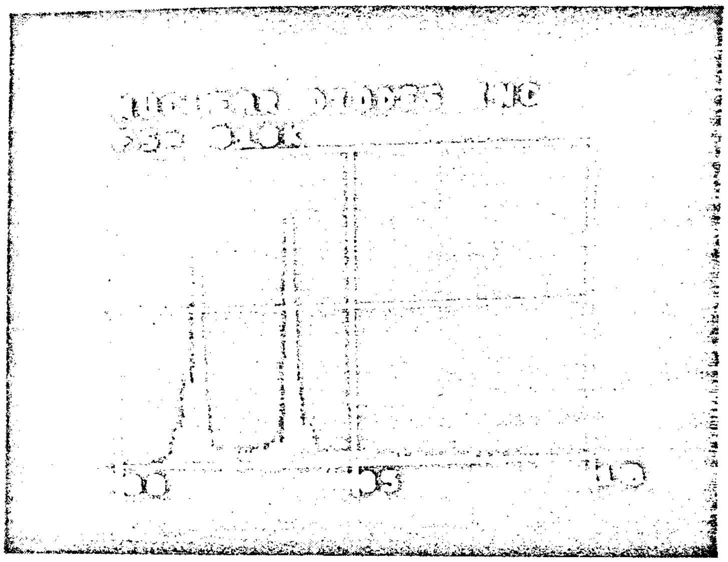


shot

Figure 19 - Sample CB3



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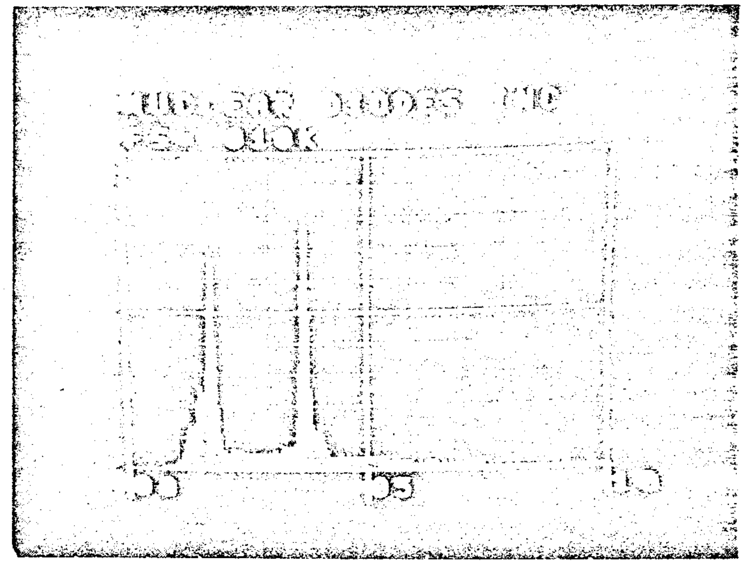

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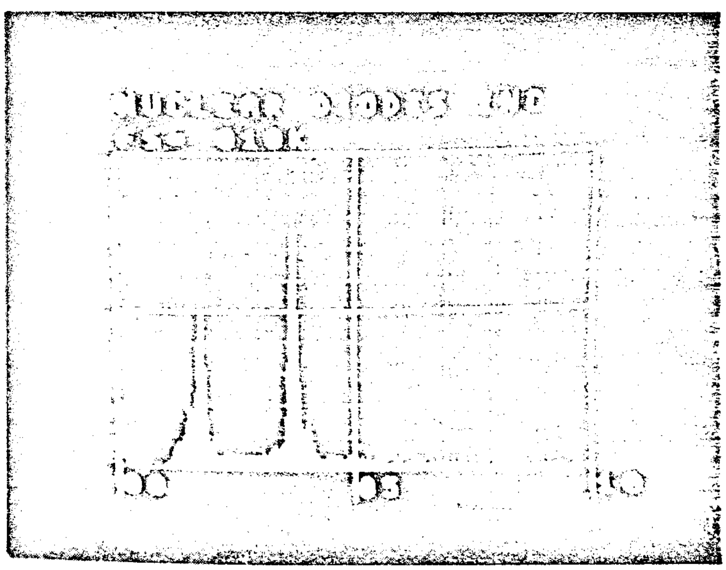

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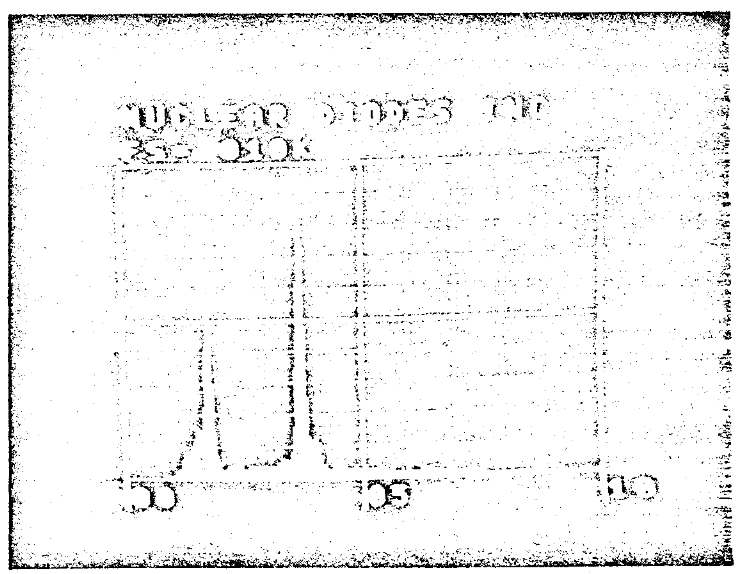
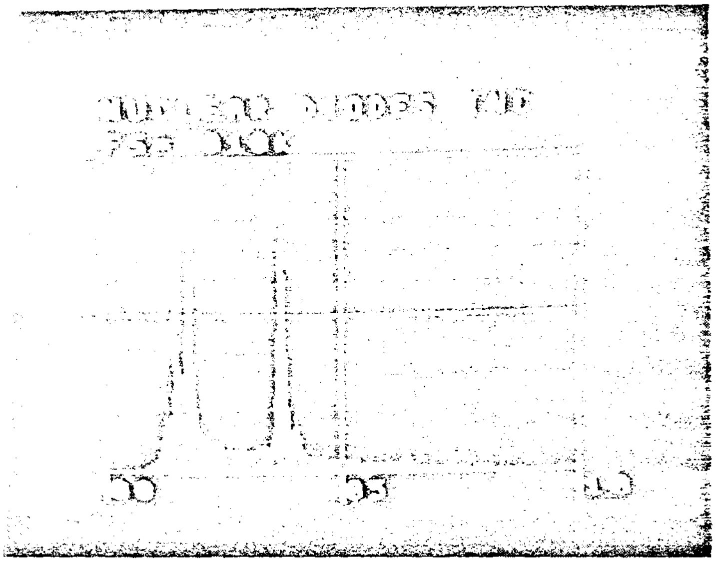


shot

Figure 20 Sample CB4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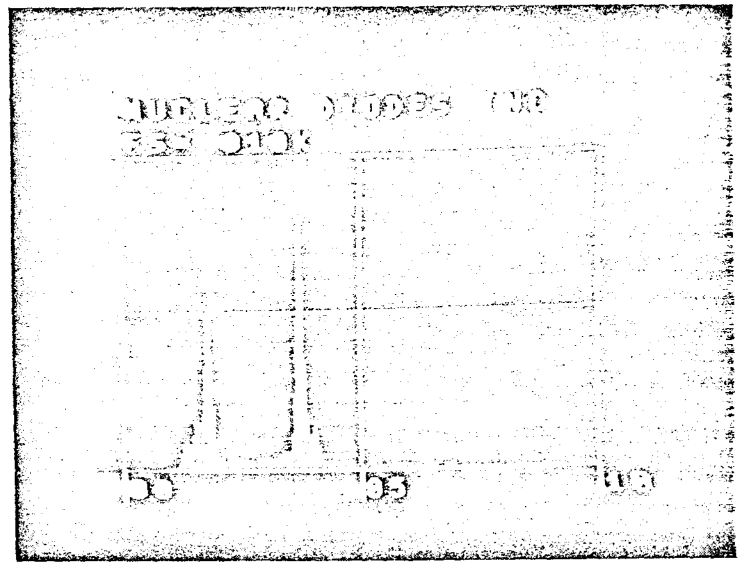
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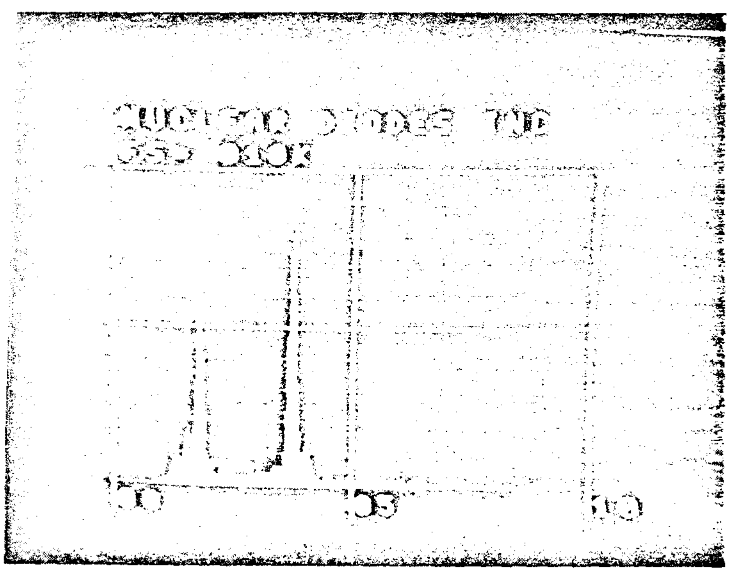
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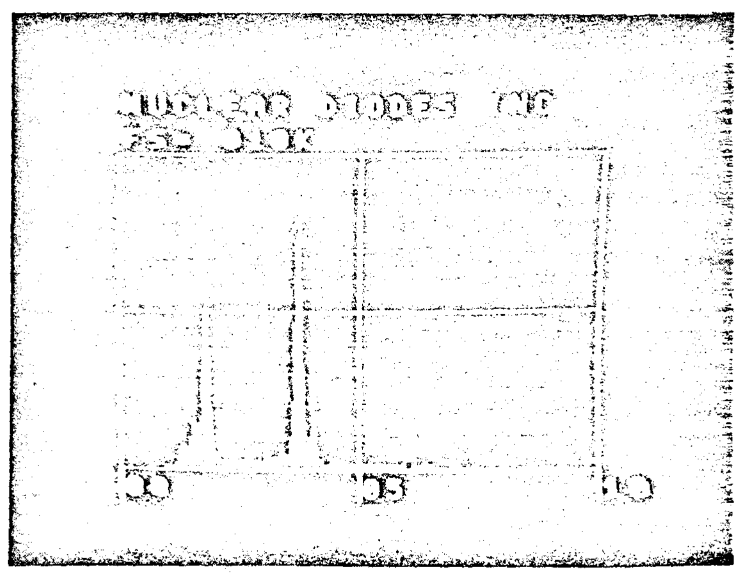
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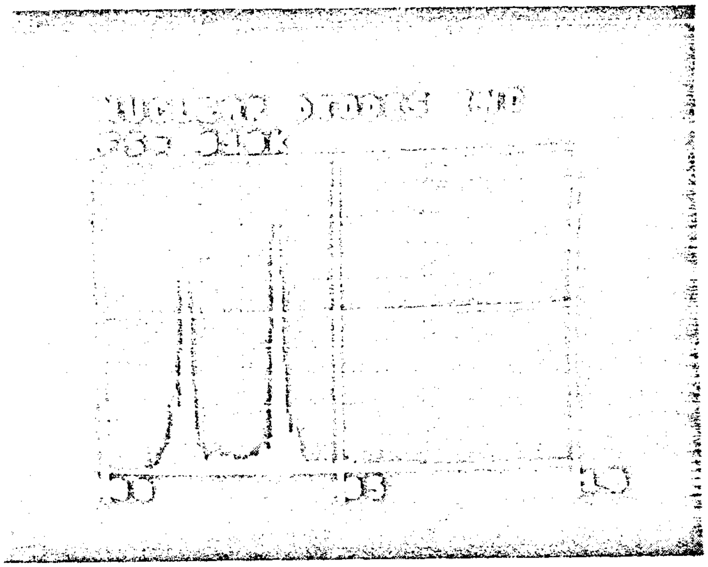
Figure 21 Sample CB5



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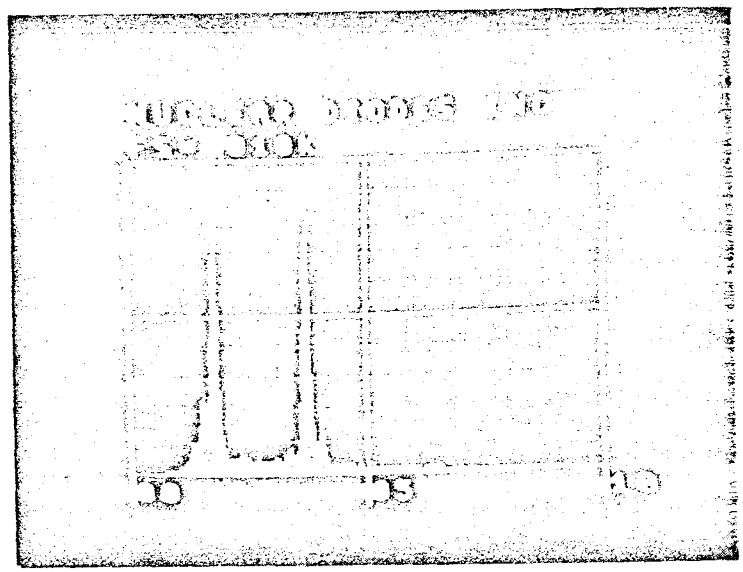

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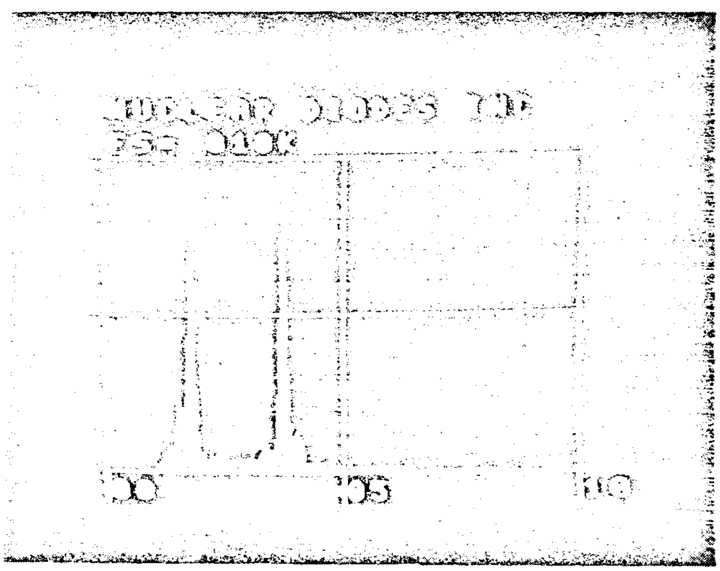

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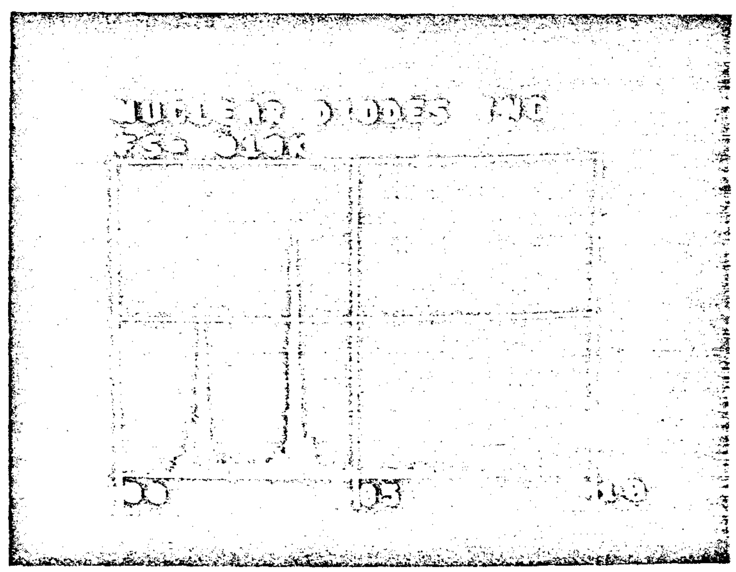

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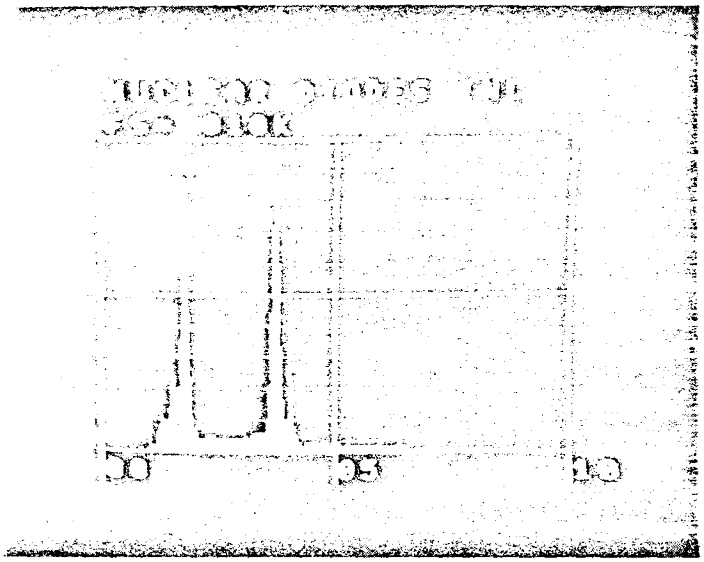
Figure 22 Sample CB6



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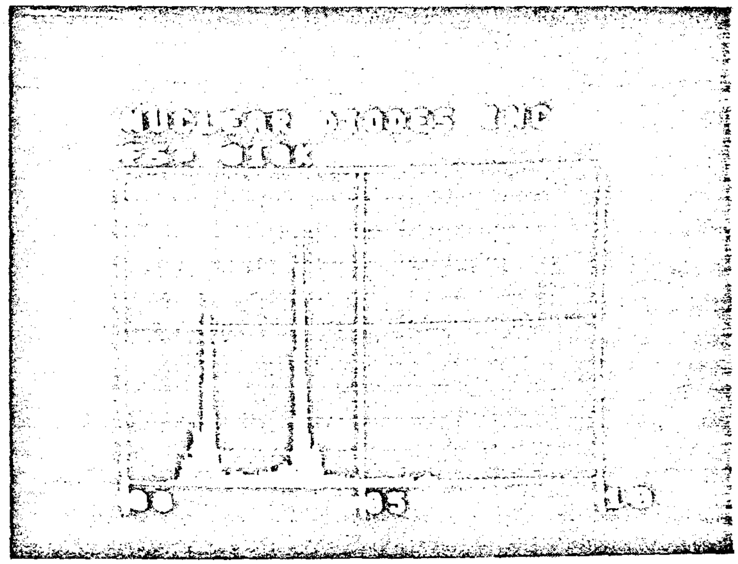

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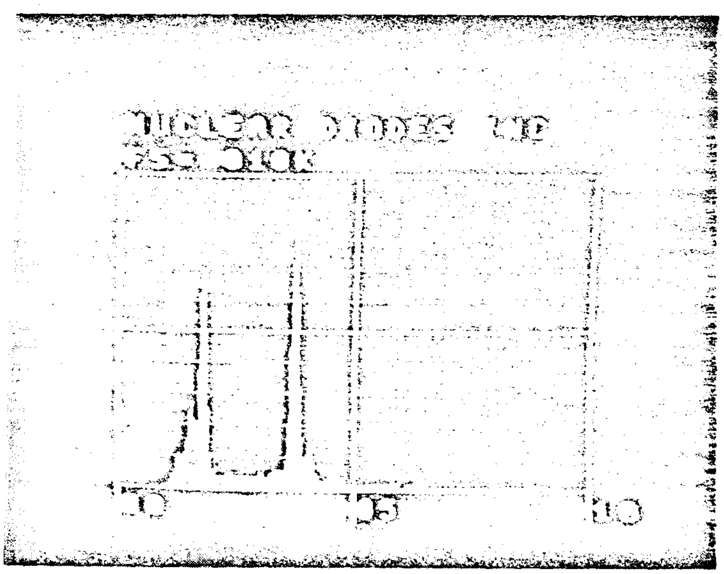

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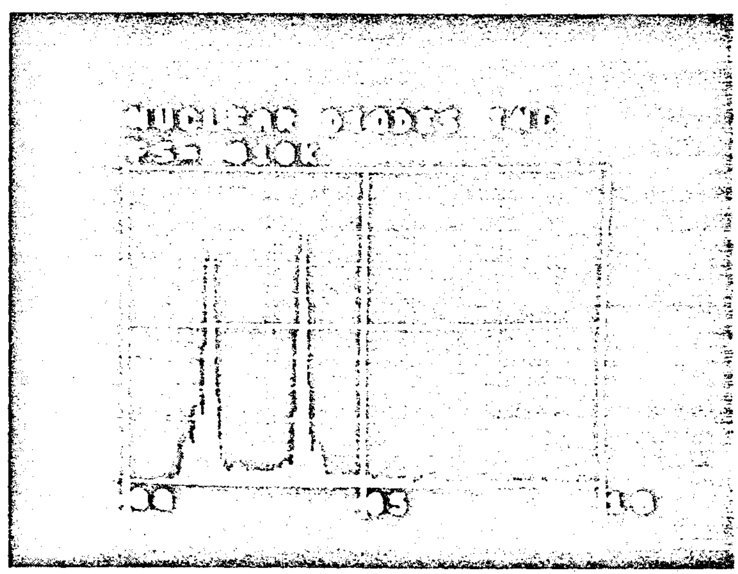

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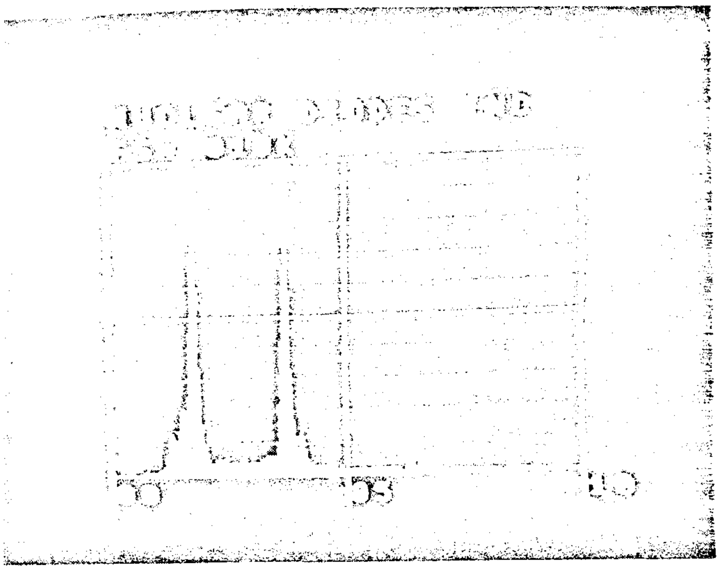
Figure 23 Sample CB7



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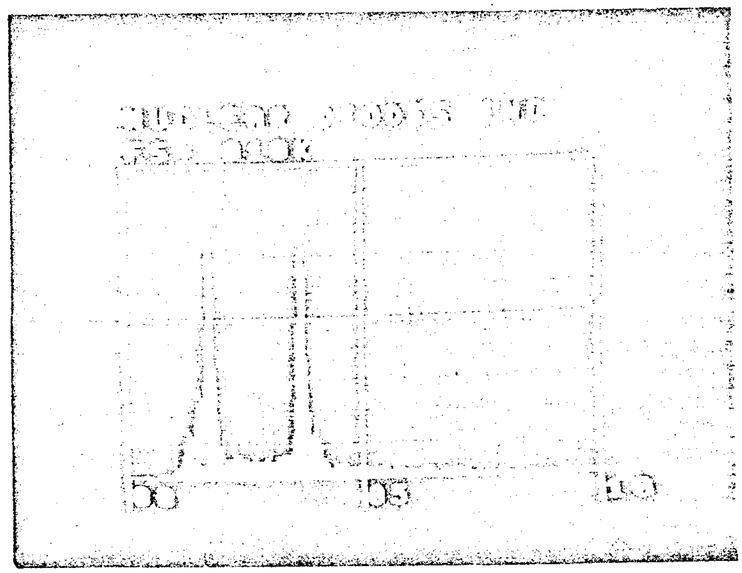

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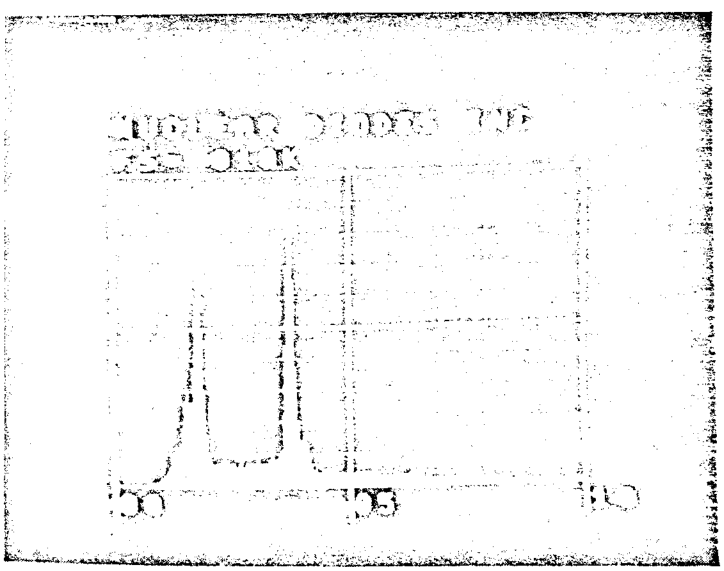

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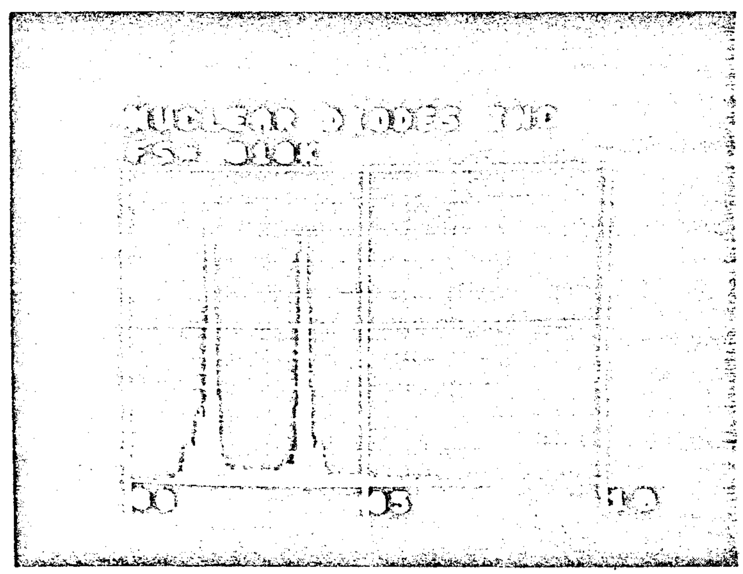

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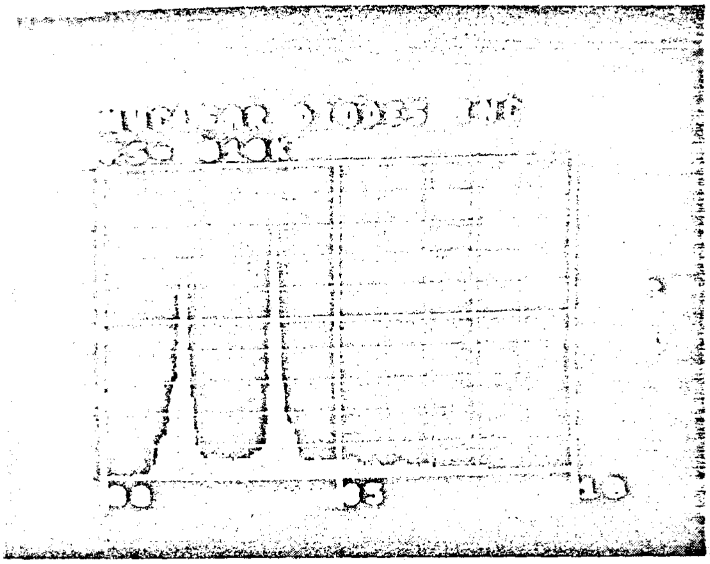
Figure 24 Sample CB8



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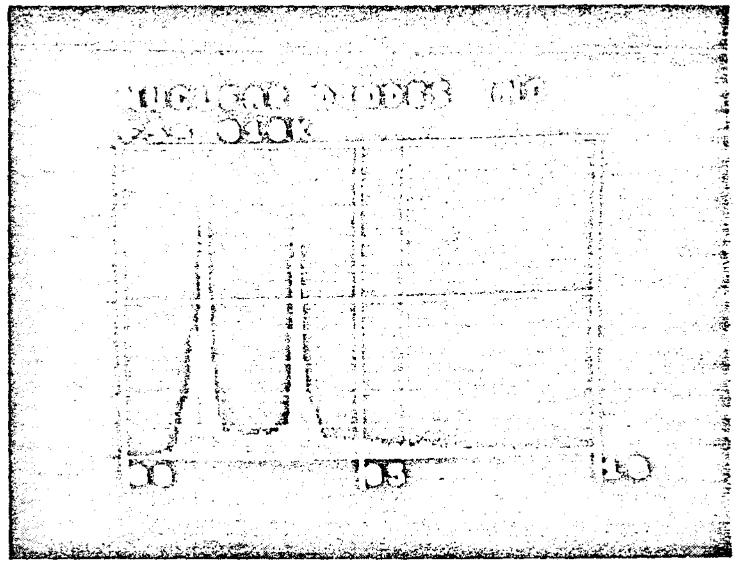

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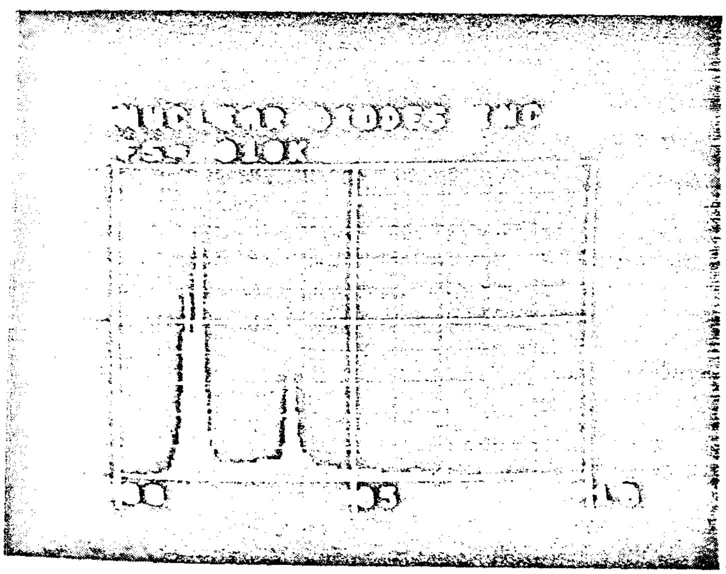

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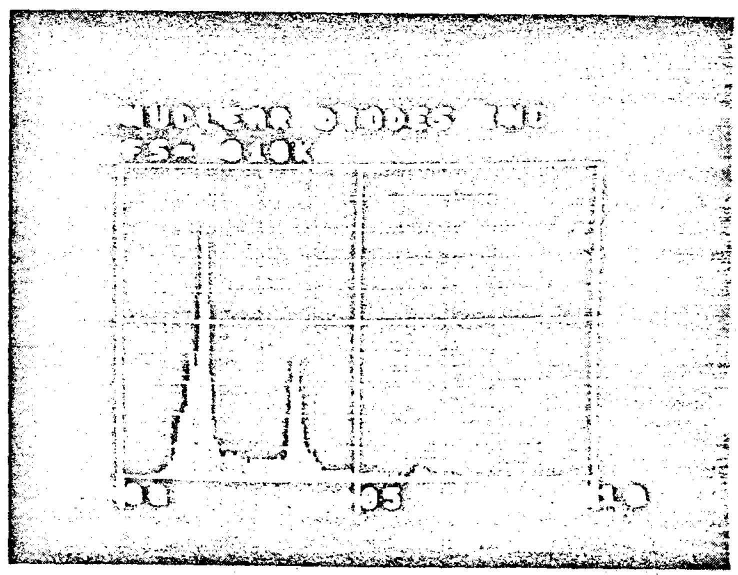
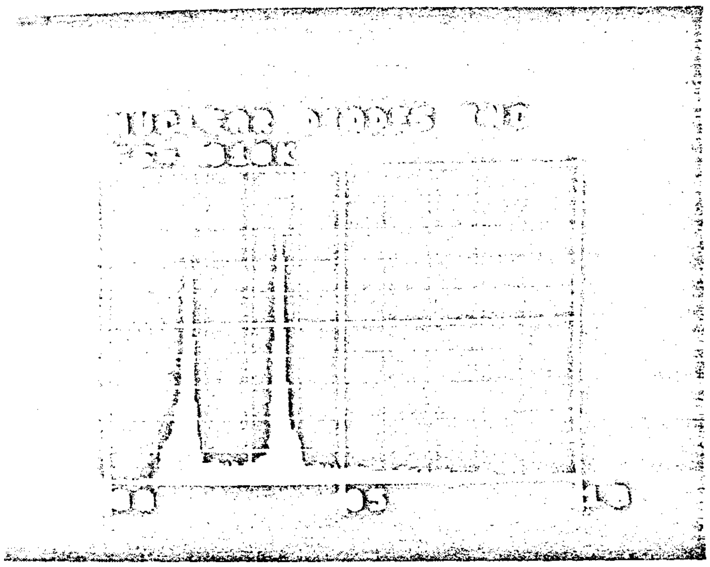


shot

Figure 25 Sample CB9



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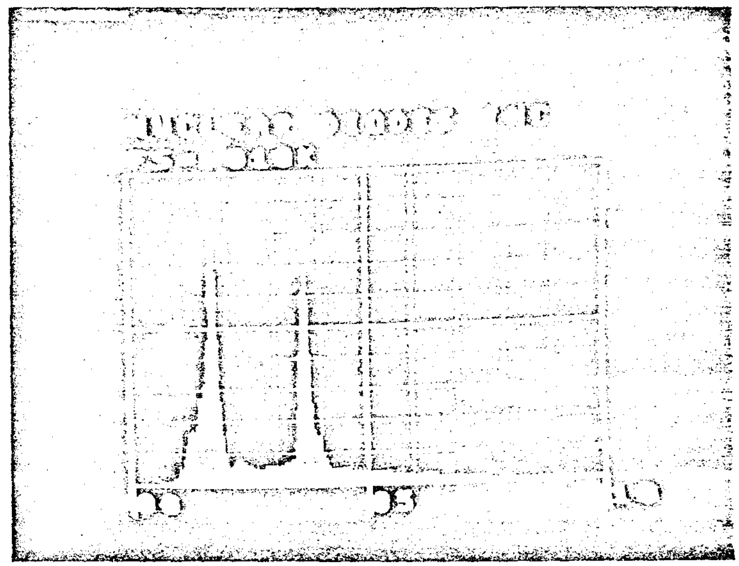

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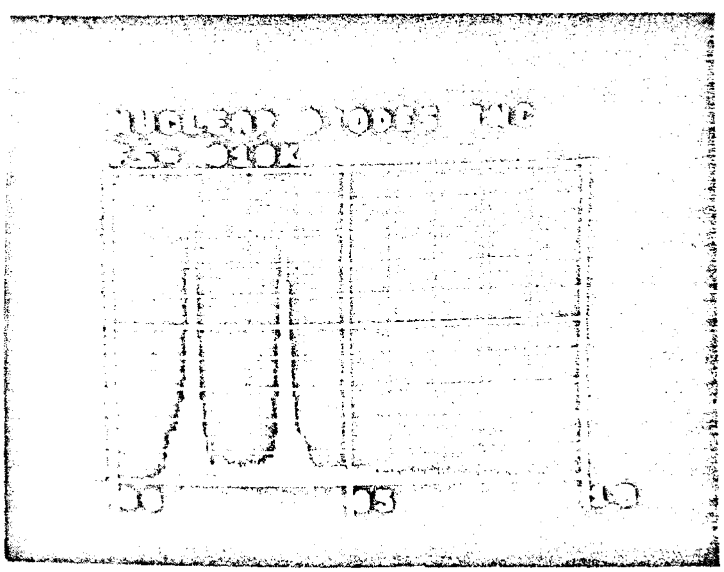

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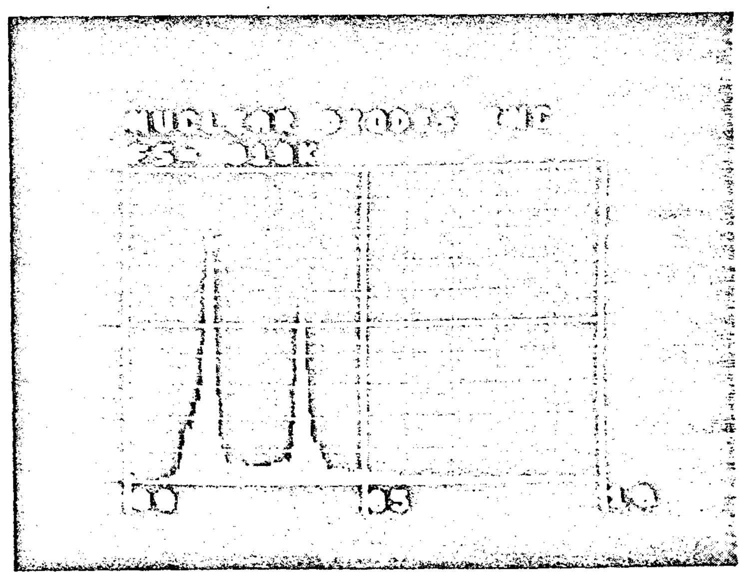
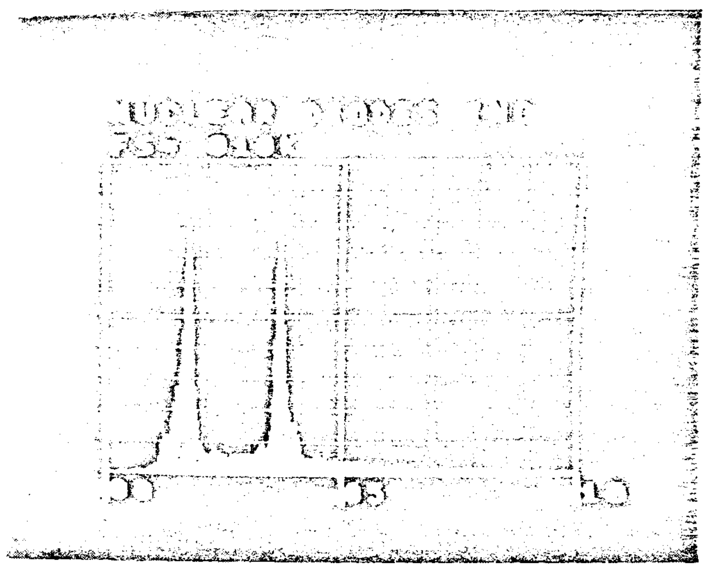


shot

Figure 26 Sample CB10



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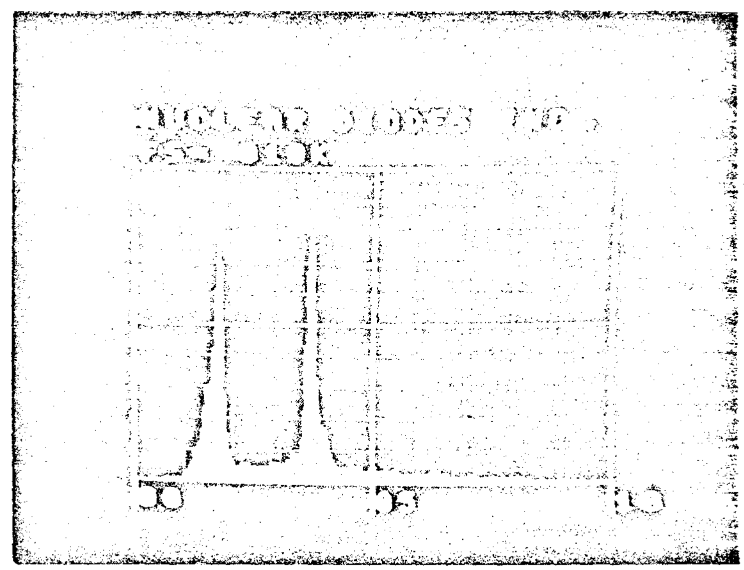

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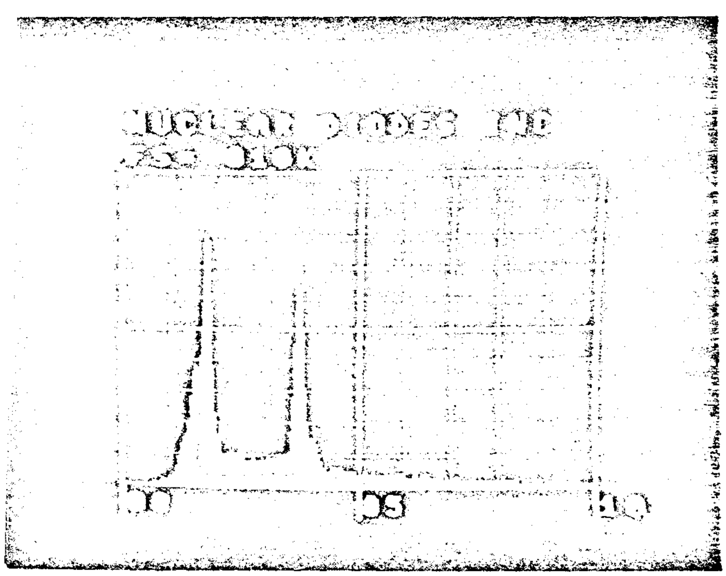

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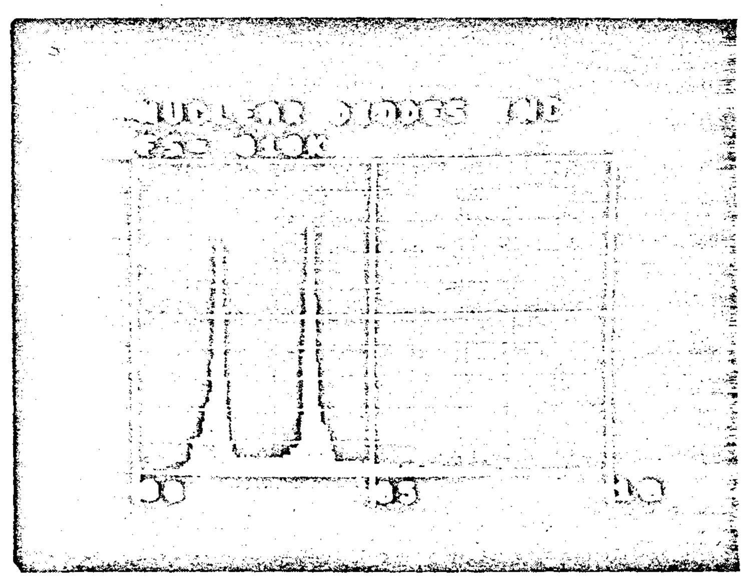

shot

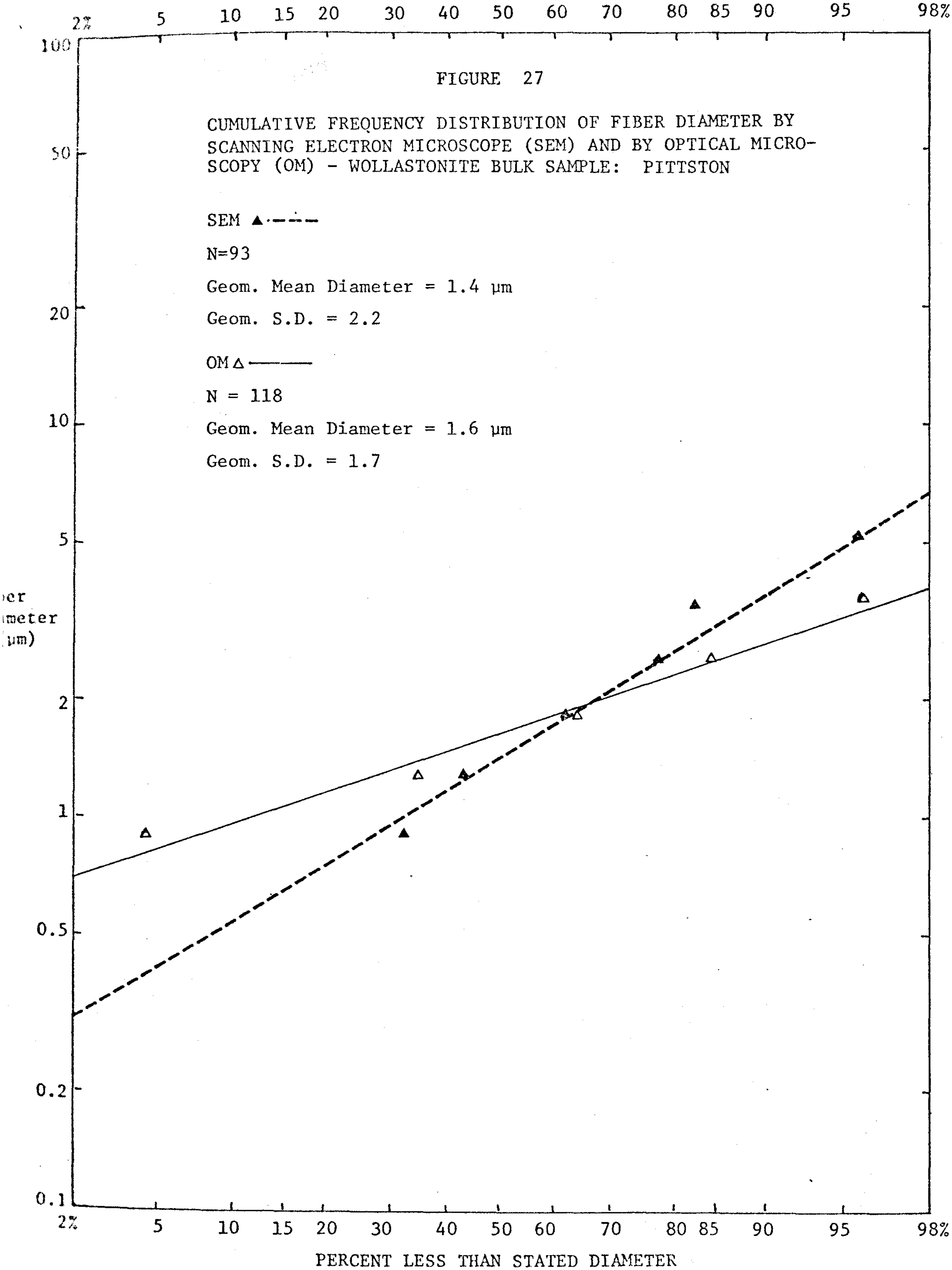

FIGURE 27

CUMULATIVE FREQUENCY DISTRIBUTION OF FIBER DIAMETER BY SCANNING ELECTRON MICROSCOPE (SEM) AND BY OPTICAL MICROSCOPY (OM) - WOLLASTONITE BULK SAMPLE: PITTSTON

SEM ▲·---

N=93

Geom. Mean Diameter = 1.4 µm

Geom. S.D. = 2.2

OM △———

N = 118

Geom. Mean Diameter = 1.6 µm

Geom. S.D. = 1.7