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The report includes data on ambient asbestos in the San Francisco Bay Area cities and other locations, from a study funded by the National Insulation Mfr's Assoc.

16. Abstracts Fibre content of freeway air was compared to that of ambient air upwind from the freeway. Portions of Millipore AA filters containing suspended particulates collected in Los Angeles at four freeway and four upwind sites were examined for fiber content with microscopy and transmission electron microscopy (TEM). Electron micrographs of selected samples are shown. The TEM method is described and compared with three other TEM methods for asbestos analysis. The technique used in this study leaves fiber or fibre bundles intact; fibres in unbroken clumps were not counted. Chrysotile, amphiboles and glass fibers were identified; length and diameter were measured. Single fibers were counted, including a group of unknowns which were a substantial part (65%) of the total fibers. Results are tabulated for 120 samples. At freeway sites, chrysotile, amphiboles, glass fibers and unknowns ranged from 0-100, 0-10, 0-4 and 0-18 f/l, respectively; upwind sample ranges were 0-9, 0-8 and 0-30 f/l, respectively. Freeway samples differed from upwind samples in fibril content, 15% and 3%, respectively.

17. Key Words and Document Analysis. 17a. Descriptors

Chrysotile
Amphiboles
Glass fibers
Electron microscopy
Microscopy
Freeways
Atmospheric composition
Air pollution
Particle size distribution
Concentration (composition)
Motor vehicles
Quantitative analysis
Brake linings
Disposal
Talc
Sampling
Counting

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## SUMMARY

This report summarizes estimates, by electron and light microscopy, of the number and size distribution of fibers collected on membrane filters from air in four Los Angeles freeway sites, upwind ambient air controls, and in ambient air from San Francisco Bay Area Cities and other California locations. The chrysotile asbestos fiber concentration in the air at all locations is low in the range of zero - 10 fibers/liter. Based upon comparison of fiber concentration in various sites upwind and downwind, and at various distances from freeways, motor vehicles using the Los Angeles freeway system do not appear to be an important source of airborne chrysotile asbestos fibers. The Los Angeles samples do not differ appreciably in fiber concentrations of chrysotile asbestos from the San Francisco Bay Area samples.

The concentration of glass and unidentified fibers was estimated in the Los Angeles and San Francisco Bay Area samples and found to be low i.e. in the same order of magnitude as for chrysotile asbestos. The concentration of amphibole asbestos fibers in the air were estimated in the Los Angeles freeway sites and found to be in the same order of magnitude as the chrysotile asbestos concentration.

A method is described for the use of electron microscopy suitable for quantitative analysis and identification of chrysotile and amphibole asbestos fibers in ambient air and at emission sources.

# RECOMMENDATIONS

It is recommended that the estimates of airborne fibers in the ambient air of Los Angeles and San Francisco Bay Area Cities provided by this study be used as a base line for comparing the fiber levels in the ambient air in future surveys. One or more suitable sites can be selected in Los Angeles and in the San Francisco Bay Area. Considerations should also be given to including one or more sites where there is repetitive braking. The foregoing should be considered in conjunction with programs to monitor air near probable stationary emission sources.

# INTRODUCTION

This report summarizes the results of one year's study of the number and size distribution of asbestos, glass, and other fibers in the ambient air of Los Angeles, with special emphasis on motor vehicles on the Los Angeles freeways as a source of asbestos fibers. Data on the numbers of chrysotile asbestos, glass and unknown fibers in the ambient air in several Bay Area locations and in other California sites are included for the comparative purposes.

The need for information on the level of asbestos fibers in ambient air and of emission sources is clearly stated in a report on asbestos by the National Research Council Committee on Biologic Effects of Atmospheric Pollutants published in 1971[1]. The first paragraph of the conclusions and recommendations summarizes the available information on the pathogenicity of asbestos: "Pathogenicity of Asbestos Minerals--Any of the commercially used asbestos minerals, when inhaled in sufficient numbers, as in uncontrolled occupational exposures, can cause disabling fibrosis of the lungs. An association between occupational exposures to asbestos and bronchogenic carcinoma has been established, but the dose-response relation and the role of cofactors have not been defined. Evidence of a causal association between some but not all exposures to asbestos fibers and diffuse malignant mesotheliomas of the pleura and peritoneum is substantial, but evidence of such a relation with other tumors is inconclusive. Although the different types of

asbestos differ in some of their biologic effects, no type can be regarded as free of hazard. The hypothesis that asbestos fibers act as cofactors or carriers of carcinogens is attractive, but as yet unproved."

The last paragraph of the report, summarizies the need and feasibility of controls; "Asbestos is too important in our technology and economy for its essential use to be stopped. But, because of the known serious effects of uncontrolled inhalation of asbestos minerals in industry and uncertainty as to the shape and character of the dose-response curve in man, it would be highly imprudent to permit additional contamination of the public environment with asbestos. Continued use at minimal risk to the public requires that the major sources of man-made asbestos emission into the atmosphere be defined and controlled. In the absence of such controls, local fiber concentrations might at times approach those in occupational sites. Analytic methods and epidemiologic data are not yet adequate for the development of an ambient air standard, but emission controls are needed and appear to be feasible."

The reason for considering freeways as a source of asbestos as an air pollutant is that brakes and clutches of the very large number of motor vehicles operating on the freeways contain chrysotile asbestos. It is possible that small amounts of chrysotile asbestos fibers can get into the air on the freeways during the process of braking. However, the heat created during breaking decomposes most of the chrysotile fibers[1, 2, 3, 4]. This study is in large part a comparison of fiber content of freeway air to that of ambient air upwind from the freeway. Other sources of chrysotile asbestos in urban ambient air are from industries manufacturing and using products containing

asbestos, building construction and demolition, and open city dumps. Naturally -occurring asbestos in serpentine rock outcropping can also contribute to the asbestos content in ambient air. A source of non-chrysotile asbestos in freeways and ambient air is from talc, which can contain asbestos fibers of the amphibole type-tremolite, and is used in the manufacture of rubber tires and some brake linings. An analysis of the number of amphibole fibers in freeway and ambient air are included in this report. To make the fiber analysis complete the number of glass fibers were counted as well as fibers not yet identified which could be mistaken for asbestos fibers by light microscopy and which could have some biological activity[5].

The sampling of air on the freeways and upwind from the freeways (ambient air controls) was done primarily by the California Division of Highways, Los Angeles Division 7, Freeway Operators. Eight samples obtained in March, 1972 were obtained by Thomas Cahill's group (Department of Physics, U.C. Davis) on the Santa Monica Freeway, 4th avenue pedestrian overcross. Samples were obtained at 4 sites on the Los Angeles, 42-mile freeway loop which is part of the Los Angeles Freeway Surveillance and Control Project of the California Division of Highways. The 42-mile freeway loop is unique in that by means of sensors in the road bed the volume of traffic, residence time and speed of the motor vehicles is continuously monitored with a computer at the control center in downtown Los Angeles. There are meteorological stations near or at each of the sites. Consequently, data on traffic volume and speed and wind direction and speed are available to correlate with fiber concentration on the freeway for the time intervals sampled. A complete description of the Los Angeles, 42-mile loop facility can be found in the 2nd annual

report to the California Legislature[6].

The sampling sites and the analytical methods for determination of the number, size distribution, and identification in the air sampled on the Freeway and in air upwind from the freeway (ambient air) will be described and discussed in detail. The techniques include 1) the method of collecting the fibers and particulates from air onto membrane filters, 2) preparation of the membrane filters and counting procedures by light microscopy, and 3) sample preparation and counting procedures by electron microscopy. Procedures of other laboratories using electron microscopy for fiber analysis will be discussed.

## METHODS

This section will include: I. Description of sample collection sites, II. Method of air sampling, III. Analytical procedures-light microscopy, and IV. Analytical procedures-electron microscopy. V. Experimental design.

### I. Description of sample collection sites

The four sampling sites on the Los Angeles 42-mile freeway loop are indicated on a section of a map of Los Angeles containing the 42-mile freeway loop, Figure 1. Diagrams of the sites Figures 2, 3, 4, 5, show the positions of the air samplers on the freeway and in the upwind (control) positions, together with the type of cross section of the freeway at the sites. The general wind direction and the orientation of the freeway at the sites are indicated.

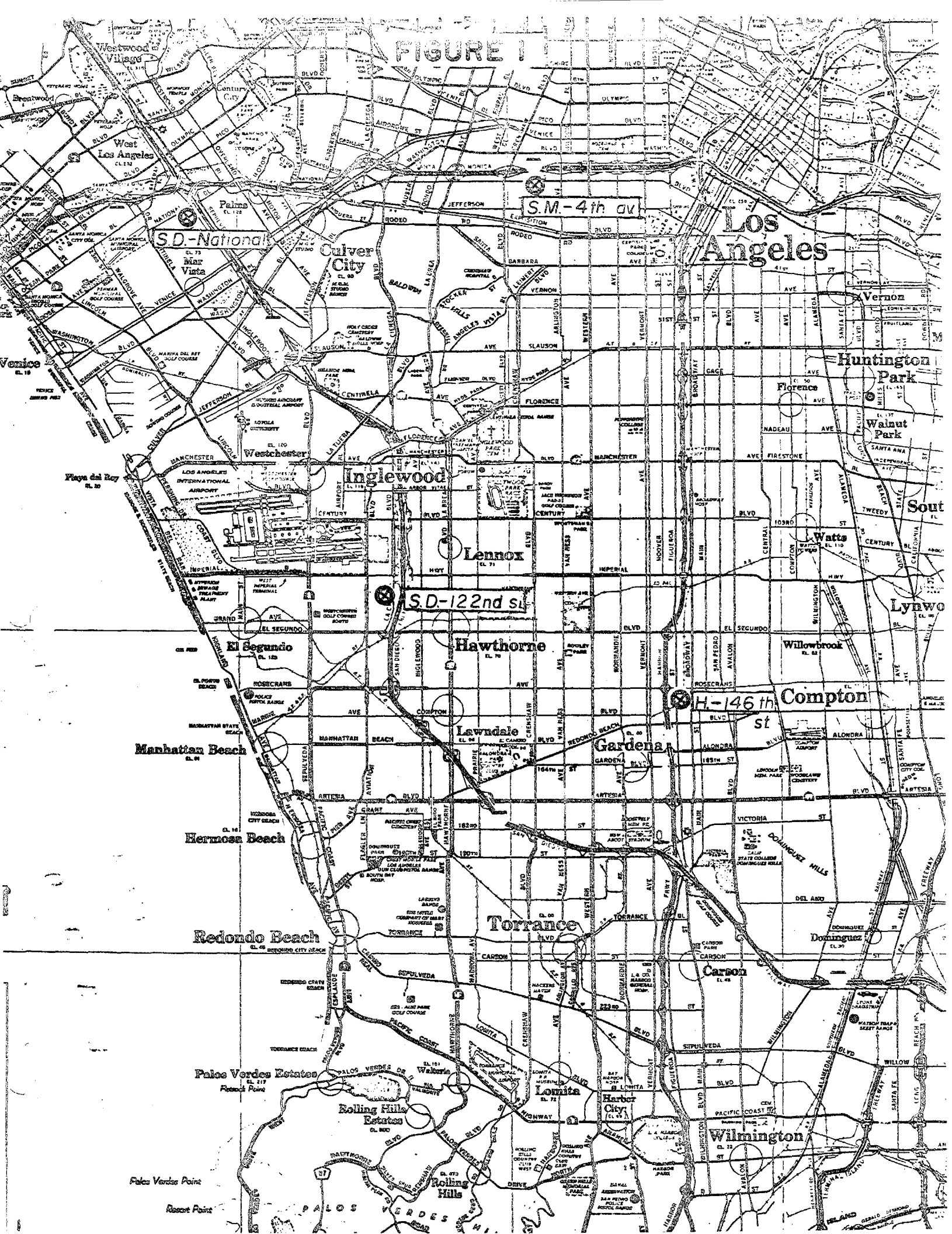
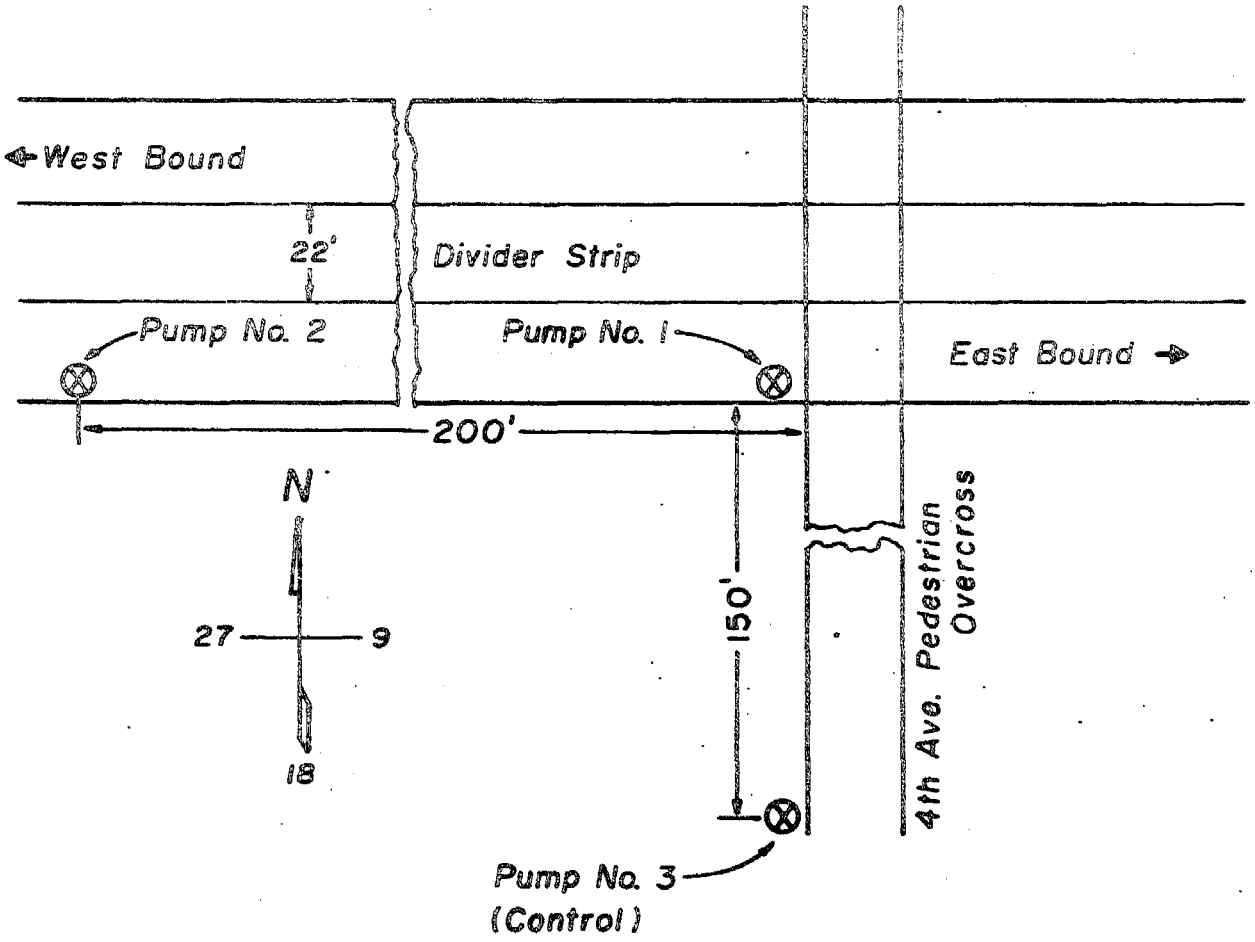
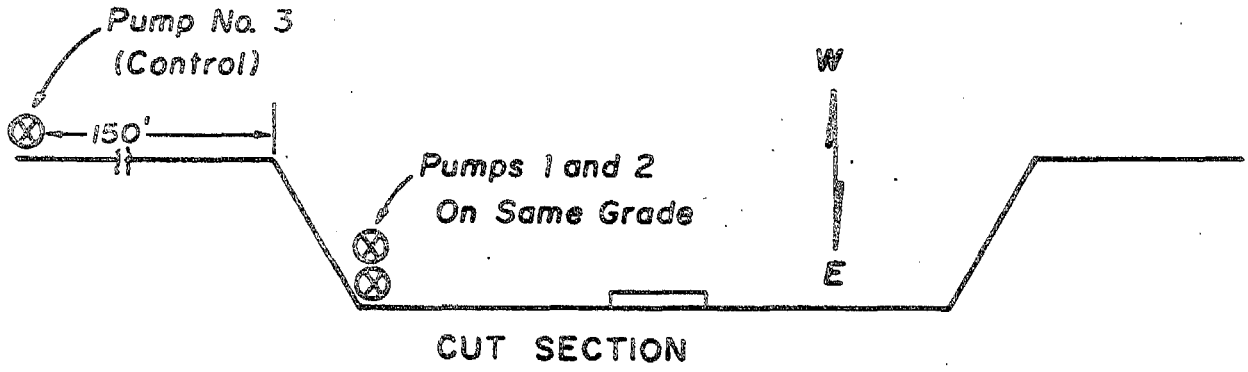


FIGURE 1
S.M.-4th av
S.D.-National
S.D.-122nd st
H.-146th st
Los Angeles
Westwood Village
Century City
West Los Angeles
Palms
Culver City
Mar Vista
Venice
Playa del Rey
Westchester
Inglewood
Lennox
Hawthorne
El Segundo
Manhattan Beach
Hermosa Beach
Redondo Beach
Lawndale
Gardena
Compton
Torrance
Carson
Willowbrook
Watts
Vernon
Huntington Park
Florence
Walnut Park
Lynwood
Dominguez
Wilmington
Harbor City
Lomita
Palos Verdes Estates
Rolling Hills Estates
Rolling Hills
Palos Verdes Point
Resort Point

# FIG. 2
# SANTA MONICA FREEWAY AT
# 4th AVE. PEDESTRIAN OVERCROSS

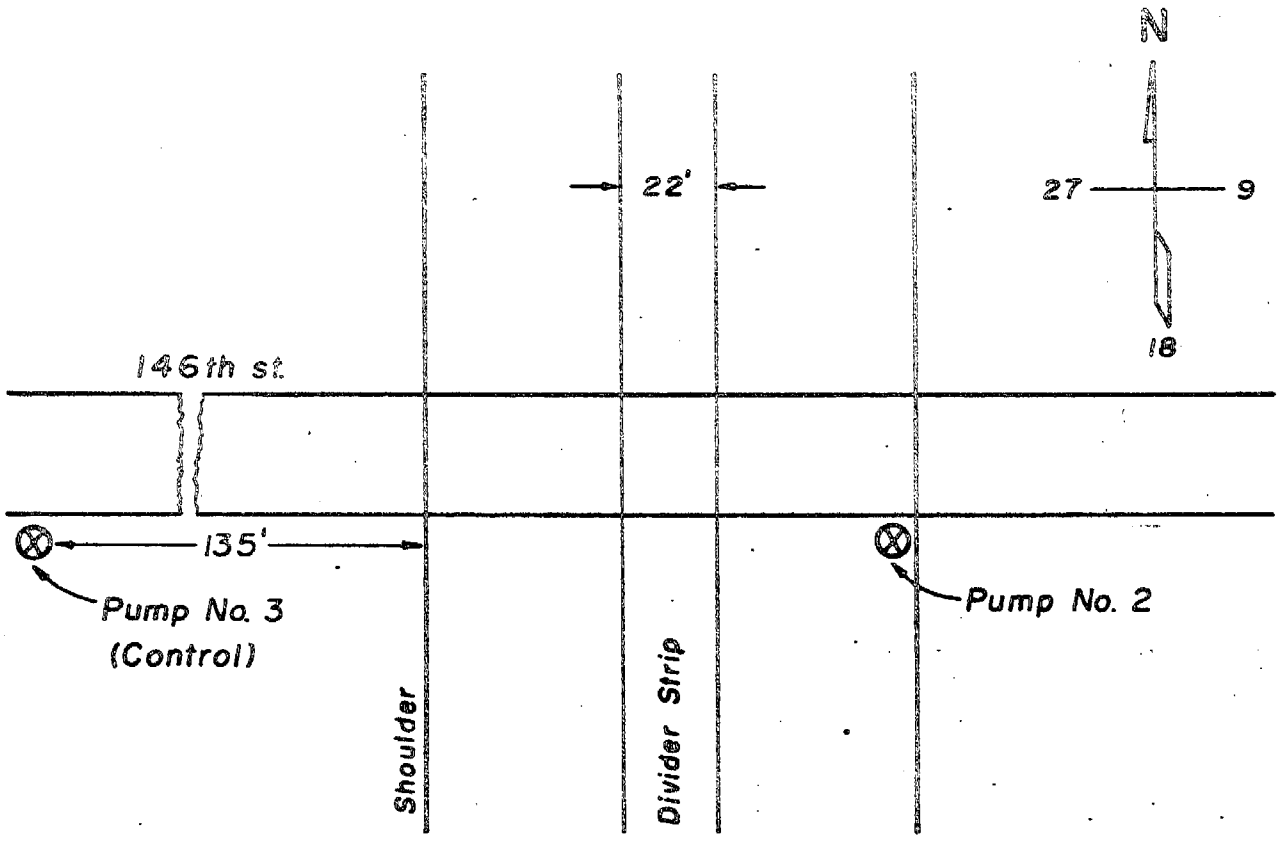



CUT SECTION

FIG. 3

# HARBOR FREEWAY AT 146th ST.



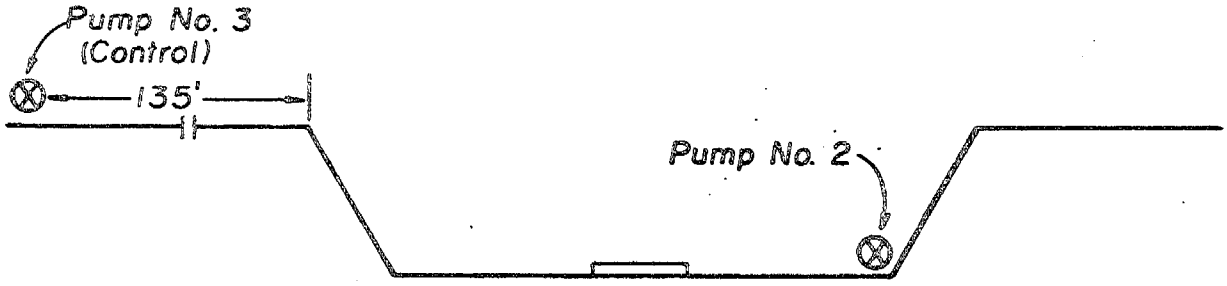
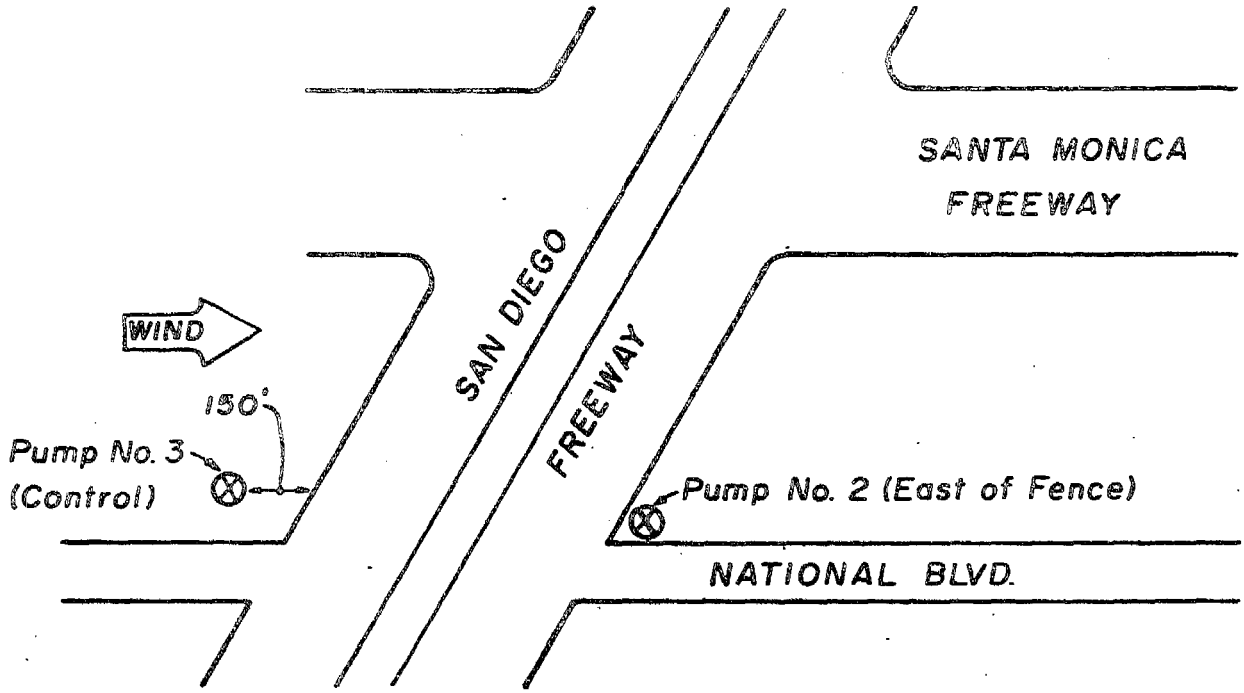
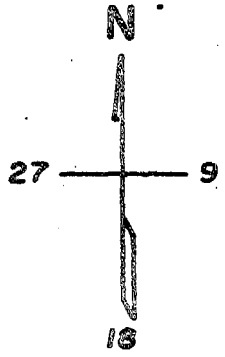



FIG. 4

# SAN DIEGO FREEWAY AT NATIONAL BLVD.



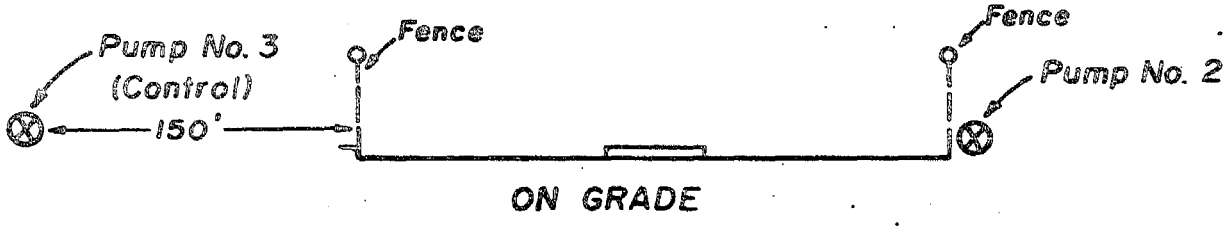
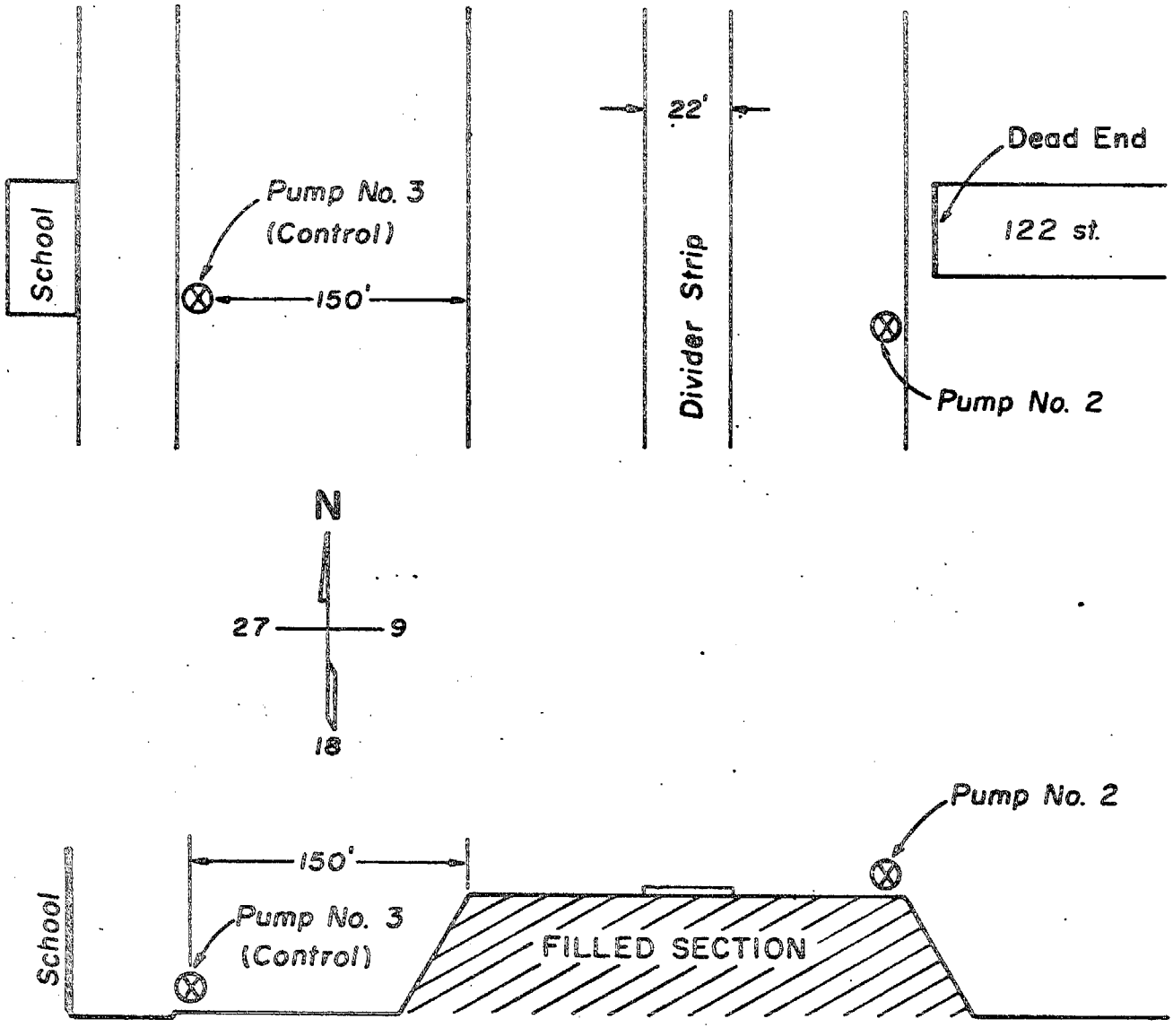



FIG. 5

# SAN DIEGO FREEWAY AT 122nd ST.



Following is a description of the sites:

1. Santa Monica Freeway at the 4th street pedestrian overcross.

This site is a cut section. The area surrounding the site is essentially residential. The freeway is oriented approximately east and west. The prevailing wind was from the west roughly parallel to the freeway. Two sampling units were used on the freeway, one at the pedestrian overcross and the second 200 feet west of the first. They were placed at the edge of the shoulder one lane removed from the east bound motor vehicles. The ambient air sampling unit (control) was placed 200 feet to the south of the top edge of the freeway (on grade).

2. Harbor Freeway at 146th Street pedestrian overcross

This site is a cut section. The freeway is oriented north and south. The prevailing wind is from the west at a right angle to the freeway. The sampling site was at the east edge of the freeway one lane removed from the north bound moving vehicles. The ambient air (control) sampling site was 135 feet from the west shoulder of the freeway (85 feet from the top edge of the freeway). The area immediately surrounding the freeway is essentially residential. There is a major city street (Vermont St.) four blocks to the west (upwind) and parallel to the freeway. A mile upwind of the freeway at Rosecrans Avenue and Halldale Street there is a dry refuse compacting center which could be a source of asbestos from building materials. The San Diego freeway is four miles west and parallel to the Harbor Freeway. There are industrial and power plants west of the San Diego Freeway.

3. San Diego Freeway at National Boulevard

This site is on grade. The freeway is oriented north-south. The prevailing wind in the early morning is from the east; in the afternoon the wind is from the west of the freeway shoulder, on grade. The area surrounding the site is essentially residential.

4. San Diego Freeway at 122nd Street

This site is elevated. The freeway is oriented north-south. The prevailing wind is from the west. The sampling site was on the east side of the freeway at the edge, a lane away from the northbound moving vehicles. The upwind (control) site was 100 feet from the near shoulder (west). The site is just east and about a mile south of the Los Angeles International Airport. The immediate area surrounding the site is essentially residential. There is industry including power plants in El Segundo, two or 3 miles to the west of the site.

5. Three samples were obtained in downtown Los Angeles as controls away from freeways. The sampling site was 10 feet above street level, 10 feet north of 6th Street near Vermont Street close to the Division of Highways Building.

6. Other sites where ambient air was sampled for fiber analysis in 1971 in a study supported by the National Insulation Manufacturers Association were:

| | |
|---|---|
| Earl Warren Hall-roof | U.C. Campus, Berkeley<br>Urban-residential area |
| Space Sciences Lab-roof | Light industry about two miles away |
| | " " " |
| Latimer Hall-roof | " " " |
| Molecular Biology Lab-roof | " " " |

| | |
|---|---|
| San Jose State College roof-of science Bldg. | Near center of San Jose. Urban-residential area. Light & moderately heavy industry 2 to 5 miles away. |
| Air Resources Board | Downtown Los Angeles-on a smoggy day. Sampled out of 2nd floor window of ARB Building. |
| White Mountain | California Mountain, central California, east of Sierra's and near Nevada. Surrounded by desert. Elevation 12,470 ft. |
| Car #6 in Emeryville, Ca. | Downwind from the dump used by a plant which manufactures asbestos. (The volume of air sampled was only 0.65 cubic feet). |
| Car #8 | Highway 101, California near San Francisco Airport. Volume of air sampled- 2.3 ft.$^3$. |
| Car #9 | Highway 101 Palo Alto to San Jose volume of air sampled- 1.5 ft.$^3$. |
| Car #10 | Highway 17 San Jose to Oakland volume of air sampled- 2.4 ft.$^3$. |

For the samples obtained on the freeways, data was obtained on wind speed and direction from anemometers at or close to the sampling sites. The speed is recorded in miles per hour (mph) and the direction is indicated by numbers correlating to the degrees of a circle: N = 0 or 36, E = 9, S = 18 and W = 27. The average speed and number of motor vehicles traveling in the lanes on the side where the air sampling unit was placed were obtained from computer printout sheets for the time intervals sampled from the Los Angeles 42-mile freeway loop surveillance center in downtown Los Angeles. The data was recorded at 5 minute intervals.

II Method of Air Sampling

Membrane filters were used to collect fibers along with particulates from the air at the sampling sites. The use of membrane filters for

collecting asbestos fibers from air in work environments and the procedure for quantitative analysis of the number of fibers by light microscopy was developed by the USPHS and was published in 1968 by Edwards and Lynch[7]. It is the method adopted by OSHA in 1972 for determination of industrial exposures to asbestos fibers[8]. This method was adapted by Balzer, Cooper and Fowler[9] for sampling ambient air and air from ventilation systems. A larger membrane filter in a metal open face filter holder was used with an air flow rate of 1-2 cfm, much greater than the liter per minute rate commonly used used for sampling occupational areas. For this study, fibers and particulates from freeway and ambient air were collected on 47-mm diameter type AA Millipore filters, 0.8μ nominal pore size, mounted in 47-mm diameter open type metal Millipore aerosol filter holders. Gelman air sampling vacuum pumps (Model No. 13408) capable of a flow rate through the membrane filter of 1-2 cfm were used with either 10 feet or 25 feet of 1/2 inch OD, 1/4 inch I D Tygon tubing connected to the filter holder. Calibration curves, were prepared for use in the field of the vacuum in inches of mercury indicated on the pump vacuum gauge versus flow rate of air in cfm through a membrane filter. The pumps were calibrated using an 0.8μm pore size filter in a 47-mm diameter in-line Millipore aerosol filter holder with both a 10-foot and 25-foot length of tubing connecting the filter holder to the pump. A precalibrated Fischer rotometer was used for calibration of the vacuum gauges on the pumps. The flow rate of the 4 pumps for most samples, with either 10 feet or 25 feet of tubing, was close to 1.5 cfm. The pump gauge reading was recorded at the beginning and end of the sampling period and averaged for the calculation of the flow rate. The beginning and end of the sampling period was recorded so that the total air

volume sampled could be calculated and also serve as a record of the time of day of the sampling period.

The filter assemblies were placed filter side down, 5 to 6 feet above the pavement at the edge of the freeway or the same distance above ground 100 to 200 feet upwind of the freeway for the control samples.

After sampling the filter assembly was turned to the upright position, the filter removed and stored in a plastic disposable 48 mm X 8.5 mm petri dish. The dish and a data sheet was labeled with a number from a roll of time consecutive number tape (each number printed 6 times) obtained from the Professional Tape Company, Riverside, Illinois. Extra numbers were placed on the petri dish so that all data sheets could be labeled with the same number.

The Bay Area ambient air samples were collected, stored and labeled in the same way as the samples from Los Angeles.

III. Analytical Procedure for counting and sizing fibers by light microscopy

The method of Edwards and Lynch[7] of the USPHS was used for counting asbestos, glass, and other fibers on the samples obtained on membrane filters. A sector (approx. 1/5 of the filter) is cut out of the membrane filter, mounted on a glass microscope slide with few drops of a viscous mounting medium of the same refractive index of the filter and covered with a glass coverslip. The mounting medium is a 1:1 mixture of diethyl oxalate and dimethyl pthalate with 5-7% wt/vol of broken Millipore filters added to increase the viscosity. A Leitz Dialux binocular microscope equipped with a 40X apochromatic phase contrast objective lens, a Heine variable phase contrast substage condenser and a pair of compensating 10X eyepieces. The

magnification is 400X. A Portca reticle is placed in one of the eyepieces. The clear half of the reticle is a square and is divided into 6 small rectangles of equal size by 1 vertical line and two equidistant horizontal lines. The length of the sides of the clear square is measured by means of an optical micrometer calibrated with a stage micrometer. This length equals 100L. The area of the square is considered a field. There are 9 numbered clear circles and 9 numbered black circles of graded sizes. The diameter of the circles are calibrated and are used for sizing the diameters of the fibers and the length of small fibers. The size gradation of the circles is defined by the formula: $D = L\ 2^n$, where $D$ = the diameter of the circle, $n$ = the circle number and $L = \frac{100L}{100}$. The square used for counting is approximately one fifth of the area of the microscope viewing field. The number of fibers are counted in 100 fields. The edges of the filter sector are avoided as there may be some movement of fibers at the edge. The pattern of fields counted is as follows: The first field is positioned close to the apex of the sector, the slide is moved along the radius one full microscope field diameter at a time and the fibers are counted in the center as prescribed by the clear area of the Porton grating. At a point close to the arc of the sector the slide is moved at right angles for a few fields and a series of fields parallel to the radius are counted moving the slide in a direction opposite to the 1st series of fields. Close to the apex a few fields are positioned at right angles toward the other side of the radius and a series of fields are counted in a line parallel to the radius moving toward the arc of the sector. The method of calculation of the number of fibers per liter of air sampled is as follows:

$$\frac{\text{Total No. of fibers}}{\text{no. of fields}} \times \frac{\text{effective area of fibers in mm}^2}{\text{area of 1 field in mm}^2} \times \frac{\quad}{\text{vol of air in 1}} = \text{fibers/liter}$$

IV Analytical procedures - Electron Microscopy

The procedures are reported in detail in Appendix A.

V. Experimental Design

The sampling program was initially designed to take advantage of the California Division of Highways proposed air sampling system for the Los Angeles 42-mile freeway loop, involving mobile laboratories, and personnel available for sampling, to obtain a few thousand samples from several sampling sites. Each sample of particulates from the air was to be collected on membrane filters for two hours. From these samples, 120 were to be analysed for fiber content, 60 from the freeway and 60 ambient air controls. The samples were to be chosen according to wind, weather, and motor vehicle traffic conditions from data obtained from the Los Angeles 42 mile freeway loop control center. This freeway sampling system was delayed so an alternative program was adopted. This program involved the use of one mobile laboratory which was used at four sampling sites, already described. A total of 120 samples were obtained, each of approximately two hour sampling time, during peak traffic hours and at other times. Several consecutive samples were obtained in the morning and/or afternoon for a few days at each site. Data on the volume and speed of traffic as well as wind direction and velocity were obtained for each of the 2 hour freeway samples from the control

collecting asbestos fibers from air in work environments and the procedure for quantitative analysis of the number of fibers by light microscopy was developed by the USPHS and was published in 1968 by Edwards and Lynch[7]. It is the method adopted by OSHA in 1972 for determination of industrial exposures to asbestos fibers[8]. This method was adapted by Balzer, Cooper and Fowler[9] for sampling ambient air and air from ventilation systems. A larger membrane filter in a metal open face filter holder was used with an air flow rate of 1-2 cfm, much greater than the liter per minute rate commonly used used for sampling occupational areas. For this study, fibers and particulates from freeway and ambient air were collected on 47-mm diameter type AA Millipore filters, 0.8μ nominal pore size, mounted in 47-mm diameter open type metal Millipore aerosol filter holders. Gelman air sampling vacuum pumps (Model No. 13408) capable of a flow rate through the membrane filter of 1-2 cfm were used with either 10 feet or 25 feet of 1/2 inch OD, 1/4 inch I D Tygon tubing connected to the filter holder. Calibration curves, were prepared for use in the field of the vacuum in inches of mercury indicated on the pump vacuum gauge versus flow rate of air in cfm through a membrane filter. The pumps were calibrated using an 0.8μm pore size filter in a 47-mm diameter in-line Millipore aerosol filter holder with both a 10-foot and 25-foot length of tubing connecting the filter holder to the pump. A precalibrated Fischer rotometer was used for calibration of the vacuum gauges on the pumps. The flow rate of the 4 pumps for most samples, with either 10 feet or 25 feet of tubing, was close to 1.5 cfm. The pump gauge reading was recorded at the beginning and end of the sampling period and averaged for the calculation of the flow rate. The beginning and end of the sampling period was recorded so that the total air

## RESULTS

Tables I-IV summarize the concentration of chrysotile asbestos fibers in fibers/liter of air (f/l), analysed by light (LM) and electron microscopy (EM) in the samples from the freeway and in the upwind ambient air controls at each of the Los Angeles 42-mile freeway loop sites. Included in the tables are the analysis by electron microscopy (EM) of the concentrations (f/l) of amphibole asbestos (mostly tremolite), glass, and unknown fibers (unidentified) for the freeway and control samples. The tables also include the starting and stopping times for each sample and the date of sampling. For the freeway samples the number of motor vehicles which passed the sampling sites, and then average speed, during the sampling time periods are included. Variation in speed within the sample time interval, if any are indicated. The wind direction and velocity are included for an area close to the sampling sites during the time intervals of sampling (within a few hours).

Table V contains the concentration (f/l) of glass, asbestos and unknown fibers in ambient air in the San Francisco Bay Area and other California sites analysed by light and electron microscopy.

Table VI contains the average chrysotile fiber concentration and range of concentrations found in the four sites on the Los Angeles freeways and the ambient air controls, analysed by electron microscopy. The first few samples on the Santa Monica freeway site are excluded.

Table VII is a comparison of the average chrysotile concentrations (f/l) between the Los Angeles Area and the San Francisco Bay Area. The first few

samples on the Santa Monica freeway site, and one Bay Area sample (near a point source) are excluded. Table VIII is a summary of the chrysotile fiber size distribution, diameter and length, of composites measured by electron microscopy of the Los Angeles freeway and upwind control samples (matched pairs), and table VIIIA is the fiber size distribution, diameter, only of the Bay Area Cities ambient air samples.

Using the fiber diameter distributions as listed in Tables VIII, and VIIIA the cumulative percentages at given diameters were determined and are shown graphically in Figure 6. The geometric mean diameter of both the freeway and control composites were 0.3μm and their standard geometric deviations were 3.8 and 3.2 respectively. In the Bay Area composite the diameter sizes above 0.03μm are distributed like the upper tail of a log normal distribution. Approximately 50% of the fibers were measured as single fibrils (0.03μm). In view of the assymetric nature of the distribution the 50% point is considered as the geometric mean - $d_g$ + 0.03μm, and the $\sigma_g$ = 7.7.

Table IX is a summary of the distributions of fiber types in composites for Los Angeles freeway and control samples.

Table X is the statistical testing of measured differences at the 95% confidence level of the Los Angeles freeway and control matched pair samples for EL and LM (t test).

Table XI contains the confidence intervals of several fiber counts by EM and the formula used for calculating the intervals.

Table XII is the glass fiber concentration in the Los Angeles Freeway loop samples by LM & EM. Table XIII is the comparison of the average glass fiber concentration between the Los Angeles area and the San Francisco Bay

by LM and EM.

Table XIV is the concentration of glass fibers in the Los Angeles freeway and control samples by light microscope.

Table XV is a composite of the average concentrations of unknown fibers in the Los Angeles freeway-loop samples and Bay Area ambient air samples.

Table XVI is a summary of the data on the collection efficiency of the 0.8μm pore size Nuclepore filters for chrysotile asbestos fibrils and small bundles.

TABLE I. Santa Monica Freeway at 4th Avenue Pedestrian Overcross

| SAMPLE # | CHRYSOTILE ASBESTOS f/l | | | | AMPHIBOLE ASBESTOS f/l | | GLASS FIBERS f/l | | UNKNOWN FIBERS f/l | | TIME | DATE | TRAFFIC | | WIND mph | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Frwy | | Cont | | Frwy | Cont | Frwy | Cont | Frwy | Cont | | | No. of Motor Vehicles | Av Speed mph | Vel | Dir |
| | LM | EM | LM | EM | EM | EM | EM | EM | EM | EM | | | | | | |
| 2000 | 0.5 | 1.4 | | | | | | | | | 1307-1700 | 3/22 | Heavy | 70} 1300-1600<br>20} 1600-1700 | 9-15 | 25 |
| 2001 | 2.1 | 98.0<br>16 clumps | | | 0 | | 0 | | 2.4 | | 0850-1100 | 3/23 | Heavy | 70} 0850-1000<br>20} 1000-1100 | 3 | 22 |
| 2002 | 1.7 | 22.5<br>3 clumps | | | 0 | | 1.5 | | 3.0 | | 1145-1325 | 3/23 | Normal | 60-70 | 6 | 25 |
| 2003 | 0.7 | 16.4<br>1 clump | | | 0 | | 0 | | 0 | | 1945-2220 | 3/23 | Normal | 60-70 | 23 | 25 |
| 2004 | 1.3 | 0 | | | 2.5 | | 1.3 | | 1.3 | | 0700-0904 | 3/24 | Heavy | 20 Jam | 3 | 25 |
| 2005 | 0 | 0 | | | 2.6 | | 0 | | 2.6 | | 1220-1420 | 3/24 | Normal | 60-70 | 5 | 25 |
| 2006 | | | 0.9 | 1.3 | 0 | | 1.3 | | 10.4 | | 1655-1855 | 3/24 | --- | --- | 3 | 30 |
| Bay Bridge Plaza | 1.0 | 1.4 | | | 1.4 | | 0 | | 1.4 | | 0903-1050 | 3/9 | 11,500 | --- | --- | --- |

(Table I. Santa Monica Freeway at 4th Avenue Pedestrian Overcross Continued)

| SAMPLE # | CHRYSOTILE ASBESTOS f/l | | | | AMPHIBOLE ASBESTOS f/l | | GLASS FIBERS f/l | | UNKNOWN FIBERS f/l | | TIME | DATE | TRAFFIC | | WIND mph | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Frwy | | Cont | | Frwy | Cont | Frwy | Cont | Frwy | Cont | | | No. of Motor Vehicles | Av Speed mph | Vel | Dir |
| | LM | EM | LM | EM | EM | EM | EM | EM | EM | EM | | | | | | |
| 2599 | 2.3 | 0 | | | 3.7 | | 0 | | 12.3 | | 0850-1050 | 6/27 | --- | --- | --- | --- |
| 2600 | 1.0 | 4.5 | | | 1.5 | | 1.5 | | 3 | | 1529-1725 | 7/17 | --- | --- | 11 | 25 |
| 2601 | 1.8 | 3.6 | | | 1.2 | | 0 | | 2.6 | | 1526-1735 | 7/17 | --- | --- | 11 | 25 |
| 2602 | 1.0 | 1.4 | | | 0 | | 1.4 | | 1.4 | | 1243-1443 | 7/18 | 15,400 | 62 | 9 | 25 |
| 2603 | 0.9 | 1.2 | | | 1.2 | | 1.2 | | 1.2 | | 1249-1451 | 7/18 | 15,400 | 62 | 9 | 25 |
| 2604 | | | 11.0 | 1.2 | | 0 | | 0 | | 3.6 | 1257-1505 | 7/18 | | | 9 | 25 |
| 2605 | 0.5 | 1.4 | | | 0 | | 1.4 | | 0 | | 1448-1645 | 7/18 | 15,800 | 60 | 11 | 25 |
| 2606 | 1.0 | 1.3 | | | 0 | | 1.3 | | 1.3 | | 1502-1652 | 7/18 | 15,800 | 60 | 11 | 25 |
| 2607 | | | 2.4 | 1.3 | | 0 | | 0 | | 2.6 | 1508-1704 | 7/18 | | | 11 | 25 |

(Table I. Santa Monica Freeway at 4th Avenue Pedestrian Overcross Continued)

| SAMPLE # | CHRYSOTILE ASBESTOS f/l | | | | AMPHIBOLE ASBESTOS f/l | | GLASS FIBERS f/l | | UNKNOWN FIBERS f/l | | TIME | DATE | TRAFFIC | | WIND mph | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Frwy | | Cont | | Frwy | Cont | Frwy | Cont | Frwy | Cont | | | No. of Motor Vehicles | Av Speed mph | Vel | Dir |
| | LM | EM | LM | EM | EM | EM | EM | EM | EM | EM | | | | | | |
| 2608 | 1.2 | 0 | | | 0 | | 0 | | 1.7 | | 1234-1413 | 7/19 | 12,000 | 61 | --- | --- |
| 2609 | 0.56 | 0 | | | 1.5 | | 1.5 | | 9.0 | | 1233-1419 | 7/19 | 12,000 | 61 | --- | --- |
| 2610 | | | 2.0 | 1.4 | | 0 | | 0 | | 2.8 | | 7/19 | | | --- | --- |
| 2611 | 1.8 | 0 | | | 0 | | 1.6 | | 0 | | 1418-1559 | 7/19 | 13,200 | 58 | 10 | 26 |
| 2612 | | | 4.2 | 0 | | 0 | 0 | | 0 | | 1427-1612 | 7/19 | | | 10 | 26 |
| 2613 | 0.6 | 0 | | | 1.1 | | 0 | | 1.1 | | 1602-1708 | 7/19 | 12,900 | 65 | 11 | 25 |
| 2614 | 0.6 | 0 | | | 0 | | 0 | | 0 | | 1610-1745 | 7/19 | 12,900 | 65 | 11 | 25 |
| 2615 | | | 7.4 | 0 | | 0 | | 0 | | 2.0 | 1614-1806 | 7/19 | | | 11 | 25 |
| 2616 | 0 | 0 | | | 1.3 | | 0 | | 0 | | 1257-1457 | 7/20 | 16,000 | 61 | 9 | 25 |
| 2617 | 0 | 0 | | | 0 | | 0 | | 2.4 | | 1255-1458 | 7/20 | 16,000 | 61 | 9 | 25 |

(Table I. Santa Monica Freeway at 4th Avenue Pedestrian Overcross Continued)

| SAMPLE # | CHRYSOTILE ASBESTOS f/l | | | | AMPHIBOLE ASBESTOS f/l | | GLASS FIBERS f/l | | UNKNOWN FIBERS f/l | | TIME | DATE | TRAFFIC | | WIND mph | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Frwy | | Cont | | Frwy | Cont | Frwy | Cont | Frwy | Cont | | | No. of Motor Vehicles | Av Speed mph | Vel | Dir |
| | LM | EM | LM | EM | EM | EM | EM | EM | EM | EM | | | | | | |
| 2618 | | | 2.0 | 0 | | 0 | | 0 | | 3.8 | 1253-1450 | 7/20 | | | 9 | 25 |
| 2619 | 1.0 | 0 | | | 1.2 | | 1.2 | | 2.4 | | 1833-2034 | 7/21 | --- | --- | 10 | 25 |
| 2620 | 0.5 | 0 | | | 3.0 | | 3.0 | | 0 | | 1852-2036 | 7/21 | --- | --- | 10 | 25 |
| 2621 | | | 1.0 | 2.7 | | 1.4 | | 2.7 | | 0 | 1847-2044 | 7/21 | | | 10 | 25 |
| 2622 | 1.0 | 0 | | | 0 | | 2.4 | | 0 | | 2055-2252 | 7/21 | | | --- | --- |
| 2623 | 0 | 0 | | | 1.4 | | 0 | | 2.9 | | 2058-2247 | 7/21 | --- | --- | --- | --- |
| 2624 | | | 1.3 | 0 | | 1.2 | | 0 | | 0 | 2052-2058 | 7/21 | | | --- | --- |

## Table II. Harbor Freeway at 146th

| SAMPLE # | CHRYSOTILE ASBESTOS f/l | | | | AMPHIBOLE ASBESTOS f/l | | GLASS FIBERS f/l | | UNKNOWN FIBERS f/l | | TIME | DATE | TRAFFIC | | WIND mph | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Frwy | | Cont | | Frwy | Cont | Frwy | Cont | Frwy | Cont | | | No. of Motor Vehicles | Av Speed mph | Vel | Dir |
| | LM | EM | LM | EM | EM | EM | EM | EM | EM | EM | | | | | | |
| 2625 | 2.0 | 1.3 | | | 8.0 | | 1.3 | | 4.0 | | 1625-1745 | 7/28 | --- | --- | --- | --- |
| 2626 | | | 2.0 | 4.0 | | 1.3 | | 1.3 | | 3.0 | 1625-1745 | 7/28 | | | | |
| 2628 | 1.5 | 0 | | | 0 | | 0 | | 4.0 | | 0900-1100 | 7/31 | 8,012 | 70 | --- | --- |
| 2627 | | | 3.0 | 1.3 | | 2.6 | | 1.3 | | 4.0 | 0900-1100 | 7/31 | | | | |
| 2632 | 0.4 | 0 | | | 0 | | 0 | | 0 | | 1330-1548 | 7/31 | Inc | 70 | --- | --- |
| 2631 | | | 1.6 | 1.4 | | 0 | | 0 | | 4.0 | 1400-1542 | 7/31 | | | | |
| 2634 | 4.0 | 3.0 | | | 0 | | 0 | | 9.0 | | 1016-1158 | 8/1 | 5,510 | 70 | 3 | 10 |
| 2633 | | | 2.5 | 1.6 | | 0 | | 0 | | 1.6 | 1015-1152 | 8/1 | | | | |
| 2635 | 1.3 | 12.0 | | | 4.0 | | 0 | | 5.5 | | 0950-1200 | 8/2 | 6,834 | 70 | 3 | 10 |
| 2636 | | | 5.5 | 1.2 | | 8.4 | | 1.2 | | 6.0 | 0950-1200 | 8/2 | | | | |

(Table II. Harbor Freeway at 146th Continued)

| SAMPLE # | CHRYSOTILE ASBESTOS f/l | | | | AMPHIBOLE ASBESTOS f/l | | GLASS FIBERS f/l | | UNKNOWN FIBERS f/l | | TIME | DATE | TRAFFIC | | WIND mph | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Frwy | | Cont | | Frwy | Cont | Frwy | Cont | Frwy | Cont | | | No. of Motor Vehicles | Av Speed mph | Vel | Dir |
| | LM | EM | LM | EM | EM | EM | EM | EM | EM | EM | | | | | | |
| 2638 | | | 4.0 | 0 | | 0 | | 2.0 | | 8.0 | 1205-1337 | 8/2 | | | | |
| 2639 | 3.0 | 0 | | | 0 | | 0 | | 1.6 | | 1355-1533 | 8/2 | 5,974 | 73 | 8 | 17 |
| 2640 | | | 3.0 | 0 | | 0 | | 0 | | 1.5 | 1345-1527 | 8/2 | | | | |
| 2641 | 1.2 | 7.0 | | | 0 | | 0 | | 7.0 | | 0730-0935 | 8/3 | 11,700 | 70 | 5 | 14 |
| 2642 | | | 1.0 | 0 | | 3.0 | | 0 | | 5.0 | 0730-0930 | 8/3 | | | | |
| 2643 | 1.0 | 0 | | | 0 | | 0 | | 1.3 | | 0938-1135 | 8/3 | Inc | 70 | 5 | 14 |
| 2644 | | | 2.0 | 0 | | 3.0 | | 0 | | 4.3 | 0932-1130 | 8/3 | | | | |
| 2645 | 1.0 | 0 | | | 0 | | 0 | | 5.0 | | 1138-1329 | 8/3 | 6,016 | 70 | 5 | 14 |
| 2646 | | | 4.2 | 1.5 | | 4.5 | | 0 | | 4.5 | 1132-1320 | 8/3 | | | | |
| 2647 | 1.5 | 0 | | | 1.5 | | 0 | | 10.0 | | 1323-1518 | 8/3 | 6,764 | 73 | 9 | 27 |

(Table II. Harbor Freeway at 146th Continued)

| SAMPLE # | CHRYSOTILE ASBESTOS f/l | | | | AMPHIBOLE ASBESTOS f/l | | GLASS FIBERS f/l | | UNKNOWN FIBERS f/l | | TIME | DATE | TRAFFIC | | WIND mph | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Frwy | | Cont | | Frwy | Cont | Frwy | Cont | Frwy | Cont | | | No. of Motor Vehicles | Av Speed mph | Vel | Dir |
| | LM | EM | LM | EM | EM | EM | EM | EM | EM | EM | | | | | | |
| 2648 | | | 2.0 | 0 | | 1.4 | | 0 | | 2.7 | 1331-1526 | 8/3 | | | | |
| 2649 | 1.8 | 1.4 | | | 1.4 | | 0 | | 9.8 | | 0715-0915 | 8/4 | 12,500 | 20 min-50 rest-70 | 2 | 24 |
| 2650 | | | 2.3 | 2.5 | | 0 | | 0 | | 30.0 | 0720-0922 | 8/4 | | | | |
| 2651 | 2.7 | 0 | | | 0 | | 0 | | 6.5 | | 0919-1120 | 8/4 | Inc | --- | 3 | 24 |
| 2652 | | | 14.1 | 0 | | 1.0 | | 2.0 | | 6.3 | 0925-1150 | 8/4 | | | | |
| 2653 | 1.4 | 4.0 | | | 0 | | 0 | | 1.3 | | 0728-0930 | 8/7 | 12,100 | 40 min-35 rest-70 | 4 | 14 |
| 2654 | | | 0.5 | 0 | | 0 | | 0 | | 1.4 | 0724-0924 | 8/7 | | | | |
| 2656 | 1.4 | 2.7 | | | 0 | | 0 | | 8.0 | | 0932-1130 | 8/7 | 6,700 | 70 | 4 | 14 |
| 2655 | | | 1.8 | 0 | | 0 | | 0 | | 0 | 0925-1125 | 8/7 | | | | |

(Table II. Harbor Freeway at 146th Continued)

| SAMPLE # | CHRYSOTILE ASBESTOS f/1 | | | | AMPHIBOLE ASBESTOS f/1 | | GLASS FIBERS f/1 | | UNKNOWN FIBERS f/1 | | TIME | DATE | TRAFFIC | | WIND mph | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Frwy | | Cont | | Frwy | Cont | Frwy | Cont | Frwy | Cont | | | No. of Motor Vehicles | Av Speed mph | Vel | Dir |
| | LM | EM | LM | EM | EM | EM | EM | EM | EM | EM | | | | | | |
| 2658 | 0 | 0 | | | 1.0 | | 0 | | 2.5 | | 0859-1051 | 8/8 | --- | --- | 3 | 24 |
| 2657 | | | 2.6 | 3.1 | | 0 | | 0 | | 3.0 | 0858-1043 | 8/8 | | | | |
| 2659 | 2.2 | 0 | | | 1.6 | | 0 | | 13.0 | | 1053-1233 | 8/8 | --- | --- | 5 | 24 |
| 2660 | | | 3.9 | 0 | | 1.6 | | 0 | | 3.0 | 1046-1225 | 8/8 | | | | |
| 2661 | 0.9 | 0 | | | 3.0 | | 0 | | 10.0 | | 1015-1208 | 8/9 | 6,300 | 70 | 4 | 25 |
| 2662 | | | 3.0 | 1.4 | | 1.4 | | 1.4 | | 5.6 | 1010-1201 | 8/9 | | | | |

## Table III. San Diego Freeway at National

| SAMPLE # | CHRYSOTILE ASBESTOS f/1 | | | | AMPHIBOLE ASBESTOS f/1 | | GLASS FIBERS f/1 | | UNKNOWN FIBERS f/1 | | TIME | DATE | TRAFFIC | | WIND mph | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Frwy | | Cont | | Frwy | Cont | Frwy | Cont | Frwy | Cont | | | No. of Motor Vehicles | Av Speed mph | Vel | Dir |
| | LM | EM | LM | EM | EM | EM | EM | EM | EM | EM | | | | | | |
| 2669 | 0.4 | 0 | | | 1.2 | | 0 | | 14.0 | | 1350-1600 | 8/28 | 15,200 | 85 min-56<br>45 min-41 | 4 | 26 |
| 2670 | | | 1.3 | 0 | | 1.3 | | 0 | | 6.0 | 1406-1609 | 8/28 | | | | |
| 2671 | 0.6 | 1.7 | | | 0 | | 0 | | 1.7 | | 1603-1740 | 8/28 | 11,800 | 54 | 4 | 26 |
| 2672 | | | 1.5 | 1.5 | | 1.5 | | 0 | | 1.5 | 1611-1750 | 8/28 | | | | |
| 2673 | 1.1 | 1.5 | | | 4.5 | | 0 | | 3.0 | | 1258-1505 | 8/30 | 14,000 | 57 | --- | --- |
| 2674 | | | 0.9 | 0 | | 1.2 | | 0 | | 5.0 | 1305-1515 | 8/30 | | | | |
| 2675 | 0.5 | 0 | | | 1.3 | | 0 | | 2.5 | | 1508-1705 | 8/30 | 14,600 | 80 min-42<br>45 min-56<br>Av- 47 | --- | --- |
| 2676 | | | 0.9 | 0 | | 1.4 | | 1.4 | | 1.4 | 1517-1715 | 8/30 | | | | |

(Table III. San Diego Freeway at National Continued)

| SAMPLE # | CHRYSOTILE ASBESTOS f/1 | | | | AMPHIBOLE ASBESTOS f/1 | | GLASS FIBERS f/1 | | UNKNOWN FIBERS f/1 | | TIME | DATE | TRAFFIC | | WIND mph | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Frwy | | Cont | | Frwy | Cont | Frwy | Cont | Frwy | Cont | | | No. of Motor Vehicles | Av Speed mph | Vel | Dir |
| | LM | EM | LM | EM | EM | EM | EM | EM | EM | EM | | | | | | |
| 2677 | 0.5 | 1.4 | | | 0 | | 1.4 | | 0 | | 0800-0954 | 9/6 | 14,400 | 49 | 2 | 11 |
| 2678 | | | 2.1 | 0 | | 0 | | 0 | | 0 | 0815-1001 | 9/6 | | | | |
| 2679 | 2.0 | 0 | | | 0 | | 0 | | 3.0 | | 1056-1105 | 9/6 | 6,102 | 49 | 2 | 11 |
| 2680 | | | 1.0 | 0 | | 3.0 | | 0 | | 0 | 1003-1159 | 9/6 | | | | |
| 2681 | 0.5 | 1.4 | | | 0 | | 0 | | 3.0 | | 0810-1007 | 9/11 | 15,000 | 55 | 4 | 26 |
| 2682 | | | 0.5 | 0 | | 1.5 | | 0 | | 0 | 0822-1012 | 9/11 | | | | |
| 2683 | 0.5 | 0 | | | 0 | | 0 | | 0 | | 1008-1200 | 9/11 | 12,000 | 54 | 4 | 26 |
| 2684 | | | 1.4 | 0 | | 0 | | 0 | | 6.0 | 1014-1209 | 9/11 | | | | |

## Table IV. San Diego Freeway at 122nd

| SAMPLE # | CHRYSOTILE ASBESTOS f/l | | | | AMPHIBOLE ASBESTOS f/l | | GLASS FIBERS f/l | | UNKNOWN FIBERS f/l | | TIME | DATE | TRAFFIC | | WIND mph | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Frwy | | Cont | | Frwy | Cont | Frwy | Cont | Frwy | Cont | | | No. of Motor Vehicles | Av Speed mph | Vel | Dir |
| | LM | EM | LM | EM | EM | EM | EM | EM | EM | EM | | | | | | |
| 2685 | 1.6 | 1.5 | | | 0 | | 0 | | 17.0 | | 0936-1129 | 9/26 | 9,800 | 66 | 3 | 13 |
| 2686 | | | 1.1 | 0 | | 1.6 | | 0 | | 27.0 | 0957-1141 | 9/26 | | | | |
| 2687 | 1.0 | 0 | | | 0 | | 0 | | 1.3 | | 1131-1326 | 9/26 | 8,900 | 69 | 3 | 13 |
| 2688 | | | 1.5 | 0 | | 0 | | 0 | | 9.0 | 1144-1337 | 9/26 | | | | |
| 2689 | 1.4 | 0 | | | 1.3 | | 0 | | 3.0 | | 0858-1057 | 9/27 | 12,400 | 68 | 3 | 6 |
| 2690 | | | --- | --- | | | | | | | --- | --- | | | | |
| 2691 | 0.4 | --- | | | | | | | | | 1101-1307 | 9/27 | --- | --- | 3 | 6 |
| 2692 | | | --- | --- | | | | | | | --- | --- | | | | |
| 2693 | 1.4 | 0 | | | 0 | | 0 | | 18.0 | | 1310-1440 | 9/27 | 7,385 | 70 | 11 | 24 |
| 2694 | | | 0.5 | 0 | | 0 | | 1.6 | | 11.0 | 1302-1445 | 9/27 | | | | |

(Table IV. San Diego Freeway at 122nd Continued)

| SAMPLE # | CHRYSOTILE ASBESTOS f/1 | | | | AMPHIBOLE ASBESTOS f/1 | | GLASS FIBERS f/1 | | UNKNOWN FIBERS f/1 | | TIME | DATE | TRAFFIC | | WIND mph | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Frwy | | Cont | | Frwy | Cont | Frwy | Cont | Frwy | Cont | | | No. of Motor Vehicles | Av Speed mph | Vel | Dir |
| | LM | EM | LM | EM | EM | EM | EM | EM | EM | EM | | | | | | |
| 2695 | 0.6 | 0 | | | 3.6 | | 1.8 | | 0 | | 1134-1309 | 9/28 | 7,400 | 69 | 3 | 12 |
| 2696 | | | 1.0 | 0 | | 0 | | 0 | | 0 | 1127-1318 | 9/28 | | | | |
| 2697 | 0.6 | 2.0 | | | 0 | | 0 | | 6.0 | | 1313-1443 | 9/28 | 8,000 | 67 | 12 | 24 |
| 2698 | | | 2.0 | 9.0 | | 0 | | 0 | | 4.0 | 1322-1455 | 9/28 | | | | |
| 2699 | 1.2 | 0 | | | 1.8 | | 0 | | 0 | | 0816-0955 | 9/29 | --- | --- | 2 | 12 |
| 2700 | | | 1.4 | 0 | | 1.4 | | 0 | | 17.0 | 0805-1003 | 9/29 | | | | |
| 2701 | 1.3 | 0 | | | 0 | | 0 | | 7.0 | | 1000-1133 | 9/29 | --- | --- | 2 | 12 |
| 2702 | | | 1.2 | 0 | | 1.8 | | 0 | | 5.0 | 1007-1143 | 9/29 | | | | |
| 2501 | 1.5 | 3.0 | | | 3.0 | | 0 | | 9.0 | | 0651-0845 | 10/5 | 16,300 | 57 | 2 | --- |
| 2500 | | | 1.0 | 0 | | 6.0 | | 0 | | 0 | 0639-0838 | 10/5 | | | | |

(Table IV. San Diego Freeway at 122nd Continued)

| SAMPLE # | CHRYSOTILE ASBESTOS f/1 | | | | AMPHIBOLE ASBESTOS f/1 | | GLASS FIBERS f/1 | | UNKNOWN FIBERS f/1 | | TIME | DATE | TRAFFIC | | WIND mph | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Frwy | | Cont | | Frwy | Cont | Frwy | Cont | Frwy | Cont | | | No. of Motor Vehicles | Av Speed mph | Vel | Dir |
| | LM | EM | LM | EM | EM | EM | EM | EM | EM | EM | | | | | | |
| 2503 | 1.0 | 0 | | | 3.0 | | 0 | | 4.0 | | 0846-1044 | 10/5 | 11,800 | 66 | 3 | 30 |
| 2502 | | | 1.4 | 0 | | 0 | | 0 | | 4.0 | 0840-1038 | 10/5 | | | | |
| 2505 | 1.3 | 1.3 | | | 7.0 | | 0 | | 0 | | 1044-1243 | 10/5 | 9,800 | 69 | 3 | 30 |
| 2504 | | | 1.0 | 0 | | 0 | | 0 | | 1.5 | 1040-1237 | 10/5 | | | | |
| 2507 | 1.3 | 1.3 | | | 1.3 | | 0 | | 1.3 | | 1245-1441 | 10/5 | 9,400 | 70 | 9 | 25 |
| 2506 | | | 2.0 | 1.5 | | 1.5 | | 0 | | 1.5 | 1239-1434 | 10/5 | | | | |
| 2509 | 1.3 | 0 | | | 8.0 | | 0 | | 4.0 | | 0655-0825 | 10/6 | --- | | 2 | 34 |
| 2508 | | | 1.2 | 7.2 | | 4.0 | | 0 | | 0 | 0643-0818 | 10/6 | | | | |
| 2511 | 0.5 | 0 | | | 10.0 | | 3.0 | | 0 | | 0826-1013 | 10/6 | --- | | 3 | 21 |
| 2510 | | | 0.5 | 0. | | 3.0 | | 0 | | 3.0 | 0820-1006 | 10/6 | | | | |

(Table IV. San Diego Freeway at 122nd Continued)

| SAMPLE # | CHRYSOTILE ASBESTOS f/l | | | | AMPHIBOLE ASBESTOS f/l | | GLASS FIBERS f/l | | UNKNOWN FIBERS f/l | | TIME | DATE | TRAFFIC | | WIND mph | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Frwy | | Cont | | Frwy | Cont | Frwy | Cont | Frwy | Cont | | | No. of Motor Vehicles | Av Speed mph | Vel | Dir |
| | LM | EM | LM | EM | EM | EM | EM | EM | EM | EM | | | | | | |
| 2513 | 1.7 | 0 | | | 0 | | 4.0 | | 0 | | 1015-1150 | 10/6 | --- | | 3 | 21 |
| 2512 | | | 1.7 | 0 | | 2.0 | | 0 | | 0 | 1008-1145 | 10/6 | --- | | | |
| 2515 | 1.1 | 0 | | | 0 | | 0 | | 4.0 | | 0709-0850 | 10/10 | 14,000 | 59 | 2 | 3 |
| 2514 | | | 0 | 3.0 | | 2.0 | | 0 | | 3.0 | 0657-0843 | 10/10 | | | | |
| 2523 | 1.7 | 0 | | | 0 | | 2.0 | | 4.0 | | 0654-0834 | 10/11 | 14,000 | 52 | 2 | 12 |
| 2522 | | | 1.7 | 0 | | 0 | | 0 | | 4.0 | 0642-0827 | 10/11 | | | | |
| | | | DOWNTOWN LA CONT | | | | | | | | | | | | | |
| 2538 | | | 8.0 | 1.4 | | 4.0 | | 1.0 | | 1.0 | 0838-1030 | 10/26 | --- | --- | --- | --- |
| 2539 | | | 1.3 | 0 | | 3.0 | | 1.0 | | 1.0 | 1031-1235 | 10/26 | --- | --- | --- | --- |
| 2540 | | | 1.0 | 0 | | 0 | | 3.0 | | 3.0 | 1236-1430 | 10/26 | --- | --- | --- | --- |

See Footnote

Table V. Chrysotile Asbestos, Glass and Unknown Fibers in Ambient Air

| SAMPLE | ELECTRON MICROSCOPE | | | LIGHT MICROSCOPE | | |
|---|---|---|---|---|---|---|
| | GLASS | ASBESTOS (f/l) | UNKNOWN | GLASS | ASBESTOS (f/l) | UNKNOWN |
| San Jose | 1.3 | 0 | 1.5 | 2.0 | 3.5 | 5.0 |
| San Jose | 1.6 | 0 | 1.7 | 2.0 | 1.6 | 2.0 |
| San Jose | 1.2 | 0.9 | 1.2 | 0.5 | 2.2 | 5.0 |
| San Jose | 0.6 | 0.2 | 3.0 | 0.4 | 2.9 | 4.0 |
| Space Sciences Lab. | 3.0 | 0 | 13.0 | 1.0 | 0.9 | 0.4 |
| Space Sciences Lab. | 0 | 0 | 1.0 | 0.02 | 0.2 | 0.1 |
| Space Sciences Lab. | 0.04 | 0 | 0.1 | --- | No Data | --- |
| Space Sciences Lab. | 0 | 0 | 3.0 | 0.5 | 0.50 | 2.0 |
| Earl Warren Hall | 0.35 | 0.07 | 0.1 | 0.7 | 1.3 | 2.0 |
| Earl Warren Hall | 2.0 | 0.16 | 2.0 | 3.0 | 1.2 | 2.0 |
| Earl Warren Hall | 2.0 | 0 | 0.7 | 8.0 | 1.8 | 2.0 |
| Earl Warren Hall | 2.0 | 0 | 0.5 | 2.0 | 1.2 | 4.0 |
| Earl Warren Hall | 1.0 | 1.9 | 3.0 | 6.0 | 4.0 | 2.0 |
| Earl Warren Hall | 1.0 | 2.0 | 0.6 | 2.0 | 2.1 | 4.0 |
| Earl Warren Hall | 2.0 | 3.2 | 4.0 | 7.0 | 4.0 | 5.0 |
| Earl Warren Hall | 3.0 | 1.75 | 4.0 | 3.0 | 1.3 | 4.0 |
| Earl Warren Hall | 0 | 1.5 | 2.0 | 4.0 | 3.2 | 0.6 |
| Earl Warren Hall | 2.0 | 2.4 | 4.0 | 7.0 | 1.8 | 0.6 |
| Earl Warren Hall | 0.3 | 1.0 | 1.0 | 1.0 | 0.6 | 0 |
| Earl Warren Hall | 1.0 | 1.4 | 1.0 | 9.0 | 2.2 | 3.0 |
| Earl Warren Hall | 1.0 | 1.0 | 3.0 | 10.0 | 1.8 | 2.0 |
| Earl Warren Hall | 1.0 | 0 | 1.0 | 5.0 | 1.8 | 0.2 |
| Earl Warren Hall | 0.3 | 0.03 | 0.2 | 0.2 | 0 | 0.1 |
| Earl Warren Hall | 0 | 0 | 3.0 | 0.1 | 0 | 0.1 |
| Earl Warren Hall | 0.7 | 0 | 3.0 | 0 | 0 | 0 |
| Car #6 | 238.0 | 238.0 | 1190.0 | 308.0 | 692.0 | 0.2 |
| Car #8 | 0 | 0 | 242.0 | 0.1 | 0 | 0.4 |
| Car #9 | 0 | 0 | 163.0 | 0 | 0 | 0.04 |
| Car #10 | 0 | 0 | 221.0 | 0 | 0.8 | 0.03 |
| Air Resources Board (L.A.) | 0 | 0 | 48.0 | 8.0 | 5.7 | 119.0 |
| Air Resources Board (L.A.) | 4.0 | 0 | 80.0 | 7.0 | 2.4 | 109.0 |
| Air Resources Board (L.A.) | 0 | 0 | 13.0 | 2.0 | 0 | 19.0 |
| Latimer Hall | 0 | 0 | 5.0 | 0.1 | 0.2 | 0.3 |
| Latimer Hall | 0 | 0 | 13.0 | 0.6 | 2.6 | 0.6 |
| Latimer Hall | 0 | 0 | 5.0 | 0.1 | 0.3 | 0.3 |
| Latimer Hall | 0.2 | 0 | 3.0 | 0.2 | 0.3 | 0.1 |
| Molecular Biology Lab. | 0 | 0 | 0 | 2.0 | 1.5 | 3.0 |
| Molecular Biology Lab. | 0.4 | 0.2 | 2.0 | 0.5 | 1.0 | 0.3 |
| White Mountain | 0.04 | 0.1 | 0.5 | 0.1 | 0.2 | 0 |
| White Mountain | 0.1 | 0.02 | 0.3 | 0.8 | 0.10 | 0.1 |

Table VI. Chrysotile Fiber Concentrations--L.A. Freeway Loop

| Location | Average Fiber Concentration, (f/l) | | Ranges Fiber Concentration, (f/l) | |
|---|---|---|---|---|
| | Freeway | Control | Freeway | Control |
| Santa Monica @ 4th | 0.7 | 0.7 | 0 - 5 | 0 - 3 |
| Harbor @ 146th | 1.6 | 1.1 | 0 - 12 | 0 - 4 |
| San Diego @ National | 0.8 | 0.2 | 0 - 2 | 0 - 1.5 |
| San Diego @ 122nd | 0.5 | 0.9 | 0 - 3 | 0 - 9 |
| Composite | 0.9* | 0.8** | 0 - 12 | 0 - 9 |

Fiber Mass Concentration:
* $2.7 \times 10^{-5}$ µgm/l
** $4.3 \times 10^{-5}$ µgm/l

Table VII. Comparison of Average Chrysotile Concentrations, (f/l), Between L.A. Area and S.F. Bay Area by EM and LM

| | L.A. - Freeways | | | | Bay Area | |
|---|---|---|---|---|---|---|
| | Freeway | | Control | | Ambient* | |
| | EM | LM | EM | LM | EM | LM |
| (f/l) | 0.9 | 1.2 | 0.8 | 2.4 | 0.5 | 1.5 |
| No. Samples | 60 | 60 | 53 | 53 | 39 | 38 |

*Fiber Concentration Range: 0 - 3 f/l EM
0 - 10 f/l LM

Table VIII. Chrysotile Fiber Size Distribution of Composites by Electron Microscope

| L.A. Freeway | | L.A. Control | |
|---|---|---|---|
| Fiber Number | Fiber Size D x L, (μm) | Fiber Number | Fiber Size D x L, (μm) |
| 2 | 0.03 x 5 | 1 | 0.03 x 10 |
| 2 | 0.03 x 10 | 4 | 0.1 x 5 |
| 1 | 0.03 x 12 | 1 | 0.1 x 10 |
| 1 | 0.03 x 15 | 1 | 0.2 x 5 |
| 2 | 0.1 x 5 | 2 | 0.2 x 10 |
| 5 | 0.2 x 5 | 1 | 0.2 x 30 |
| 2 | 0.2 x 10 | 3 | 0.3 x 5 |
| 1 | 0.2 x 40 | 3 | 0.5 x 5 |
| 2 | 0.3 x 5 | 2 | 0.7 x 5 |
| 1 | 0.3 x 20 | 1 | 0.7 x 15 |
| 1 | 0.3 x 25 | 1 | 0.7 x 20 |
| 2 | 0.5 x 5 | 2 | 1 x 5 |
| 4 | 0.5 x 10 | 2 | 1 x 10 |
| 1 | 0.5 x 20 | 1 | 1 x 15 |
| 1 | 0.7 x 10 | 1 | 1.5 x 10 |
| 1 | 0.7 x 15 | 2 | 3 x 10 |
| 1 | 1 x 10 | 1 | 5 x 20 |
| 1 | 1 x 15 | 29 | |
| 2 | 1 x 20 | | |
| 1 | 1 x 30 | | |
| 1 | 1 x 60 | | |
| 1 | 1.5 x 5 | | |
| 1 | 1.5 x 20 | | |
| 1 | 1.5 x 25 | | |
| 1 | 3 x 30 | | |
| 39 | | | |

Table VIII(A). Chrysotile Fiber Size Distribution of Composite by Electron Microscopy (Continued)

Ambient Air - Bay Area Cities (diameters only)

| Fiber Number | Fiber Diameter (μm) |
|---|---|
| 46 | .03 |
| 16 | 0.1 |
| 7 | 0.2 |
| 8 | 0.3 |
| 7 | 0.5 |
| 1 | 0.6 |
| 0 | 0.7 |
| 1 | 1.0 |
| 2 | 1.5 |
| 1 | 2.0 |
| 1 | 3.0 |

Table IX. Distribution of Fiber Types in Composites
By EM

| | Freeway | | | | | Control | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Chrysotile | Amphibole | Glass | Unknown | Total | Chrysotile | Amphibole | Glass | Unknown | Total |
| Number of Fibers | 39* | 52 | 20 | 158 | 269 | 29** | 41 | 11 | 156 | 237 |
| % | 14.5 | 19.3 | 7.4 | 58.5 | 100.0 | 12.2 | 17.3 | 4.6 | 65.9 | 100.0 |
| Fiber Concentration (f/l) | 0.9 | 1.2 | 0.5 | 3.7 | 6.2 | 0.8 | 1.2 | 0.3 | 4.5 | 6.5 |

* 15.4% Fibrils

** 3.4% Fibrils

Total Asbestos Fiber Concentrations (f/l)

Composites of Concentrations of Amphibole Asbestos (f/l) and Chrysotile Asbestos (f/l)

| Freeway | Control |
|---|---|
| 2.1 | 2.0 |

Table X. Statistical Testing of Measured Differences at 95% Confidence Level

| Compared Measurements (f/1) | Average Difference Interval | Conclusion |
|---|---|---|
| EM Freeway - EM Control | $-1.084 \leq \bar{d} \leq 0.014$ | No Statistically Significant Difference |
| LM Freeway - LM Control | $-1.976 \leq \bar{d} \leq -0.694$ | Control Statistically, Significantly Higher |
| LM Freeway - EM Freeway | $-0.327 \leq \bar{d} \leq 0.743$ | No Statistically Significant Difference |
| LM Control - EM Control | $0.588 \leq \bar{d} \leq 2.336$ | LM Results Statistically, Significantly Higher |

$\bar{d} = \frac{\Sigma d}{N}$, where: d = difference in measurements, f/1

N = number of measurements

$$s = \frac{\Sigma(d^2) - (\Sigma d)^2}{N - 1}$$

intervals = $\bar{d} \pm 1.96 \frac{s}{N}$. If 0 is contained within the intervals, there is no significant difference in the distributions.

Table XI. Confidence Intervals of Fiber Counts, Calculated for Poisson Parameters at the 90% Confidence Level

| LOWER LIMIT | | $\lambda$ | | UPPER LIMIT |
|---|---|---|---|---|
| 0 | $\leq$ | .1 | $\leq$ | 1.7 |
| .01 | $\leq$ | .2 | $\leq$ | 2.1 |
| .02 | $\leq$ | .3 | $\leq$ | 2.4 |
| .03 | $\leq$ | .4 | $\leq$ | 2.7 |
| .05 | $\leq$ | .5 | $\leq$ | 2.9 |
| .07 | $\leq$ | .6 | $\leq$ | 3.2 |
| .1 | $\leq$ | .7 | $\leq$ | 3.4 |
| .2 | $\leq$ | 1.0 | $\leq$ | 4 |
| 0.5 | $\leq$ | 2.0 | $\leq$ | 5.8 |
| 1 | $\leq$ | 3.0 | $\leq$ | 7.5 |
| 2.1 | $\leq$ | 5.0 | $\leq$ | 10.5 |
| 5.4 | $\leq$ | 10.0 | $\leq$ | 17.3 |
| 82 | $\leq$ | 100.0 | $\leq$ | 121 |
| 174 | $\leq$ | 200 | $\leq$ | 229 |
| 267.3 | $\leq$ | 300 | $\leq$ | 336 |
| 457.3 | $\leq$ | 500 | $\leq$ | 546 |
| 553 | $\leq$ | 600 | $\leq$ | 650 |
| 649 | $\leq$ | 700 | $\leq$ | 754 |
| 745 | $\leq$ | 800 | $\leq$ | 858 |
| 939 | $\leq$ | 1000 | $\leq$ | 1064 |

$$X + 2 - 2\sqrt{X + 1} \leq \lambda \leq (X + 1) + 2\sqrt{X}$$

where: $X = \lambda$

and: $\lambda$ = the number of fibers (f/l) measured

Table XII. Glass Fiber Concentration - L.A. Freeway Loop by LM and EM

| Location | Average Fiber Concentration, (f/l) Freeway | | Average Fiber Concentration, (f/l) Control | |
|---|---|---|---|---|
| | LM | EM | LM | EM |
| Santa Monica @ 4th | .7 | 0.9 | .6 | 0.4 |
| Harbor @ 146th | 1.0 | 0.1 | .7 | 0.5 |
| San Diego @ National | .3 | 0.2 | .4 | 0.2 |
| San Diego @ 122nd | 1.2 | 0.6 | 1.0 | 0.1 |
| Composite | 0.8 | 0.5 | 0.7 | 0.3 |

Table XIII. Comparison of Average Glass Fiber Concentration, (f/l), Between L.A. Area and S.F. Bay Area by LM and EM

| | L.A. - Freeways | | | | Bay Area | |
|---|---|---|---|---|---|---|
| | Freeway | | Control | | Ambient | |
| | LM | EM | LM | EM | LM | EM |
| (f/l) | 0.8 | 0.5 | 0.7 | 0.3 | 2.5 | 0.8 |
| No. Samples | 60 | 60 | 50 | 49 | 38 | 39 |

Table XIV. Concentrations of Glass Fibers (f/l) in L.A. Freeway Loop; Freeway and Control Samples by LM.

| SANTA MONICA @ 4th Ave | | | HARBOR @ 146th St | | | SAN DIEGO @ NATIONAL | | | SAN DIEGO 122nd | | | DOWNTOWN L.A. CONTROLS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample No. | Frwy | Cont | Sample No. | Frwy | Cont | Sample No. | Frwy | Cont | Sample No. | Frwy | Cont | Sample No. | Cont |
| 2600 | 1.0 | | 2625 | 2.0 | | 2669 | 1.0 | | 2685 | 0.5 | | 2538 | .5 |
| 2601 | 0.5 | | 2626 | | 2.0 | 2670 | | 0.9 | 2686 | | 1.0 | 2539 | .9 |
| 2602 | 1.0 | | 2628 | 0.5 | | 2671 | 0.6 | | 2687 | 0.5 | | 2540 | 1.0 |
| 2603 | .5 | | 2627 | | 0.5 | 2672 | | 0.0 | 2688 | | 0.0 | | |
| 2604 | | 0.5 | 2632 | 0.4 | | 2673 | 0.0 | | 2689 | 0.5 | | | |
| 2605 | 0.0 | | 2631 | | 0.5 | 2674 | | 0.5 | 2690 | | --- | | |
| 2606 | 0.5 | | 2634 | 1.0 | | 2675 | 0.5 | | 2691 | 0.0 | | | |
| 2607 | | 0.0 | 2633 | | 0.0 | 2676 | | 0.5 | 2692 | | --- | | |
| 2608 | 0.0 | | 2635 | 0.9 | | 2677 | 0.0 | | 2693 | 1.0 | | | |
| 2609 | 0.0 | | 2636 | | 1.0 | 2678 | | 1.0 | 2694 | | 0.5 | | |
| 2610 | | 0.5 | 2638 | | .6 | 2679 | 0.0 | | 2695 | 0.0 | | | |
| 2611 | 1.0 | | 2639 | 2.0 | | 2680 | | 0.0 | 2696 | | 0.5 | | |
| 2612 | | 1.0 | 2640 | | 2.0 | 2681 | 0.5 | | 2697 | 0.6 | | | |
| 2613 | 0.6 | | 2641 | 0.0 | | 2682 | | 0.5 | 2698 | | 0.6 | | |
| 2614 | 0.6 | | 2642 | | 0.0 | 2683 | 0.0 | | 2699 | 1.0 | | | |
| 2615 | | 0.5 | 2643 | 0.5 | | 2684 | | 0.0 | 2700 | | 0.5 | | |
| 2616 | 0.5 | | 2644 | | 1.0 | | | | 2701 | 1.0 | | | |
| 2617 | 0.0 | | 2645 | 1.0 | | | | | 2702 | | 0.6 | | |
| 2618 | | 0.5 | 2646 | | 1.0 | | | | 2501 | 1.0 | | | |
| 2619 | 0.5 | | 2647 | 1.5 | | | | | 2500 | | 2.0 | | |
| 2620 | 1.0 | | 2648 | | 0.5 | | | | 2503 | 1.5 | | | |
| 2621 | | 1.0 | 2649 | 0.5 | | | | | 2502 | | 0.5 | | |
| 2622 | 1.0 | | 2650 | | 0.5 | | | | 2505 | 1.0 | | | |
| 2623 | 1.0 | | 2651 | 0.5 | | | | | 2504 | | 1.5 | | |
| 2624 | | 0.4 | 2652 | | 0.8 | | | | 2507 | 2.0 | | | |
| | | | 2653 | 0.9 | | | | | 2506 | | 0.5 | | |
| | | | 2654 | | 1.0 | | | | 2509 | 2.0 | | | |
| | | | 2656 | 0.9 | | | | | 2508 | | 2.0 | | |
| | | | 2655 | | 0.0 | | | | 2511 | 2.0 | | | |
| | | | 2658 | 0.4 | | | | | 2510 | | 1.0 | | |
| | | | 2657 | | 0.0 | | | | 2513 | 3.0 | | | |
| | | | 2659 | 1.7 | | | | | 2512 | | 2.0 | | |
| | | | 2660 | | 1.0 | | | | 2515 | 2.0 | | | |
| | | | 2661 | 1.5 | | | | | 2514 | | 2.0 | | |
| | | | 2662 | | 1.0 | | | | 2523 | 2.0 | | | |
| | | | | | | | | | 2522 | | 1.0 | | |

Table XV. Unknown Fiber Concentrations - L.A. Freeway Loop and Bay Area Ambient Air by EM

| Location | Average Fiber Concentration (f/l) | |
|---|---|---|
| | Freeway | Control |
| Santa Monica @ 4th | 2 | 2 |
| Harbor @ 146th | 6 | 8 |
| San Diego @ National | 3 | 3 |
| San Diego @ 122nd | 5 | 6 |
| Composite | 4 | 5 |

| Bay Area Ambient Air | Excluding Car Nos. 6, 8, 9, 10 | Including Car Nos. 6, 8, 9, 10 |
|---|---|---|
| | 6 | 51 |

Table XVI. Collection Efficiency of 0.8 m Nuclepore Filter for Chrysotile Asbestos Fibrils and Small Bundles

| | Asbestos Fibers Collected | |
|---|---|---|
| | $\leq$ 0.1 x 4 | $\leq$ 0.1 x 15 |
| First Filtration (0.8μm NP) | 14 | 50 |
| Second Filtration (0.2μm NP)* | 9 | 9 |

| | % Efficiency | % Passed |
|---|---|---|
| For Fibrils $\leq$ 0.1 x 4 | 14/14 + 9 = 61% | 39% |
| For Fibrils $\leq$ 0.1 x 15 | 50/50 + 9 = 85% | 15% |

*Assumed Collection Efficiency of 100%

## DISCUSSION AND CONCLUSIONS

### Analysis of chrysotile asbestos

The major conclusions that can be drawn from this study are: 1) The concentration of chrysotile asbestos in air sampled on the four Los Angeles freeway loop sites and analysed by electron microscopy is low, in the range of 0 f/l to 12f/l. 2) The chrysotile asbestos fiber concentrations in the matched upwind ambient air controls at the four sites is also low 0 f/l to 9 f/l and do not differ statistically from the chrysotile asbestos concentrations in freeway samples as measured by a paired difference t test, shown in table X. 3) The average of the chrysotile asbestos concentration in the Los Angeles ambient air control samples (1972) do not differ significantly from the average of the concentrations in ambient air sampled in 1970 in the San Francisco Bay area, other California cities, and on top of White Mountain, Calif. (range 0 f/l to 3 f/l). 4) There was no correlation of the chrysotile asbestos fiber concentrations found in the freeway samples with the number or speed of the motor vehicles passing the sites during the sampling periods. 5) There was no correlation of the chrysotile asbestos concentration in the freeway samples with wind direction or velocity.

The data on which these conclusions were based are shown in Tables I-IV which contain the chrysotile asbestos fiber count for the individual freeway and upwind ambient air control samples, sampling times, the motor vehicle volume and speed for each freeway sample (if available), and the wind direction and velocity. Table V contains the data for the chrysotile asbestos fiber concentration in ambient air sampled in the San Francisco Bay Area and

other areas. Table VI contains the chrysotile asbestos concentration averages and ranges of the Los Angeles freeway and control samples, analysed by electron microscopy, from data in Tables I-IV excluding the first 9 samples (eight of which were obtained at the Santa Monica freeway site and one from the Bay Bridge toll plaza). These samples will be discussed separately. The data from the remainder of the freeway and control samples, analysed by both electron microscopy (EM) and light microscopy (LM), starting with samples number 2600 are arranged in matched pairs, freeway: control i.e. the freeway and control samples were taken during the same time intervals and at the same time. Two or more freeway samples were taken for one control sample at the Santa Monica freeway site. The average of the chrysotile asbestos fiber concentrations of the multiple freeway samples were used to match their control samples. Table VII is a comparison of the averages of the chrysotile asbestos fiber concentrations (f/l) by EM and LM between the Los Angeles upwind ambient air controls and the ambient air samples from the San Francisco Bay Area, and other areas in California.

Using the data, chrysotile asbestos concentration (f/l) from the matched pair data in Tables I-IV a paired difference t test[11] was applied to determine statistically significant differences between chrysotile asbestos fiber concentrations in the freeway samples vs. control samples as analysed by EM and LM. The test was also applied to LM Freeway vs. EM Freeway and LM control vs. EM control. The results and method are summarized in Table X. This test showed no statistically significant difference between the matched pair samples: freeway EM vs. control EM or freeway LM vs. freeway EM. A

statistically significant difference was found in the matched pairs, LM freeway vs. LM control, and in the pairs, LM control vs. EM controls. The LM controls values are significantly higher statistically. The statistically higher differences by light microscopy analysis in the last two cases can be best explained by a discussion of some of the difference in the two methods of analysis. For environmental samples, quantitative data obtained by light microscopy is not as reliable as that obtained by electron microscopy. Due to the higher resolution and magnification of the electron microscope as well as the capability of obtaining electron diffraction patterns, identification of fibers is more accurate than by light microscopy. Single chrysotile asbestos fibers and bundles under 0.5 - .8μm diameter can be resolved by electron microscopy but not by LM. There were groups of fibers in a rosette pattern seen by electron microscopy in both freeway and control samples at the Harbor freeway and the two San Diego freeway sites. These fiber 'bundles' are occasionally fairly large and are not chrysotile asbestos but could be counted as such with the light microscope. Plates I, II, III, IV and V are electron micrographs (6000X mag) of some of these rosette like fiber bundles.

Another statistical test for the reliability of the chrysotile asbestos fiber counts are confidence intervals calculated for the fiber counts for Poisson parameters at the 90% confidence limit. A large number of asbestos fiber counts, 20 fields each from environmental and work environment samples that were transferred to Nuclepore filters from a solvent, for electron microscopy were combined and the distribution of the fibers on the filters was tested for Poisson distribution. The distribution was found to be

Poisson[12]. The confidence intervals would also apply to counts by LM provided the distribution of the fibers on the filter (Millipore used for the initial sampling was Poisson. There is evidence that the distribution is not Poisson. If not the distribution is Poisson, the counting error would be indeterminate but probably greater than determined for the fibers on the Nuclepore filters. Table XI contains the formula used for calculating the confidence intervals, and the confidence intervals for several fiber counts ($\lambda$). Table VII shows the average chrysotile asbestos fiber counts for the Los Angeles freeway and control samples as well as for the Bay Area ambient air samples. Any of the observed differences that can be constructed from these results are consistent with counting error alone.

Chrysotile Asbestos Fibers from brake linings

There was one exception to the low concentration of chrysotile asbestos fibers found in the matched pairs of freeway and control samples for all the sites. Among the first few samples obtained from the Santa Monica freeway site one sample (2001) had a relatively high concentration of chrysotile asbestos, 98 f/l. The sample was obtained at the end of the morning rush hour, from 0850 hours to 1100 hours, March 23, 1972. The traffic was heavy and moving fast for the first hour (70 mph), then slowed down to 20 mph for one hour. The wind was light, 3 mph and from the west.

The appearance of the fibers in the electron microscope of this sample was quite different from that of fibers usually found in ambient air. Most of the fiber bundles or fibrils were attached to or sticking out, many in tangles or clumps, from irregular electron-dense particles 5-15μ in diameter. There were also single fibrils and bundles. These particles melted (became spherical) in a very high intensity elecrron beam and could well have been rubber particles from brake linings. Many brands of brake linings contain ground-up used rubber tires along with asbestos and other materials. The fibers looked swollen; many fibers had debris along their edges and could not be identified by morphology alone. The chrysotile asbestos could have been altered by heat and/or friction as shown by the electron diffraction patterns. Electron diffraction patterns of the fiber tangles and some bundles were observed long enough for identification but the patterns faded out in the electron beam (moderate intensity) in a few seconds and could not be photographed. The crystalline structure of undamaged chrysotile asbestos fibers is not severely damaged by the electron beam; so the electron

diffraction pattern will persist for many seconds in a high intensity electron beam and can be photographed. Plates VI-IX are electron micrographs of asbestos fibers found in sample 2001 (Santa Monica freeway). Plate VI is a micrograph at 6000X magnification of a particle with a tangle of asbestos fibers. Plate VII is a micrograph at 60,000X magnification of some of the fibers seen in plate VI. Plate VIII is a particle with a chrysotile asbestos bundle sticking out. Plate IX shows a small chrysotile asbestos bundle at 60000X magnification. The concentration of the chrysotile fibers had dropped within about an hour to 22.5 f/l (3 clumps/l) in a 100 minute sampling period (sample 2002). By evening the concentration was 6 f/l(1 clump/l),(sample 2003), and in a 120-minute sampling period the next morning (sample 2004) there were no asbestos fibers seen even though there was a traffic jam, with heavy traffic at slow speed. Large particles will not remain airborne for a significant length of time, which could explain the decrease in the number of clumps (particles with chrysotile asbestos attached) from 16 clumps/l to 1 clump/l in a period of 13 hours. Plate X is a micrograph at 6000X magnification of an asbestos bundle (2.5μ X 35μ) in a freeway sample obtained at the Harbor @ 146th Street site. This may or may not be from a brake lining.

The best explanation for the source and increased concentration of chrysotile asbestos fibers and their association with particles in samples numbered 2001, 2002 and 2003 is that the fibers were from brake linings released into the air by sudden stopping of a few or several motor vehicles downwind from the sampling site. The fibers appear to be damaged by heat and/or friction. A few clumps were seen at other freeway sites. The level of asbestos fiber concentrations found in these 3 samples were not found in the other samples from the freeways because the occurrence of sudden stopping or panic braking

of motor vehicles is rare on the freeways. Another factor is that the Santa Monica freeway at the 4th Street pedestrian overcross lies in an east-west direction and the prevailing wind is from the west, so that an event downwind from the sampling site could affect the sampling site. At other sites, this prevailing wind was at right angles to the freeway. The release of chrysotile fiber into the air from panic stops simulated in a dynometer was reported by Lynch[4] who investigated asbestos released into air in experiments using brake linings in a dynamometer. Most of the asbestos was destroyed by heat and grinding, transferred into forsterite which is not fibrous and has shown no biological effects in limited animal experiments. Very little chrysotile asbestos is found in the brake wear debris found in brake drums.

One sample was obtained, 3/9/72, at the San Francisco Bay Bridge toll plaza by Thomas Cahill of U. C. Davis. The concentration of chrysotile asbestos in this sample was low (1.4 f/l). During the sampling period 11,500 motor vehicles went through 17 toll booths. Over 85% of the motor vehicles stopped at the toll booths so that there was a considerable amount of braking in the vicinity of the sampling site but only a small concentration of asbestos in the air.

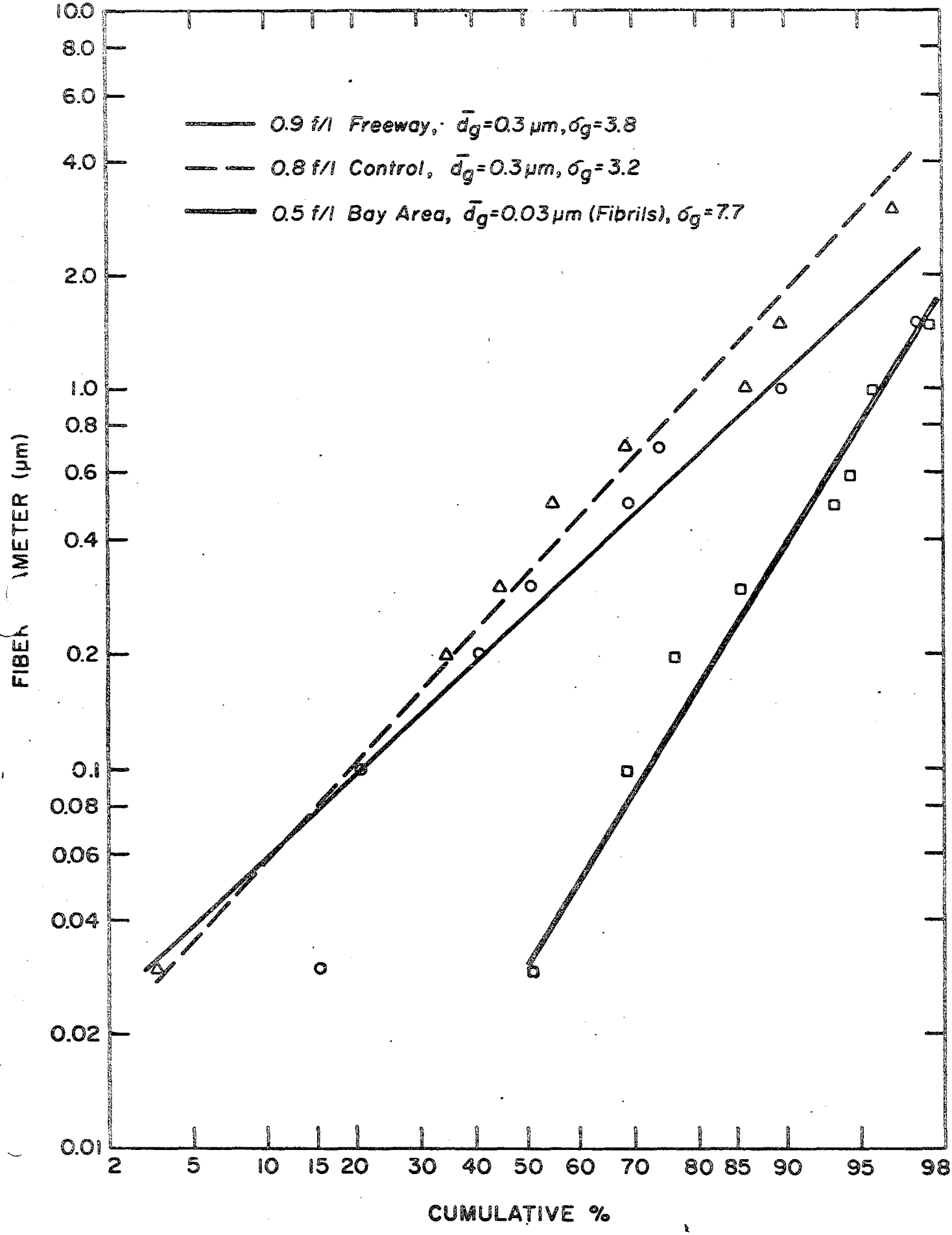
The only finding of a relatively high concentration of chrysotile asbestos, 238 f/l, in Bay Area ambient air was a sample taken downwind from an asbestos source (car #6 in Table V), an open dump in the East Bay, which at the time was used by a manufacturer of asbestos products. This estimate was based on a very small sample of air.

## Size Distribution of Chrysotile Asbestos

The diameter and length of the chrysotile asbestos fibers counted were measured during the counting procedure, using the electron microscope. A single fibril was assumed to have a diameter of 0.03μm. Table VIII contains the fiber size distribution (by electron microscopy) of composites of the Los Angeles freeway and control samples (diameter and length) and Table VIIIA contains the diameters of the composite of the Bay Area and other cities ambient air samples. Using the fiber diameter distributions from Tables VIII and VIIIA the cumulative percentages at given diameters were determined and are shown graphically in Figure 6. The geometric mean diameter of both the freeway and control composites were 0.3μm and their standard geometric deviations were 3.8 and 3.2 respectively.

In the Bay Area composite the diameter sizes above 0.03μm are distributed like the upper tail of a log normal distribution. Approximately 50% of the fibers were measured as single fibrils (0.03μm diameter). In view of the assymetric nature of the distribution the 50% point is considered as the geometric mean-$d_g$ = 0.03μm and the $\sigma_g$ = 7.7. The larger geometric mean diameter (.3μm) of the chrysotile asbestos fibers in the Los Angeles samples compared to the much smaller geometric mean diameter (.03 μm-the diameter of single fibrils) in the Bay Area samples could be due to the Los Angeles sampling sites being closer to asbestos sources than the Bay Area sampling sites. Another factor could be a lesser degree of weathering of the airborne asbestos in the Los Angeles area.

Figure 6


0.9 f/l Freeway, $\bar{d}_g$=0.3 μm, $\sigma_g$=3.8
0.8 f/l Control, $\bar{d}_g$=0.3 μm, $\sigma_g$=3.2
0.5 f/l Bay Area, $\bar{d}_g$=0.03 μm (Fibrils), $\sigma_g$=7.7
FIBER DIAMETER (μm)
10.0
8.0
6.0
4.0
2.0
1.0
0.8
0.6
0.4
0.2
0.1
0.08
0.06
0.04
0.02
0.01
2
5
10
15
20
30
40
50
60
70
80
85
90
95
98
CUMULATIVE %

## ANALYSIS OF AMPHIBOLE ASBESTOS

In addition to the chrysotile asbestos, and glass fibers the number of amphibole asbestos fibers in the Los Angeles samples were counted by electron microscopy. The term amphibole asbestos includes the fibrous forms of the amphibole group of minerals, the most common being amosite, crocidolite, tremolite and anthophyllite. They cannot be positively identified or differentiated by phase contrast microscopy. The fibrous amphiboles can be distinguished from chrysotile asbestos by morphology and electron diffraction in the electron microscope. It is difficult to differentiate the various types of amphibole asbestos that occur in ambient air even by electron microscopy, but tremolite has a morphology and an electron diffraction pattern which permits presumptive identification. The amphibole asbestos encountered in the Los Angeles freeway and control samples was probably tremolite, with a possibility of some anthophyllite. Tremolite is a calcium magnesium silicate found usually in conjunction with talc, a magnesium silicate. Anthophyllite is a magnesium silicate and can also occur with talc. Ground talc is used principally in rubber, some brake linings, paper, asphalt, ceramics, paint, roofing, and insecticides. Tremolite and talc could be released into the air during manufacture or use of all of these products. The composite average of the concentrations of amphibole asbestos is low, 1.2 f/l, and is the same in both the Los Angeles freeway and control samples. The concentration of amphibole asbestos analysed by electron microscopy is included in tables I-IV for the Los Angeles freeway and control samples. The composite concentrations and percent of amphibole asbestos in the Los Angeles

freeway and control samples are in table IX which also includes composites of the total asbestos fiber concentrations, chrysotile plus amphibole asbestos, for the Los Angeles freeway and control samples. The combined concentrations are low, 2.1 f/l for the freeway samples and 2.0 f/l for the controls. Amosite fibers were seen in the ambient air from San Jose, California, where there is an industry using amosite in a product. Tremolite fibers were not reported in the Bay Area samples. Amosite was not seen in the Los Angeles samples.

## Analysis of Glass Fibers

Glass fibers were counted and sized in the Los Angeles and Bay Area samples by light and electron microscopy. Glass fibers are man-made and get into the air primarily from use or manufacture of products containing fibrous glass. Although there are unanswered questions about fibrous glass in air the present evidence supports the position that it is primarily a nuisance dust which can produce mechanical irritation[13]. The light microscope with phase contrast optics is adequate for identification and analysis of glass fibers collected from air on membrane filters. Larger diameter glass fibers can be lost during processing of the specimen grids for electron microscopy. Small diameter beta glass, 0.2μ-0.5μ diameter, can be seen in the electron microscope but not in the light microscope. No small diameter beta glass fibers were observed by electron microscopy in the Los Angeles samples. Small diameter glass fibers of .3μm diameter and most likely beta glass, were seen by electron microscopy in the samples

taken on the Earl Warren Hall roof in the Bay Area samples. Table XII contains the composite glass fiber concentrations (f/l) for the matched pair samples from the Los Angeles freeway loop sites by LM and EM, and table XIII is a comparison of the glass fiber concentrations of the Los Angeles samples with the Bay Area ambient air samples by LM and EM excluding car #6 sample, which was obtained near an open dump containing glass fibers as well as asbestos fibers. Table XIV is the glass fiber concentrations, f/l, analysed by LM for the matched pair freeway loop samples, which could not be included in tables I-IV because of lack of space.

The composite concentrations of glass fibers in the Los Angeles area are low for both the freeway, 0.8 f/l, and control samples 0.7 f/l. These are very close to the values for the chrysotile asbestos composite concentrations in the Los Angeles samples. The composites of glass fiber concentrations in Bay Area ambient air samples are higher than in the Los Angeles samples, but not significantly so. The EM composite concentrations are lower than the LM values in all cases which is to be expected. The glass fiber diameter distributions were assembled from the analyses of the samples from the Los Angeles freeway and the Bay Area. The cumulative percentages at given diameters were calculated and the geometric mean and $\sigma g$ values determined graphically. The geometric mean diameter of the freeway and control composites by LM is 2.5μm ($\sigma g$ 1.5) and 3.1μm ($\sigma g$ 1.7) respectively and by EM, 1.1μm ($\sigma g$ 1.6) for the freeway samples and 1.4μm ($\sigma g$ 1.6) for the controls. The values of the geometric mean diameter by LM analysis is probably closer to a true value than those from the EM analysis since larger diameter fibers can be lost during electron microscopy and also, there were

very few if any small diameter beta glass fibers observed. The geometric mean diameter of the glass fibers in the Bay Area by LM is 5.3μm ($\sigma g$ 1.7) and 0.9μm ($\sigma g$ 2.1) by EM. The values of the geometric mean diameter by LM analysis is probably closer to a true value than the geometric mean diameter by EM. However there were 8.6% of 0.3μm diameter fibers (beta glass) and 16.5% of 0.5μm diameter fibers (lower diameter of ordinary glass fibers-upper limit for beta glass fibers) observed by EM.

## Analysis of Unknown Fibers

The concentrations (f/l) of a category of fibers classified as unknown is included in tables I-IV for the Los Angeles freeway and control samples and in table V the Bay Area ambient air samples. Table XV is a composite of the average of the unknown fiber concentrations at each of the Los Angeles freeway sites for the matched pairs, freeway and control samples, and for the Bay Area ambient air samples analysed by EM. A composite was made of the Bay Area samples with and without the samples from car #6, #8 #9, #10 which are not from strictly ambient air but were sampled near open dumps and near industries. The category of unknown fibers include fibers not asbestos, or glass but could not be easily identified by morphology or electron diffraction pattern. Many of these fibers are not crystalline, and some are crystalline. Wood fibers, fibers from burning paper such as $Ca\ CO_3$ or CaO fibers and fibers of chemical origin are included. The concentration of these fibers in the air sampled in the Los Angeles freeway sites and in the Bay Area ambient area is low, the composite averages are 4 f/l in the Los Angeles freeway samples, 5 f/l in the Los Angeles control samples, 6.3 f/l in the Bay Area samples (excluding the car samples) and 51 f/l including the car samples. Paul Gross[5] has reported on the possibility of a health effect from fibers in air other than asbestos fibers and glass especially fibers from burnt paper.

Particulate material, other than fibers, was observed in the electron microscope in all samples analysed for fiber concentration. The particulates observed were insoluble in methyl ethyl ketone, methyl alcohol and chloroform.

Among the particles recognized in many of the samples were diatom fragments, fly ash spheres (small spherical particles generated by burning of fuel), and aggregates of carbon particles (soot). These aggregates are found primarily in the freeway samples and the source is most likely exhaust from motor vehicles. Plate XI is an electron micrograph showing carbon particles aggregates from a sample obtained on the freeway at the San Diego at 122nd Street site. Plate XII is also an electron micrograph from a freeway sample obtained at the San Diego at 122nd Street site. This large particles with satelite dorplets could have been deposited as a single large dorplet and material removed during exposure to the high vacuum during sample preparation and electron microscopy or could have been deposited as seen in the micrograph and formed its satelites during impact on the Nuclepore filter. The particle boils, and material is destroyed in a high energy electron beam as shown in plate XIII.

## METHODS OF ESTIMATING ASBESTOS FIBER CONCENTRATION IN AIR BY ELECTRON MICROSCOPY

Four methods used for quantitative analysis, by electron microscopy, of asbestos fibers from air sampled on membrane filters will be discussed. These are: 1) the method developed in this laboratory and presented in detail in Appendix A. 2) the method developed by Battelle Memorial Institute, Columbus, Ohio[14,15]. 3) The method used by Johns-Manville Research and Engineering Center, Denver, Colorado,[16] and 4) the method used in the Mt. Sinai School of Medicine, New York, New York[17,18].

These methods involve two approaches to the problems of using the electron microscope for estimating the amount of chrysotile asbestos in air, one in which fibers are not purposely reduced to individual fibrils and one in which they are. The method used by this laboratory was designed for estimating the number and size distribution of chrysotile asbestos fibers as they occur in the air and collected membrane filters. The fibers are dispersed in a solvent without any aids except a stirring rod, and transferred to a second filter which is prepared for electron microscopy. The results are reported as the number of fibers per unit volume of air (f/l) regardless of the size of the chrysotile bundles. The size (diameter X length) of the fibers are measured during the counting procedure and a size distribution of the fibers is obtained for either single samples (if the fiber concentration is high) or in groups of samples (if the fiber concentration is low) as in ambient air). The other methods involve ashing the particulates and fibers collected on membrane filters. The ash or a portion

of it is dispersed in water or collodion by ultrasonic vibration and/or grinding (mulling). This treatment breaks up the chrysotile bundles into smaller bundles and single fibrils. The fibrils and small bundles are counted and sized by electron microscopy; the total volume of the fibrils is calculated, from which the weight of the asbestos is estimated. It is very difficult to relate the fiber concentration (f/l) in the sample of air to its mass (µg/l) because of the great variance in the fiber size distribution. For example a large fiber bundle which weighs as much as a very large number of fibrils may not be of biologic significance, as it may be too large to penetrate into a lung. Mass alone does not give a indication of the number or size of the fibers that occur in the air sampled. A comparison of asbestos fiber concentration and mass was made in England, by P. G. Harris[20] in shipyard insulation processes in 1971 and no correlation was found between the mass of crocidolite asbestos fibers and the number of fibers counted by light microscopy for relatively low concentrations of asbestos. Crocidolite fibers occur singly (not in bundles) and are of greater diameter than chrysotile asbestos fibrils, thus the number of fibers would be even easier to correlate to mass than numbers of chrysotile fibers.

The method of determining industrial exposure to chrysotile asbestos, recommended by NIOSH[19] and required by OSHA[8] involves collecting a sample of air in a work environment on a membrane filter and counting fibers using a phase contrast microscope. This method is described in an earlier section of this report. The results are reported as the number of fibers/ml of air. The present standard for asbestos in industry is 5 f/ml, to be reduced to 2 f/ml in 1975. The electron microscopy and light microscopy

methods used in this study produces data comparable to that required for measurements of industrial exposures to asbestos in air.

A more detailed discussion of the four methods follows: 1) The method described in detail in this report (Appendix A) was designed for estimating the number and size of fibers, primarily chrysotile asbestos but also amphibole asbestos, glass and other fibers as they occur in the air and collected on 0.8μ pore size Millipore filters. The results are reported in number of fibers/liter regardless of the size of the fibers. This method does not involve ashing, (either low temperature or high temperature), grinding (mulling), or ultrasonics. Instead the particulates on the Millipore filter is suspended in a solvent in which the Millipore filter is soluble. The particulates including asbestos suspend uniformly in the solvent in a short time with a minimum of stirring with a glass stirring rod. The suspension can be checked for uniformity in a Tyndal beam and also by electron microscopy. The suspended particulates are transferred to either a 0.5μ pore size or a 0.8μ pore size Nuclepore filter, 25mm or 47mm in diameter, using an appropriate membrane filter vacuum filtration apparatus. The solvent does not appreciably affect the pore size of the Nuclepore filter in the short time necessary for filtration. The distribution of the particulates on the 47mm diameter Nuclepore filter is Poisson and statistical confidence intervals at the 90% level can be determined for the estimates of the number of fibers per liter taking into account all of the factors used in the calculation of the number of fibers per liter of air from the number counted on the 20 fields of the specimen grid (see Appendix A). The counting

error indicated by the confidence intervals (see Table XI) calculated for the values of the number of fibers per liter is high for the low concentrations. For example, for an estimated count of 1 f/l, the intervals are, upper limit = 4 f/l and the lower limit = 0.2 f/l, a factor of 4 and 5 respectively. For an estimated count of 5 f/l the confidence limits are 10.5 f/l to 2.1 f/l. As the count values increase the confidence limits get smaller so that at a concentration of 1000 f/l there is a variation of $\pm$ 6%[12]. The confidence limits can be used as a measure of statistical reproducibility and precision of the counting method. Another factor for possible error in the estimate of fiber concentration is that the 0.8μ pore size Nuclepore filter used for the transfer of particulates is not an absolute filter for the very small chrysotile asbestos fibrils. An experiment was performed to determine the number and size of fibrils that pass through the filter during the vacuum filtration process. A sample containing chrysotile asbestos fibrils on a Millipore filter from an industrial source was filtered through a 0.8μ pore size Nuclepore filter and the filtrate filtered through a 0.2μ pore size filter. The results are in Table XVI. The 0.8μ pore size Nuclepore filter a collection efficiency of 88% for all fibers 0.1μ diameter X 15μ length and bigger and 61% for fibers 0.1μ diameter X 4μ length and smaller. If short fibrils are present the count would be low by an approximate factor of 2.

The electron microscopy is done at a relatively low power, 2000X, with an optical aid of a 1.5X optical magnifier (total mag. 3000X) or a 10X binocular dissection microscope (total mag., 2000X). Chrysotile asbestos fibers can be resolved by the Siemens Elmiskop I or IA electron microscope at 2000X

magnification and are visible on the screen with the aid of 1.5X or 10X optical magnification. For positive identification 20,000X magnification is used for morphology and electron diffraction of the fibers. If there is any doubt of the presence of fibrils a field can be scanned at 20,000X magnification with additional optical magnification of 10X (total 20000X), or 1.5X (total 30,000X). In the course of this investigation the fibers in many fields were counted at both 2000X and 20,000X mag. with good agreement. The advantage of counting using the microscope viewing screen at a lower magnification is the greater field size, hence a greater total area that can be counted conveniently and the elimination of the use of electron micrographs.

2) Method used by Battelle Memorial Institute

This method involves asking the sample collected on a Millipore filter for 2 days in a low temperature plasma asher. The ash containing fibers is dispersed in water ultrasonically and centrifuged at low speed. The fiber bundles break up into small bundles or fibrils and are redistributed on a 2nd Millipore filter by vacuum filtration. A carbon psendoreplioa is made of the fibers on the filter, the Millipore filter material is dissolved in acetone and the carbon film mounted on 200 mesh specimen grids. Fibrils are counted on 5 openings at a 30,000X magnification. The fiber number is converted to a value of mass of asbestos per unit volume. No statistical evaluation of the method is given.

3) The method developed by Johns-Manville Research and Research and Engineering Center

This method involves ashing the samples collected on a Millipore filter in a platinum crucible in a Muffle furnace at a temperature close to 400°C. The ash is lightly ground in an agate mortar and pestle, and dispensed in water by ultrasonic vibration. A radioactive tracer ($Au^{198}$) is added and mixed with the slurry in an ultrasonic bath. The radioactivity is measured and an aliquot of the slurry is prepared for electron microscopy by mixing the aliquot of ash in collodion in amyl acetate using a mulling technique on a glass slide, and making a film of the ash in the collodion on the glass slide. The film is floated onto water and picked up on carbon coated grids. The radioactivity on the grid is measured and the weight of the amount of ash on the grid is determined. Micrographs of 6 fields @ 4000X magnification are obtained and the fibrils and small bundles are counted at 12,000X magnification using 30X optical magnification. The fiber count is converted to mass and the asbestos concentration is reported on a mass basis. No statistical evaluation of the method is reported.

4) The method developed by Mt. Sinai School of Medicine, New York, New York

This method is similar to the one used by Johns-Manville Company with these differences, 1) the samples (on Millipore filters) are ashed in a low temperature plasma asher for a short time, 2) a radioactive tracer is not used to determine the weight of ash on the specimen grid. 3) Ultrasonic vibration is not used for the dispersal of the ash. The sample is mixed and ground with collodion in amyl acetate by mulling with a watch glass on a glass slide. A film is made and mounted on a grid as in the Johns-Manville method. Six grids are prepared of each sample and two 100μ X 100μ squares of each grid scanned at 42,000X on the electron microscope. The fibers are

counted and sized, and the results calculated to a mass basis and reported as gm asbestos per meter$^3$.

It is of interest to compare the results of analysis of chrysotile asbestos concentration by electron microscopy reported in units of mass/$m^3$ by Nicholson etal.[16] with the concentrations in number of fibers/liter and in mass/$m^3$ in the Los Angeles freeway and control samples contained in Table VI in this report.

TABLE I (ref. 16 p. 138
from Nicholson, et. al.)

Chrysotile Content of Ambient Air in NYC

Preliminary Results

| Sampling Location | Asbestos Air level in $10^{-9}$ grams/$m^3$ |
|---|---|
| Manhattan | 25-60 |
| Bronx | 25-28 |
| Brooklyn | 19-22 |
| Queens | 18-29 |
| Staten Island | 11-21 |

FROM TABLE VI (this report)

| Sampling Location | Asbestos Air Level in $10^{-9}$ grams/$m^3$ | No. of fibers/liter by f/l EM |
|---|---|---|
| Los Angeles Freeway matched pair composite | 27 | 0.9 |
| Los Angeles Control (ambient) matched pair composite | 43 | 0.8 |

The mass ($gm/m^3$) data of the New York City samples is in general agreement with the mass data for the Los Angeles samples.

The fiber counts and mass/vol. of air in the two Los Angeles composites are low and are not indicative of a nearby chrysotile asbestos source. For comparative purposes it should be noted that the asbestos fiber standard for industry adopted by the Occupational Safety and Health Administration in 1972 set a maximum short term ceiling of 10,000 fibers/liter with 5,000 f/l permitted as an 8-hour average; the latter will drop to 2,000 fibers/liter in 1976. The foregoing based on optically visible fibers may be compared with fiber counts in the Los Angeles area of less than 10 fibers/liter with most being under 1 fiber/liter.

# APPENDIX A

## Analytical Procedures - Electron Microscopy

The transfer of the sample from the Millipore filter to a Nuclepore filter used for electron microscopy is as follows (Figure 6):

1. The sample on the Millipore filter is placed in a 250ml beaker and dissolved in 100ml of a 1:1 mixture of methyl alcohol and methyl ethyl ketone. The solvent mixture has been previously filtered through a 0.5μ pore size Nuclepore filter to remove particulates. The fibers and particulates suspend evenly in the solvent as can be observed in a Tyndall beam.

2. For the Bay Area ambient air samples the suspension is filtered by a vacuum through a 0.5μ pore size Nuclepore filter (usually 25mm diameter with an effective filtration diameter of 15mm). For the Los Angeles freeway and control samples the suspension is filtered through a 0.8μ pore size, 47mm diameter Nuclepore filter with an effective filtration diameter of 35.5mm. A Millipore filter holder assembly of the proper size, designed for vacuum filtration is used to hold the Nuclepore filter. The filtration assembly is mounted in a side arm filter flask and a three way glass valve is used for controlling the vacuum. To ensure a random distribution of fibers on the Nuclepore filter the suspension is not allowed to be sucked dry during filtration or during washing. The suspension is filtered leaving about 5mm of solvent above the filter. The filtration can be stopped quickly using the 3 way valve.

3. Five aliquots of solvent, 10ml each, are used to wash the beaker and also to dilute and remove Millipore filter materials from the Nuclepore filter.

The filtration is stopped short of the filter after each aliquot of solvent is applied. The last wash is allowed to filter to completion.

4. The practically dry Nuclepore filter is transferred to a piece of filter paper (Whatman #1 or #2) in a plastic Petri dish.

Preparation of the sample on the Nuclepore filter for electron microscopy is as follows (Figure 7 and part of Figure 6).

This method is a modification of a method using Nuclepore filters for electron microscopy of particles collected from air devised by Frank et al[9].

1. A piece of the filter (1 cm X 2 cms) is cut out of the filter with a scalpel and mounted on a glass microscope slide with scotch tape.

2. The piece of filter is coated with a fairly heavy coat of silicon monoride (SiO) in a vacuum optical coater. Pieces of filter from 4 samples can be mounted on a glass slide and a total of 12 filter pieces can be coated with SiO in one operation. For the Los Angeles samples a glass slide with 4 pieces of filter was mounted on a rotating stage which revolved slowly during the coating procedure to insure an even coat of SiO.

3. A 1/8" disc (the size of a specimen grid) is cut out of the SiO coated filter with a sharp boring tool (hardened to surgical steel hardness) and mounted SiO side down on a 200 mesh stainless steel grid previously placed on top of a piece of polyurethane in chloroform. A Stentor dish or small Petri dish is used to hold the polyurethane and chloroform. The chloroform liquid is approximately 1/16" to 1/18" from the top of the polyurethane. The Nuclepore filter is dissolved by the chloroform by wick action through the pores of the SiO replica of the filter surface. The replica is left on the

grid with the particles and fibers on top of the SiO substrate. It takes about 4 hours to 6 hours to remove the Nuclepore filter material.

4. The grids are transferred to a piece of filter paper in a plastic petri dish and are ready for electron microscopy.

Electron Microscopy

A Siemens Elmiskop I or IA electron microscope operated at 100 KV was used for counting and sizing the fibers on a grid prepared from each sample. The fibers were counted and sized directly on the microscope viewing screen. The screen was ruled with pencil in a grid of 1 cm squares, with 1 cm ruled in 2mm intervals. The magnification used for counting and sizing is 2000X. This magnification and the field of view is in the order of magnitude of that of a light microscope but provides much higher resolution than a light microscope. The 2000X magnification is obtained with the projector lens turned off. The magnification scale (intermediate lens current meter) is calibrated by the use of a 20μ aperture (measured in a light microscope) in the object plane. The image of the aperture is projected onto the viewing screen and the intermediate lens current is adjusted on the meter so that the aperture opening measures 4cm on the viewing screen, which is a magnification of 2000X. The meter reading is recorded. A 100μm objective aperture is used to increase contrast. A 1.5X optical magnifier is mounted in the viewing window. The 10 X binocular microscope can be used for greater magnification if necessary. For identification of fibers by morphology and electron diffraction the electron microscope is used at 20,000 X magnification. This magnification is achieved by changing the projector pole piece to pole piece III (the magnification is the meter reading X 2000). The projector pole

piece current is turned on. The intermediate lens current is adjusted so that the meter reads 10 (a magnification of 20,000X). This magnification is close to the magnification used for selected area diffraction. Selected area diffraction is a mode of operating the electron microscope to obtain an electron diffraction pattern of a crystal or group of crystals (in our work a fiber or group of fibers) in an area selected by means of an aperture placed in the intermediate lens. This pattern is usually a spot pattern and can be used for calculating d spaces which can be compared to d spaces in the ASTM d space card index, and can be used for identification of crystals. The pattern of chrysotile asbestos fibers in a small bundle is a spot pattern in parallel array with partial concentric circles in the center of the pattern. This can with experience, be used for identification of chrysotile asbestos. Glass fibers do not diffract, so that crysotile fibers and non-crysotile fibers (glass) can be distinguished. Many amorphorus materials such as Carbon and Silicon monoxide diffract in a series of faint diffuse rings and the pattern is characteristic of an amorphous substance.

Counting Procedure

Fibers are counted and recorded for each of 20 fields in a 200 mesh specimen grid. A field is defined as a single opening in the grid. The ratio of the total number of fields in a grid to the number of fields counted is used in the calculation of the number of fibers on the whole grid, consequently an accurate calibration of the magnification of the electron microscope is not required for defining the area of a field. The total number of openings in a grid was determined by making a photographic enlargement of a grid and calculating the number of openings by counting the openings

in a diameter and using the equation for the area of a circle $A = \frac{d^2}{4}$,

where A is the total number of openings and d is the number of openings in a diameter. The number of openings must be determined for each type and batch of grid used. The ratio $\frac{\text{total fields per grid}}{\text{fields counted}}$ must be corrected to an actual area value by a factor (grid area factor) obtained for the ratio of the area of the grid to the total area of the fields in the grid. This compensates for the area of the grid bars. The length and width of several holes is calculated. For all practical purposes the holes in the grid are of equal size.

1. For the Bay Area samples filtered on 25mm diameter Nuclepore filters the factors and ratios for the calculations are as follows:

a. Total fields in grid = 452

b. No. of fields counted = 20

c. $\frac{\text{effective area of 25mm dia. Nuclepore filter}}{\text{area of disc (grid) (3.2 mm dia.)}} = \frac{176.715}{8.0} = 22$

d. grid area factor = $\frac{\text{area of grid}}{\text{total areas of fields in grid}} = \frac{8.00}{.112\text{mm} \times .112\text{mm} \times 452 \text{ fields}} =$

(grids are normally 1/8 dia. and vary from 3.2mm to 3.12mm in dia.)

e. Factor for normalizing to whole Millipore filter 1.1 to 1.3 as determined for each filter.

2. For the Los Angeles samples which were filtered on 47mm diameter Nuclepore filter the factors and ratios for the calculation are as follows:

a. $\frac{\text{effective area of 47mm dia. Nuclepore filter}}{\text{area of disc (grid, 3.12mm dia.)}} = \frac{990}{7.65} = 129.4$

b. grid area factor = $\frac{\text{area of grid}}{\text{total area of fields in grid .98mm X 452 fields}} = \frac{8}{} = 1.84$

c. The other factors are the same as in 1

Each filter with the sector removed for light microscopy was xeroxed. The filter was left in bottom section of the clear plastic Petri dish used for storage. A disc of the diameter of the effective area of the filter was cut out and weighed on an analytical balance. The sector indicated by lines in the xerox copy was cut out and the disc minus the section was weighed.

The factor $\frac{\text{weight of xerox disc}}{\text{weight of xerox disc-sector}}$ = factor for normalizing to whole Millipore filter

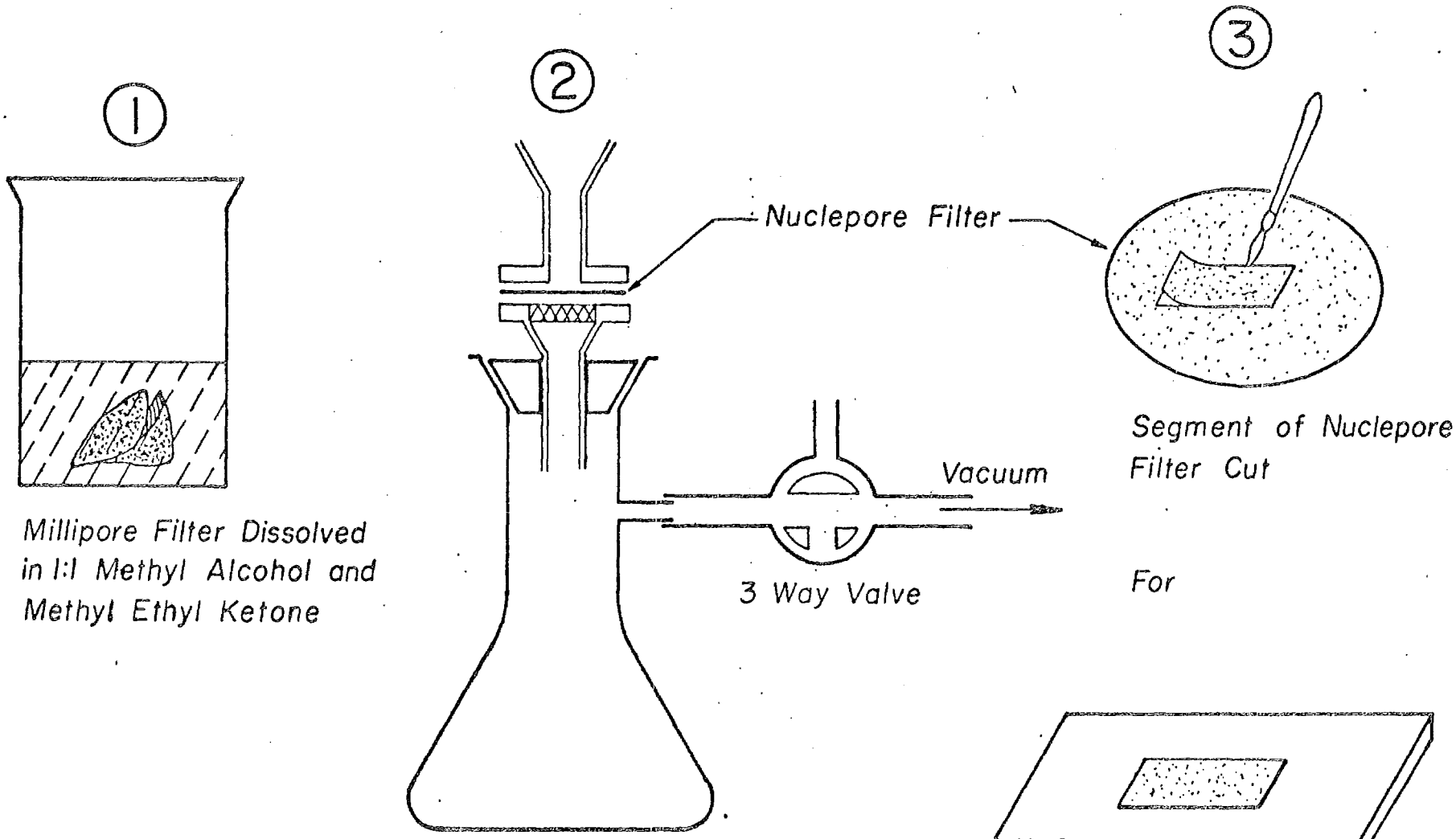
METHOD FOR CALCULATION OF FIBER COUNTS IN FIBERS/LITER

1. For samples collected on a Millipore filter (sector removed for light microscopy) and transferred to a Nuclepore filter:

$\frac{\text{fiber count}}{\text{No. of field counted}}$ X (total fields in grid) X (grid area factor) X

$\frac{\text{effective area of Nuclepore filter}}{\text{area of disc (grid)}}$ X (factor for normalizing to whole Millipore filter) = number of fibers on Millipore filter.

Fiber/liter = $\frac{\text{no. of fibers on Millipore filter}}{\text{cu. ft. air X 28.3 liters/cu. ft.}}$

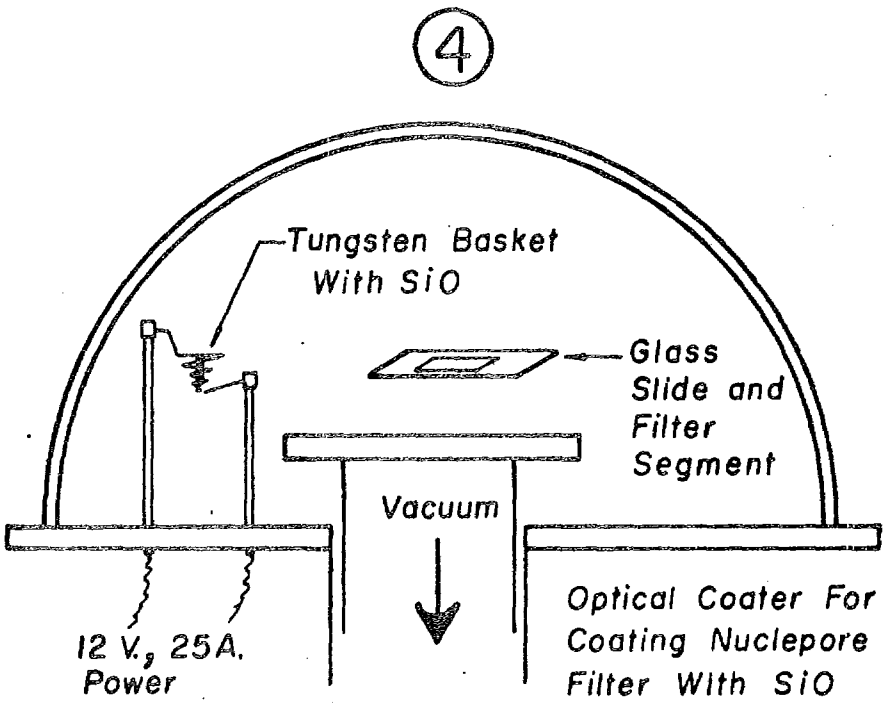


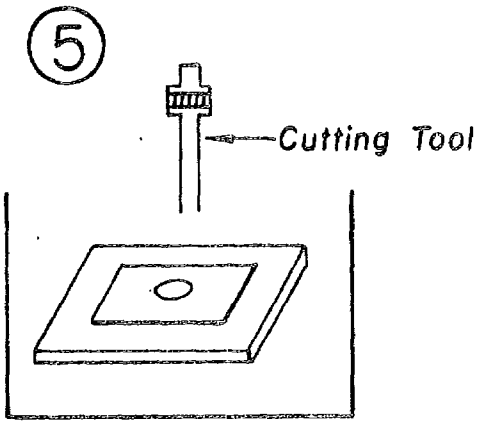

Millipore Filter Dissolved in 1:1 Methyl Alcohol and Methyl Ethyl Ketone

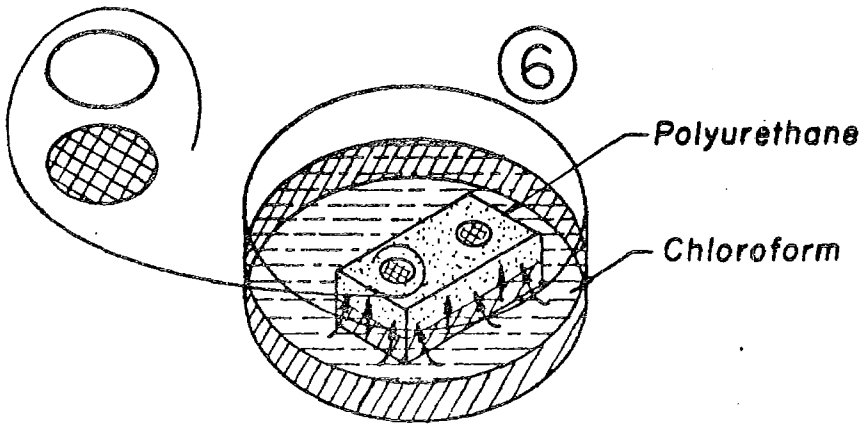
Filter Assembly For Filtration onto Nuclepore Filter

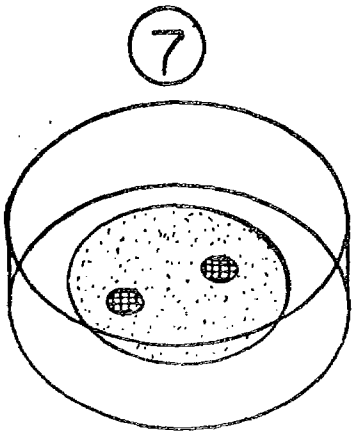
Segment of Nuclepore Filter Cut For Microscope Glass Slide

Figure 7

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ELECTRON
MICROSCOPY

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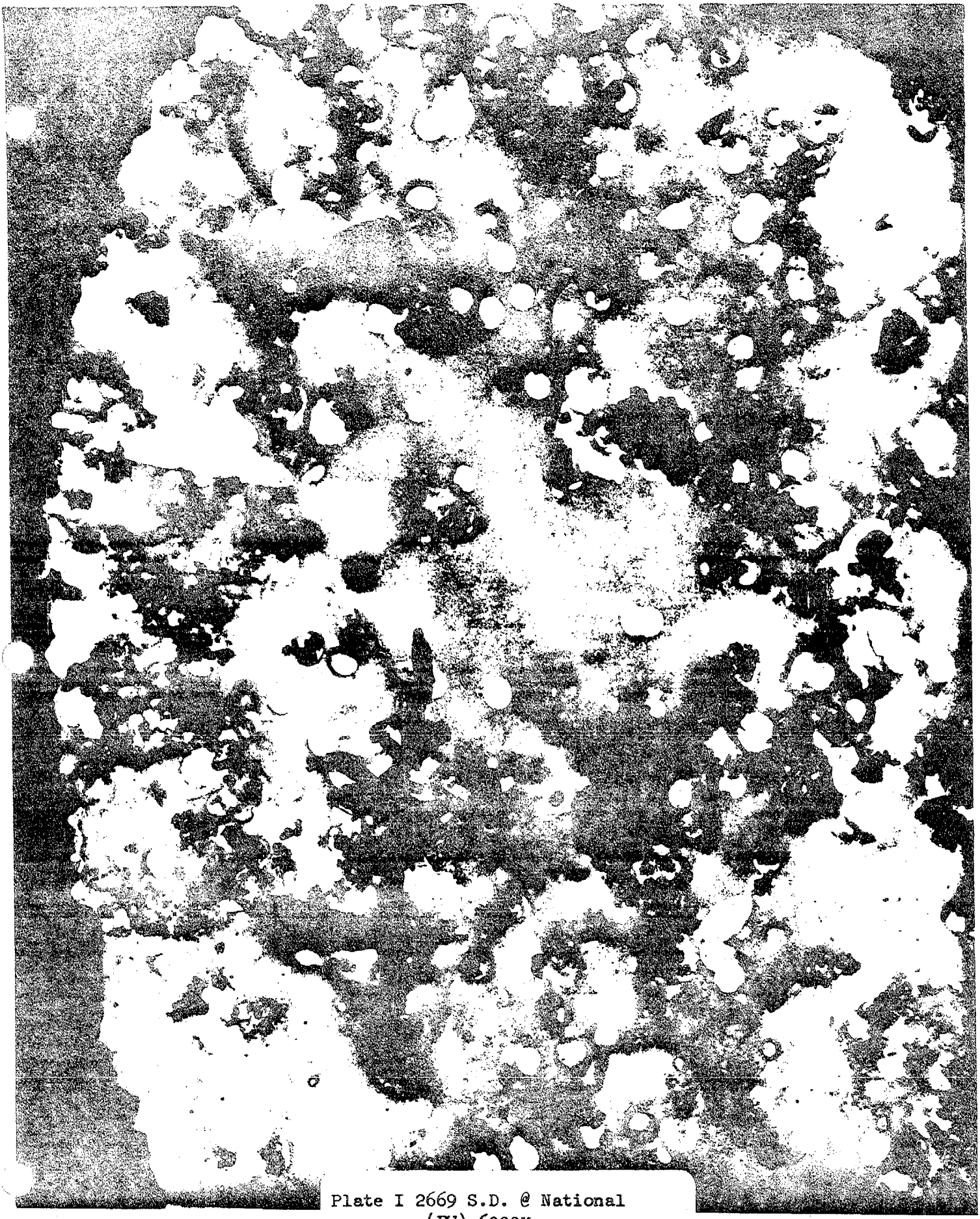

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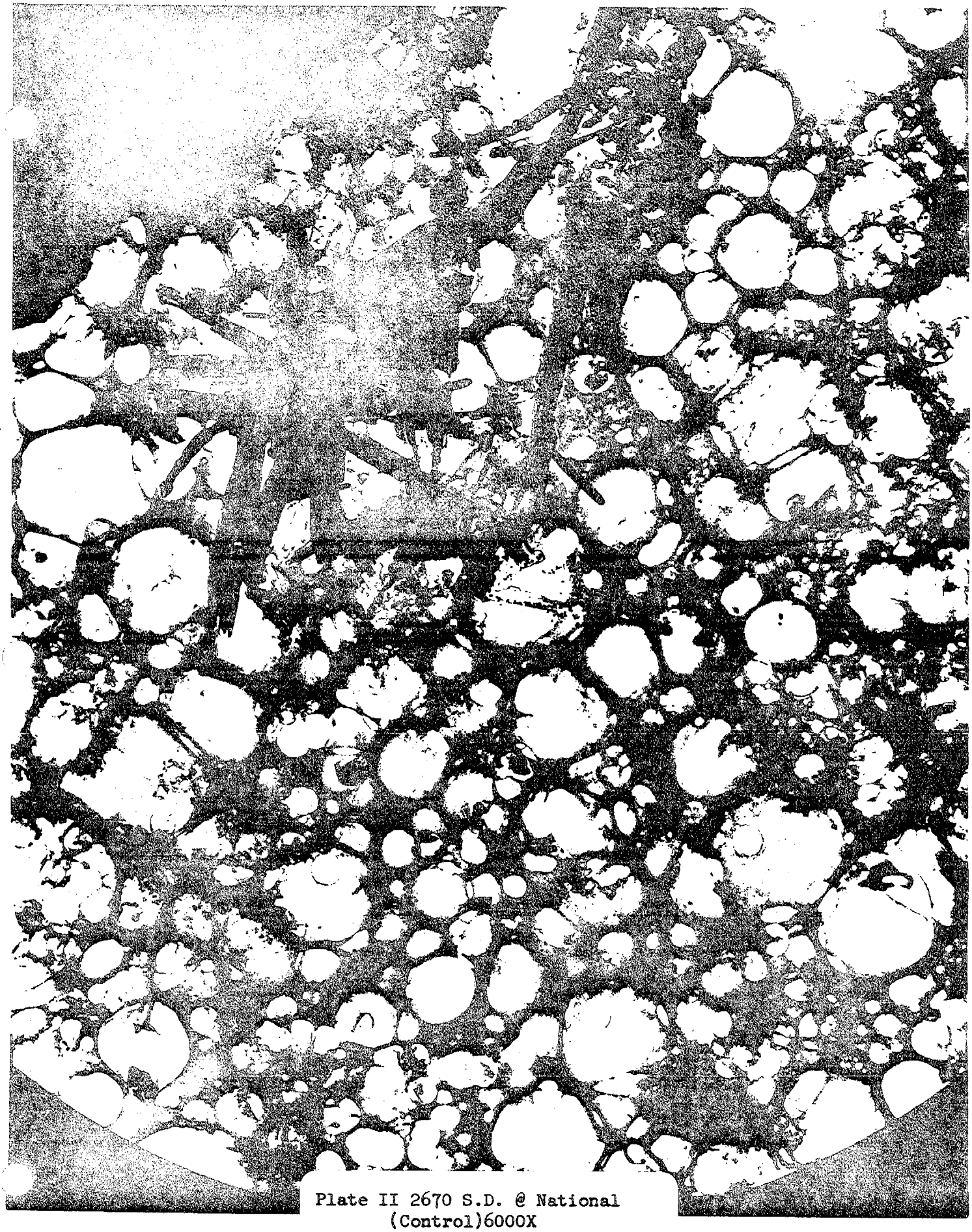

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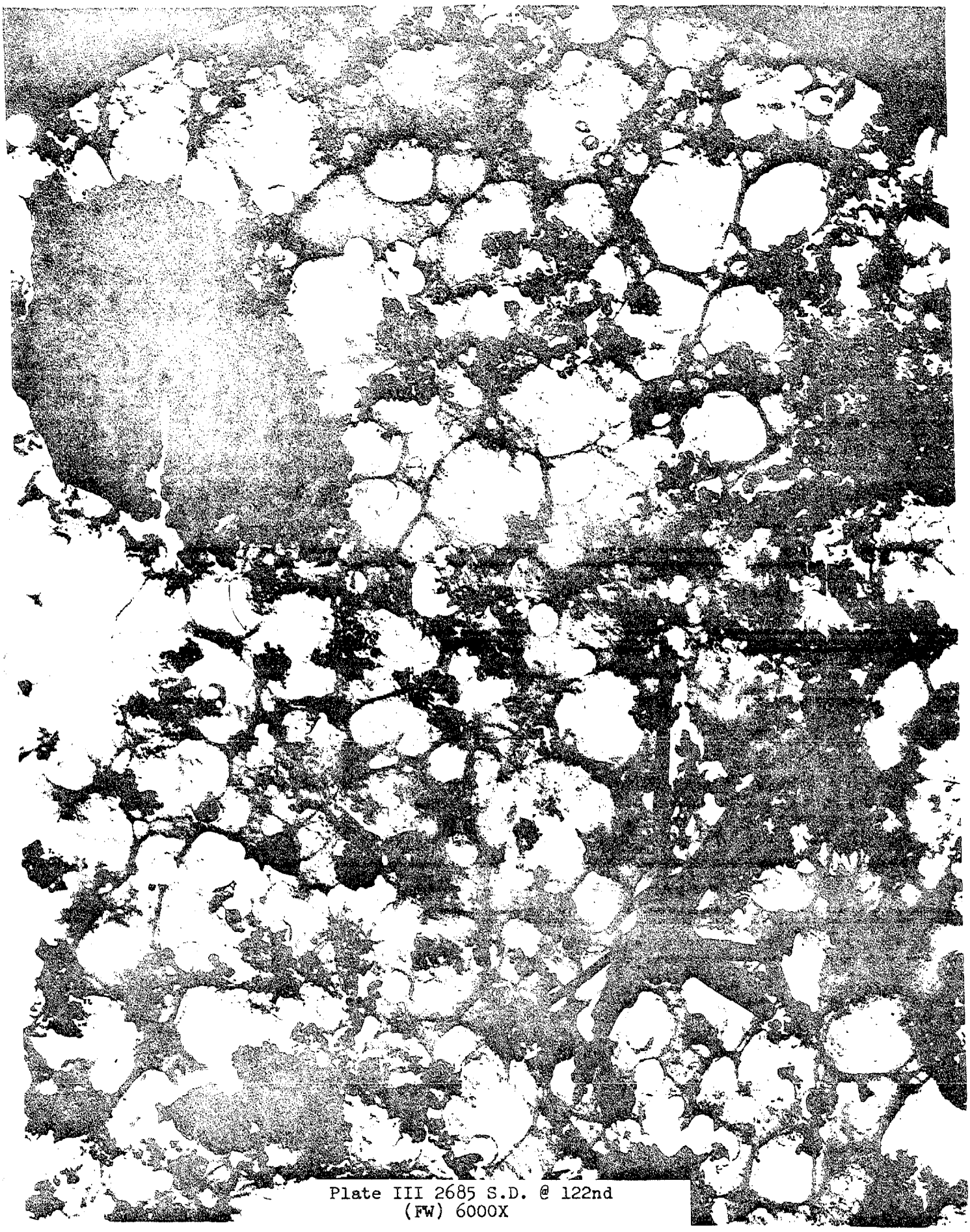

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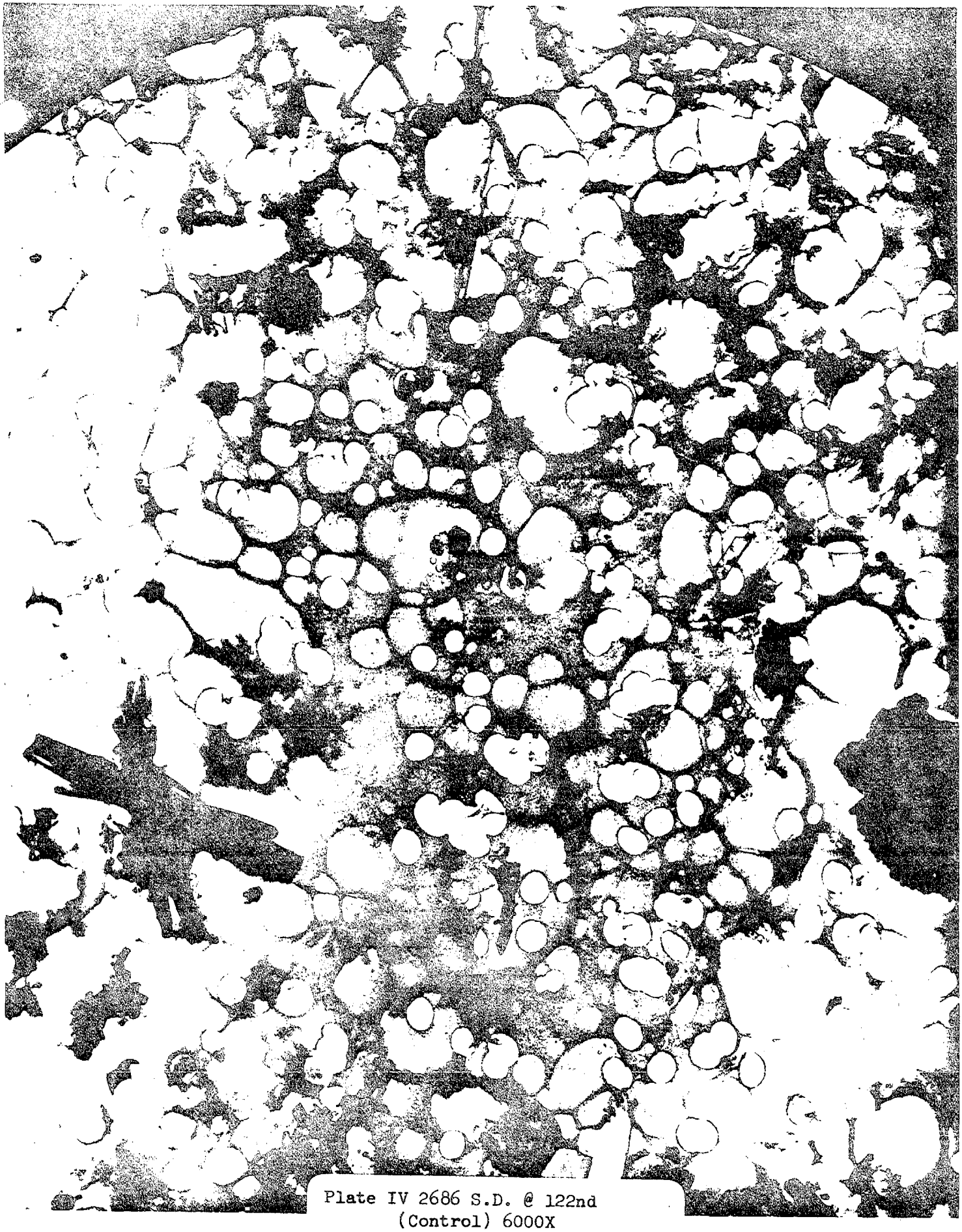

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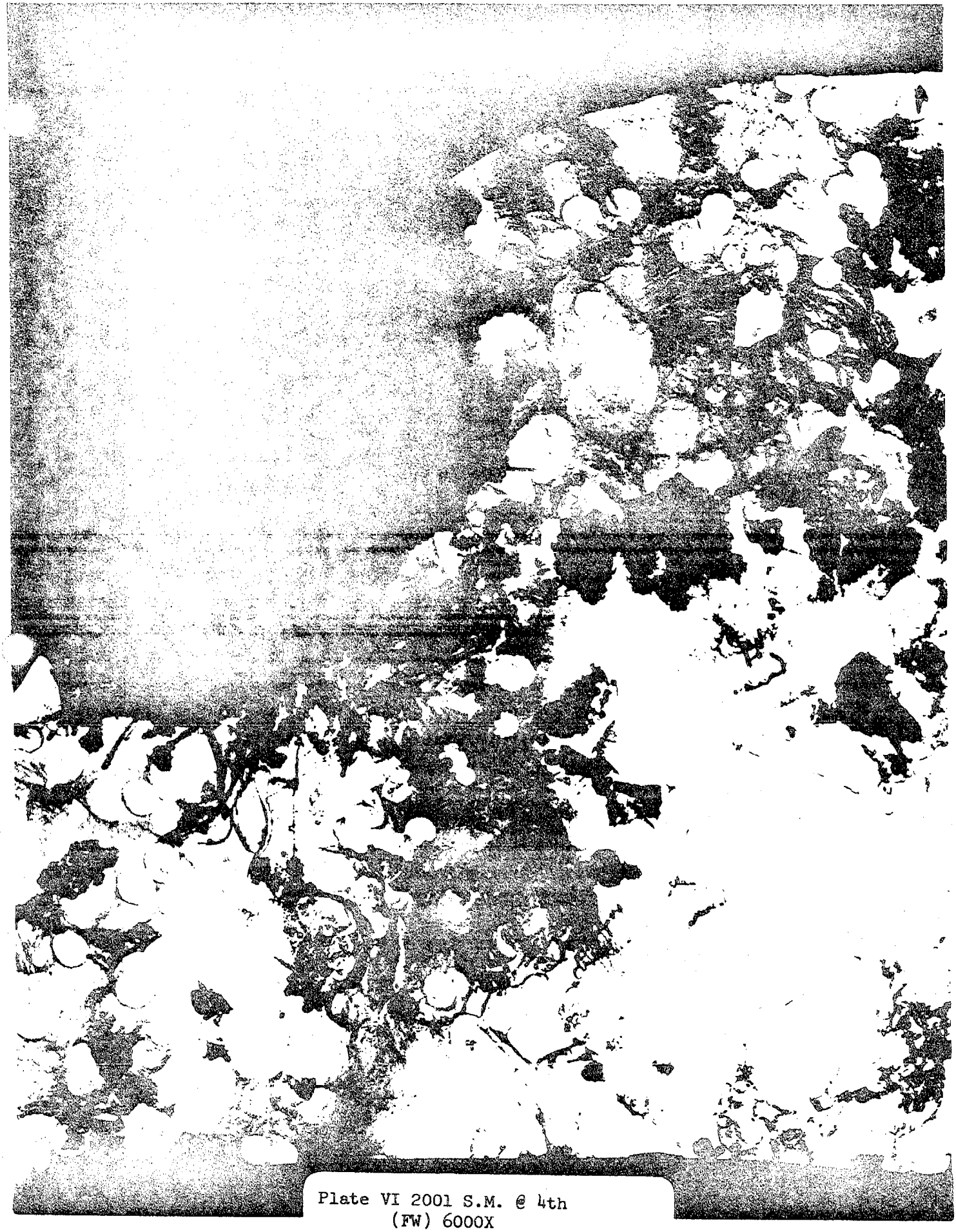

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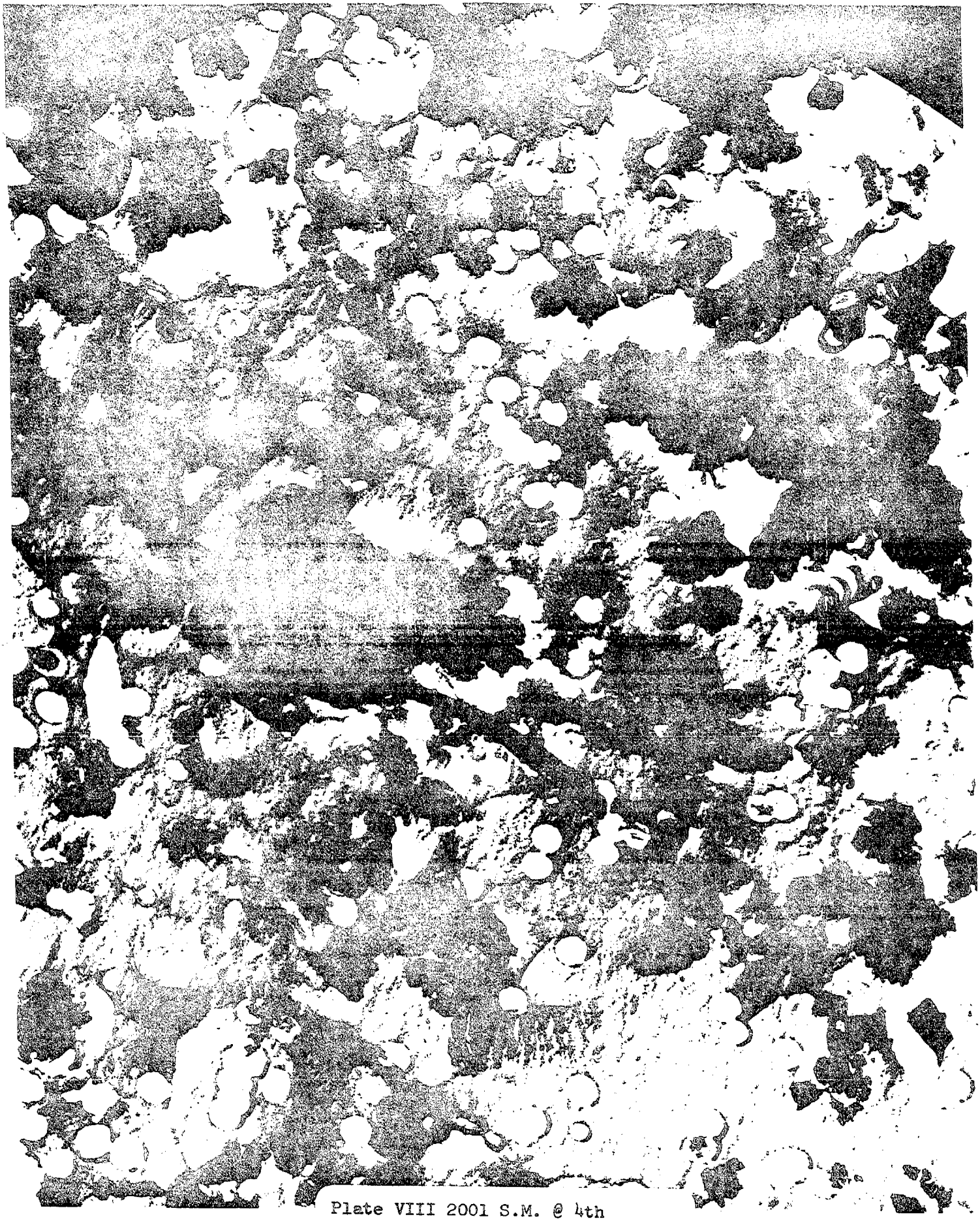

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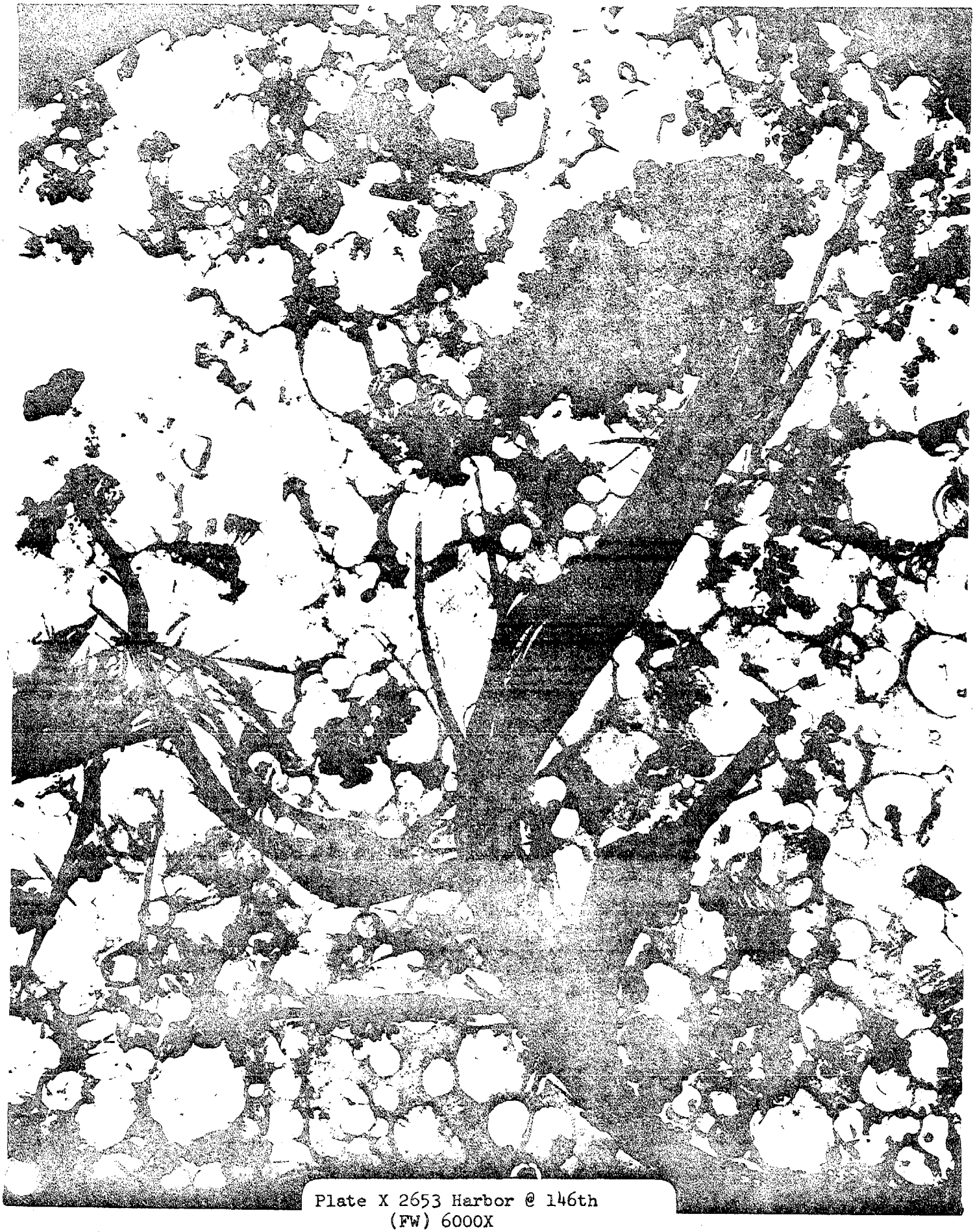

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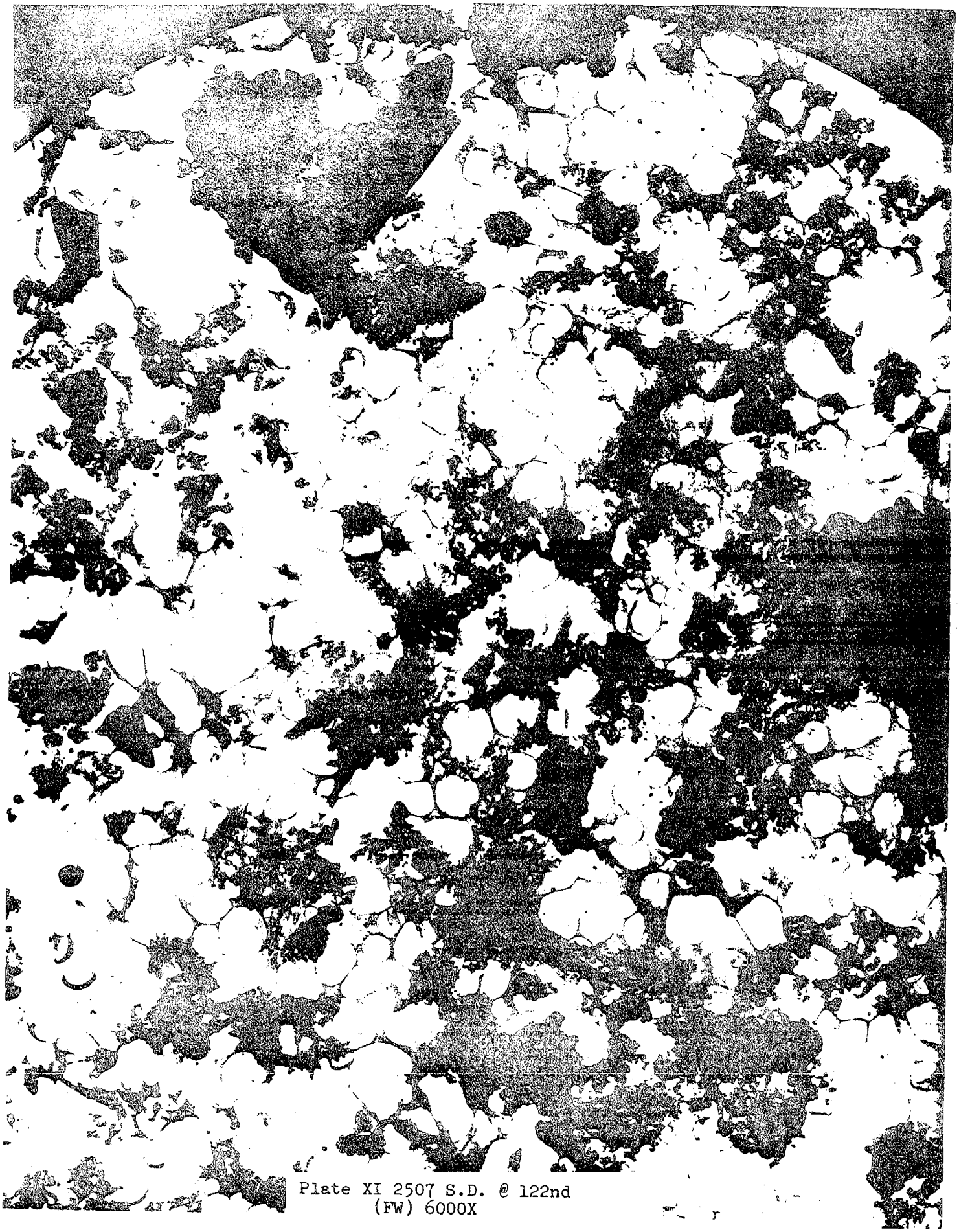

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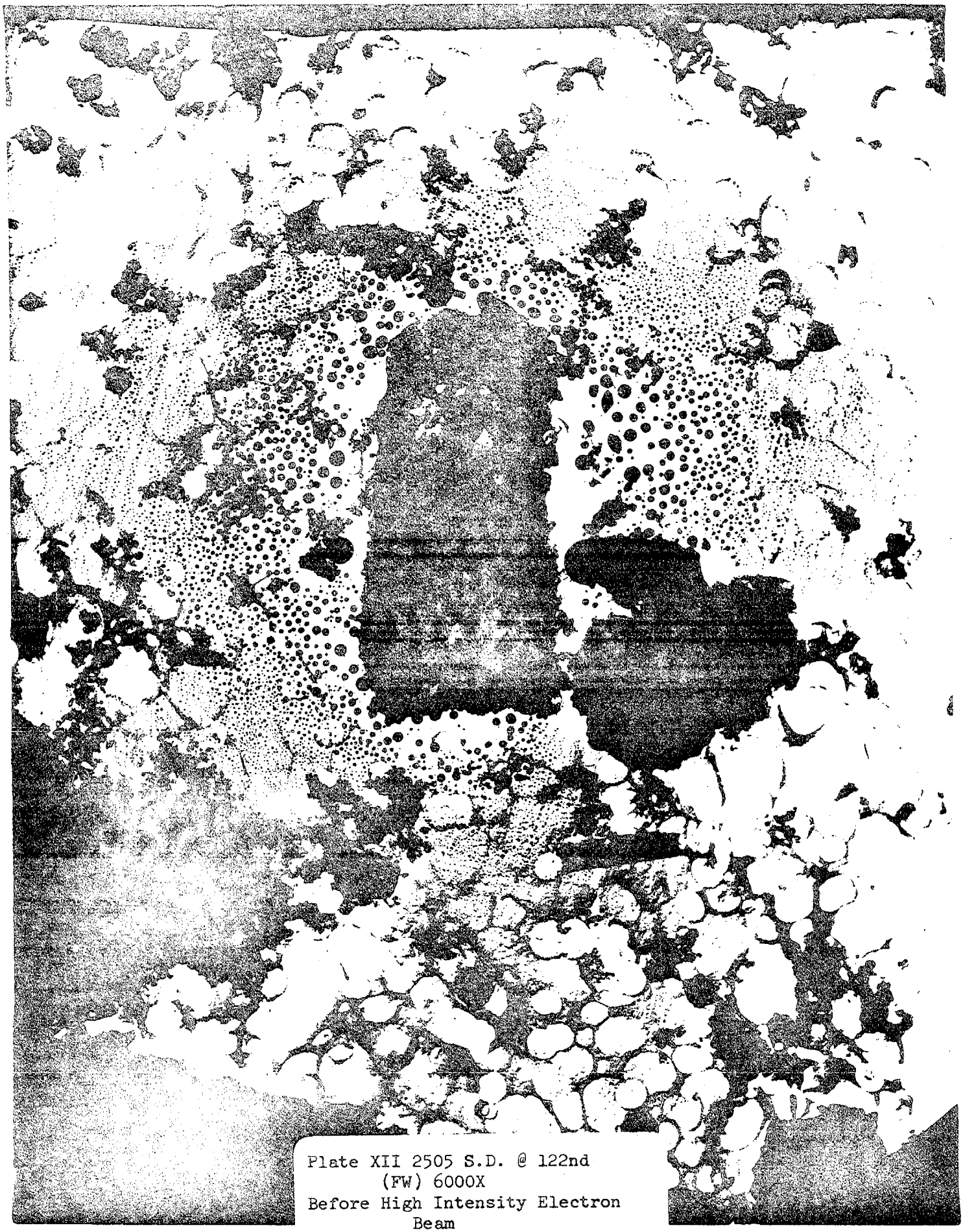

Plate XII 2505 S.D. @ 122nd
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Before High Intensity Electron
Beam

Plate XIII 2505 S.D. @ 122nd
(FW) 6000X

After High Intensity Electron Beam