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AN ANALYSIS OF AIRBORNE PARTICULATE LEVEL REDUCTION RESULTING FROM PAVING OF GRAVEL ROADS

BY

CAPT ELROY A. FLOM

2LT STEPHEN J. THOMPSON

PROJECT 2303

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AIR FORCE SYSTEMS COMMAND

UNITED STATES AIR FORCE

FJSRL-TR-78-0012

This document was prepared by the Faculty Research Division, Directorate of Chemical Sciences, Frank J. Seiler Research Laboratory, United States Air Force Academy, Colorado. The research was conducted under Project Work Unit Number 2303-F1-01, An Analysis of Airborne Particulate Level Reduction Resulting From Paving of Gravel Roads. Captain Elroy A. Flom was the Project Scientist in charge of the work.

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Gravel utilized as surfacing material for secondary roads in El Paso County, Colorado contains microscopic paticulates. The particulates, agitated into an airborne state by automobiles, represent a potentially hazardous air pollutant to the public. The airborne particulate level observed as a result of paving Ehrich Street, Colorado Springs, Colorado was reduced 1700 times by weight. The remaining airborned particulate matter is believed to be carried to the Ehrich Street area by mountain winds from Rampart Range.

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Frank J. Seiler Research Laboratory
Air Force Systems Command
US Air Force Academy, Colorado 80840

PREFACE

This report documents work done under Work Unit 2303-F1-01, Pattern Analysis and Correlation of Weather and Air Pollution Data in the Pikes Peak Region, between 1 July 1978 and 15 November 1978. The authors wish to thank Mr. Donald Stone, Mr. John James, and Mr. Ken Boyer for their cooperation in providing data for this report. In addition, thanks are due to B. J. Darcy for typing the manuscript.

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I. INTRODUCTION

Gravel and crushed quartz aggregates from the Queens Canyon Quarry, Pike View Quarry and Black Canyon Quarry cover many of the secondary roads in El Paso County, Colorado. Automobiles easily agitate the microscopic particulates in these aggregates to an airborne state. Rohl, Langer and Selikoff report 1000 times greater asbestos particulate levels in the air for areas utilizing quarried rock from Montgomery County, Maryland than urban areas with paved roads[1]. Black topping gravel roads substantially reduced this airborne particulate matter. The airborne particulate reduction has been analyzed using the scanning electron microscope (SEM) and particulate fractions from the Sierra Head Impactor (SHI).

Airborne particulates burden the human respiratory system. Gilson described the effects of mineral dusts and asbestos fibers as carcinogenic[2]. Particulates with diameters less than 100 microns are inhaled into the respiratory system's nasopharyngeal, tracheobronchial and pulmonary regions (Figures 1 and 2)[3,4]. The respiratory deposition profiles illustrate the migration of the smaller particulates deeper into the respiratory system (Figure 1). Continual inhalation of these microscopic particulates deteriorates and inhibits respiratory functions.

The SHI and SEM were used to determine the particulate reduction which resulted from paving Ehrich Street in Colorado Springs, Colorado. Conclusions were drawn from data taken before the paving process and after its completion.

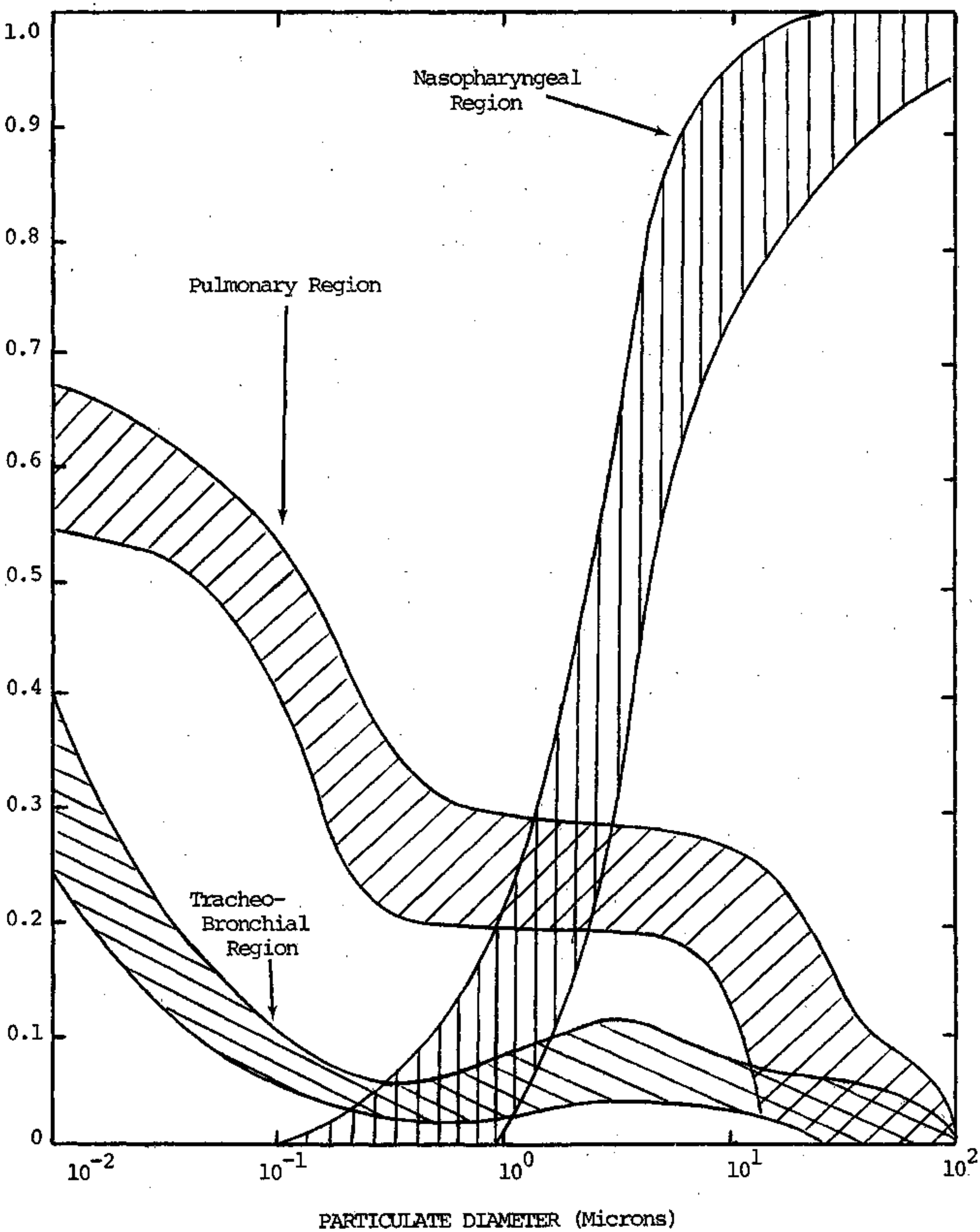

FIGURE 1 - Respiratory deposition profiles for inhaled particulates.

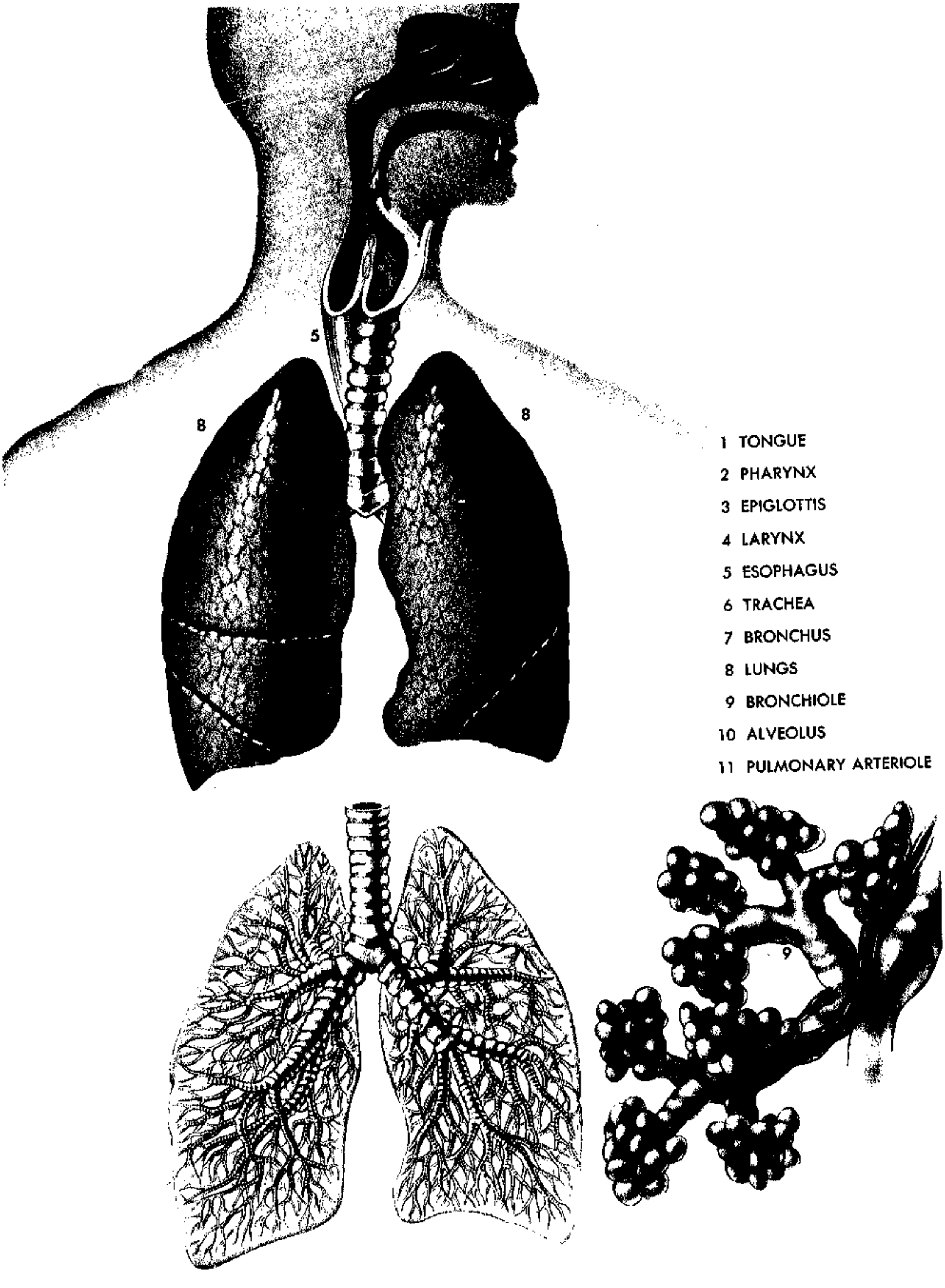

FIGURE 2 - The respiratory system: The nasopharyngeal region [above 1 and 2], the tracheo-bronchial region [6 and 7] and the pulmonary region [9].

II. THE METHOD

The SHI separates particulates according to diameter size by employing a cascade impactor effect. This effect is created by a series of five staggered slotted plates which alter the air flow velocity through the SHI. A decreasing slot width in the SHI fractionation plates from top to bottom increases the air flow velocity in accordance with the conservation of mass flow. The aerodynamic diameter of a particulate determines where it will deposit. Larger particulates deposit on the top plates of the SHI where air flow velocity is slower than air passing by the bottom plates, where smaller particulates deposit. Particulates are deposited on slotted glass fiber filters. Wiffen reports high particulate separation efficiency for this type of apparatus under similar data collection conditions[5]. Tare and final weights of the filters were used to determine particulate fraction weights.

Scanning electron micrographs were used to determine the effective separation capability of the SHI (Figures 3 and 4). Pooley reports the incorporation of this technique in particulate shape and size analysis[6]. A best case analysis of particulate sizes included measuring the maximum distance across a particulate as its diameter. This counting technique ensured a best case analysis because larger particulates will deposit in the nasopharyngeal regions rather than traveling deeper into the respiratory system (Figure 2). Also, a conglomerate, a cluster of particulates, was counted as one particulate to enhance the best case analysis. Distances on the micrographs were measured with a Charles Supper

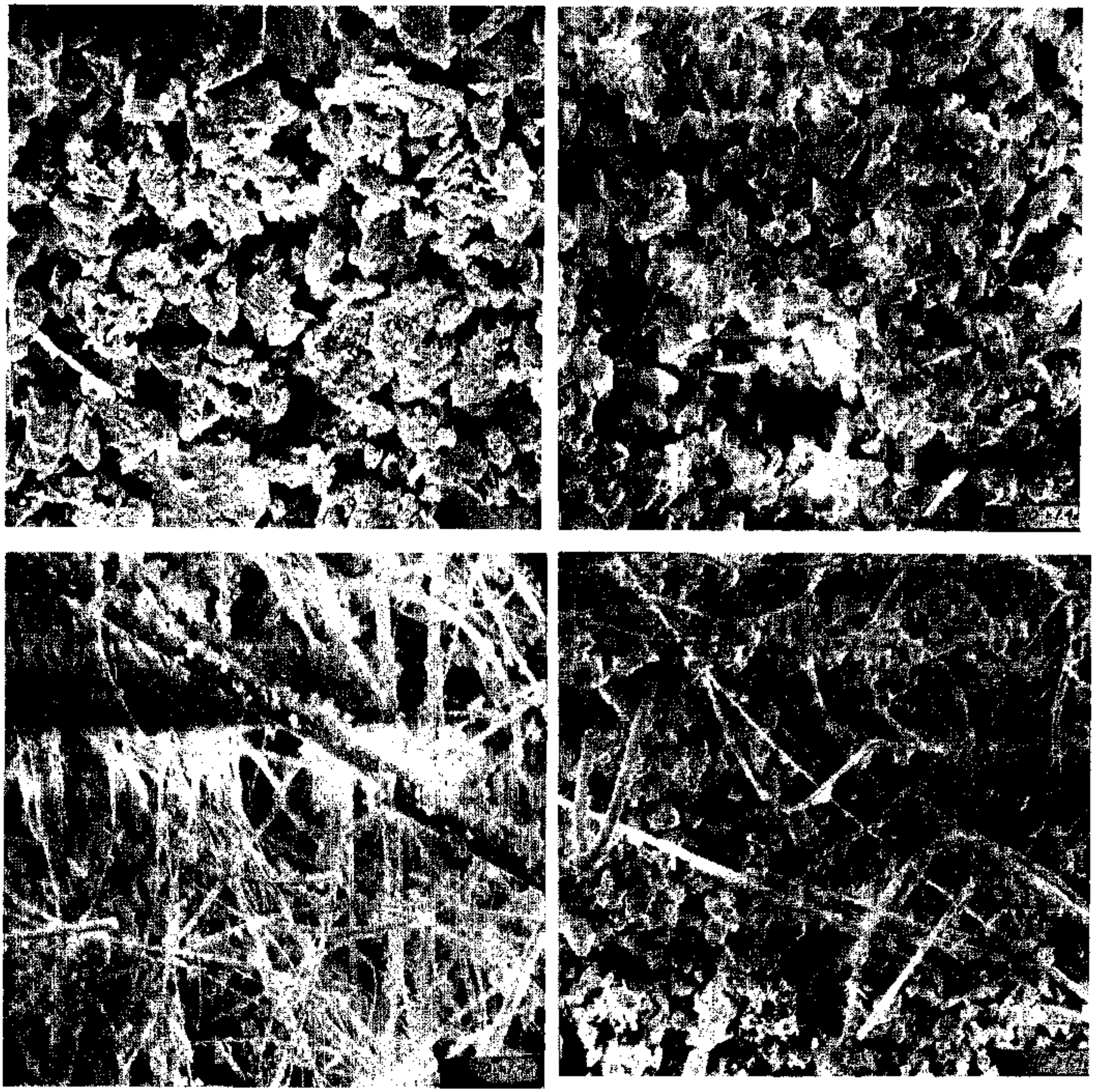

FIGURE 3 - Scanning electron micrographs of the first stage[a], second stage[b], third stage[c], and fourth stage[d] from the SHI to determine effective particulate size distribution.

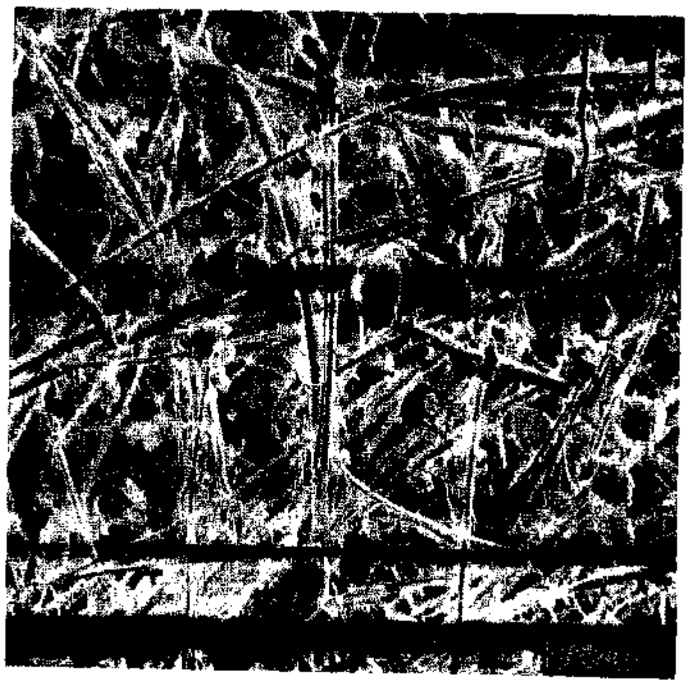

FIGURE 4 - Scanning electron micrograph of the fifth stage of SHI to determine effective particulate size distribution.

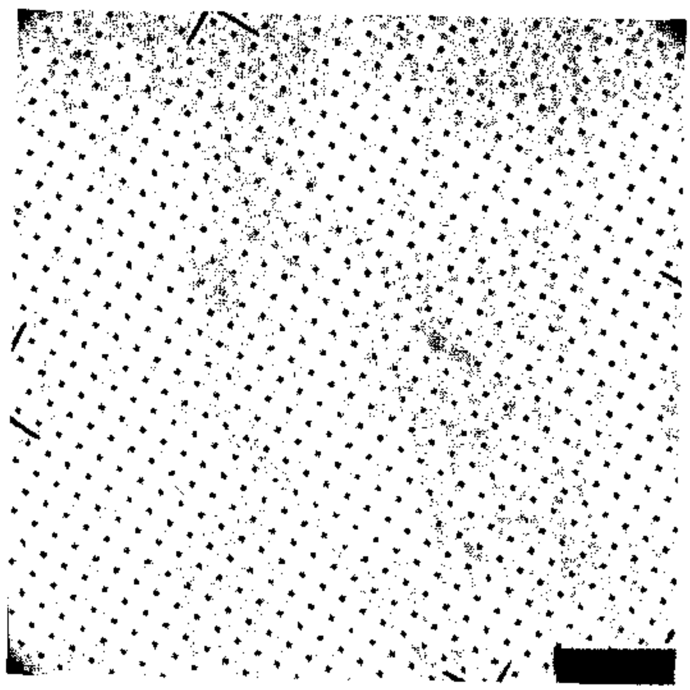

FIGURE 6 - Scanning electron micrograph of gold grid containing 1000 squares per linear inch.

Film Measuring Instrument and calibrated with a standard gold grid containing 1000 squares per linear inch (Figure 6).

III. RESULTS

Particulate fraction weights were calculated from the difference in tare and final weights of the filters (Table I). The effective size distribution for each SHI particulate fraction was found to be slightly different than the manufacturer's design specifications. Following observation and recording of all particulate diameters in each fraction, the effective size distribution was determined by varying the size boundaries of the fractions such that the number of particulates in each fraction was maximized (Table II).

The relative reduction of airborne particulates is reported as a reduction factor (Table IV). The reduction factor reflects the average decrease in weight of airborne particulate matter. The weight of each particulate fraction after paving was less than one percent of the fraction weight prior to paving.

IV. CONCLUSIONS

The airborne particulate content in the vicinity of Ehrich Street was reduced 1700 times by weight as a result of paving (Table IV). The decrease in airborne particulate matter was made more dramatic by the arid climate of Colorado. Some other areas of the country have less airborne particulate matter because of abundant precipitation. The particulate weight of the fourth fraction was reduced the most of the particulate fractions and approximately twice as much as that of the first fraction. This fraction represents those particulates most

TABLE I

PARTICULATE WEIGHTS FOR FRACTIONS FROM SHI BEFORE AND AFTER PAVING OF EHRICH STREET IS COMPLETED[1].

Fractionation Stage From the SHI	Particulates in grams collected by SHI Before Paving of Ehrich Street			Particulates in grams collected by SHI After Paving of Ehrich Street.		
	12 Sep 78	14 Sep 78	19 Sep 78	14 Oct 78	17 Oct 78	10 Nov 78[2]
First	.011	.010	.015	.000048	.000074	.000013
Second	.007	.008	.012	.000033	.000051	.000006
Third	.006	.004	.007	.000019	.000027	.000004
Fourth	.004	.002	.001	.000002	.000009	.000004
Fifth	.117	.090	.116	.000143	.000233	.000039
Total Weight	.145	.114	.151	.000245	.000394	.000066

[1]The SHI collects samples for 12 hours, 9 feet above ground level and 25 feet from the road's center. A Hi Volume sampler draws air through the SHI at 53.5 ± 2.0 ft^3/min. Weight values were recorded by the El Paso County Health Department.

[2]Precipitation fell on 8 and 9 Nov 78 reducing the airborne particulate matter.

TABLE II

COMPARISON OF DESIGNED AND EFFECTIVE SIZE
DISTRIBUTION OF PARTICULATES SEPARATED IN SHI.

Fractionation Stage From the SHI	Effective Particulate Size Distribution Where X = Particulate Diameter in Microns Determined From Scanning Electron Micrographs[1]	Manufacturers' Specifications For Particulate Size Distribution Where X = Particulate Diameter in Microns
First	$X \geq 10.0$	$X \geq 10.0$
Second	$10.0 > X \geq 5.0$	$10.0 > X \geq 4.9$
Third	$5.0 > X \geq 2.0$	$4.9 > X \geq 2.7$
Fourth	$2.0 > X$	$2.7 > X \geq 1.3$
Fifth[2]		$1.3 > X \geq .6$
Sixth[3]		$.6 > X$

[1]See Table III for percent error in effective size distribution of particulates.

[2]The fifth stage of the SHI exhibited no separating capabilities based on particulate diameter. See Table III for percentage error of particulates collected in the fifth stage.

[3]The SHI employed for data taking had only five stages.

TABLE III

WEIGHTS AND CALCULATED ERROR FOR PARTICULATE FRACTIONS[1]

Fractionation Stage From SHI	Effective Particulate Size Distribution Where X = Particulate Diameter in Microns	Weight of Collected Particulates In Grams	Percent Error In Fraction By # Of Particulates Above And Below Fraction
First	$X \geq 10.0$	.0972	38.6%
Second	$10.0 > X \geq 5.0$	.0432	34.3%
Third	$5.0 > X \geq 2.0$	.0278	29.1%
Fourth	$2.0 > X$	.0245	40.0%
Fifth[2]	$1.0 > X$	.3150	82.9%

[1] See Figures 3 and 4 for scanning electron micrographs used to determine effective particulate size distribution. See Figure 5 for control micrograph of clean glass fiber filter.

[2] Data from the fifth stage of the SHI was inconclusive in nature because 82.9% of the measured particulates were larger than the effective particulate size distribution. The large error in this fraction by the number of particulates generates an even larger weight error since all the undesired particulates have greater diameters.

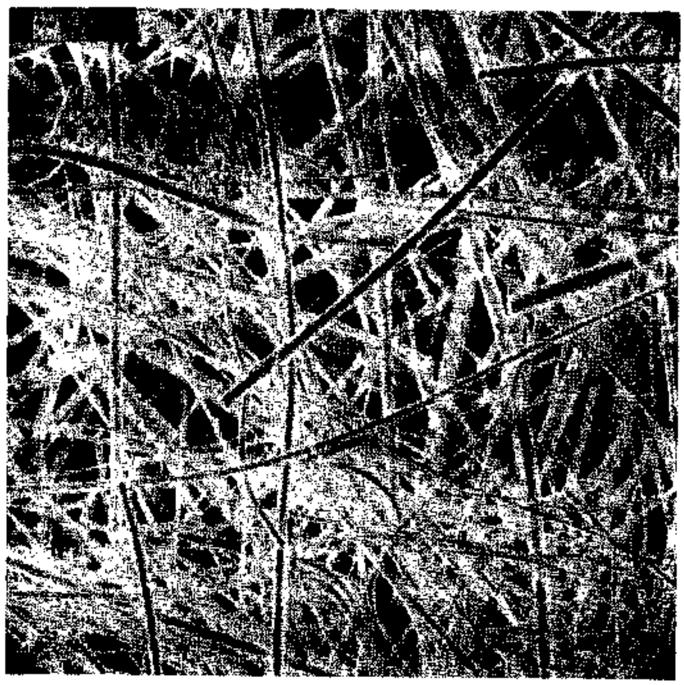

FIGURE 5 - Control scanning electron micrograph of a clean glass fiber filter.

TABLE IV

REDUCTION FACTOR OF AIRBORNE PARTICULATES BY WEIGHT FOR SHI FRACTIONATION STAGES AFTER PAVING EHRICH STREET

Fractionation Stage From the SHI	Reduction Factor of Airborne Particulates by Weight[1]
First	270
Second	300
Third	340
Fourth	460
Fifth	780
Total Weight	1700

[1] Reduction factor by weight is the average weight of particulate samples collected before paving divided by average weight of particulate samples collected after the paving process.

hazardous to the respiratory system. The majority of remaining airborne particulates after paving probably migrated into the area on mountain winds.

The effective particulate size distribution error appeared to significantly alter the particulate weights recorded (Table III). These errors would be smaller if calculated by weight since a given SHI fraction collected particulates belonging to fractions above and below it in size.

V. RECOMMENDATIONS

Paving gravel aggregate roads in El Paso County and on any Air Force installation will substantially reduce the health hazards of airborne mineral dust particulates. Such actions are recommended to reduce particulate pollution and greatly improve environmental health conditions.

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