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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
REPORT **191**

EFFECT OF AIR POLLUTION REGULATIONS ON HIGHWAY CONSTRUCTION AND MAINTENANCE

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EFFECT OF AIR POLLUTION REGULATIONS ON HIGHWAY CONSTRUCTION AND MAINTENANCE

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AND MARTIN WANIELISTA
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FAIRFIELD, NEW JERSEY

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST:
- BITUMINOUS MATERIALS AND MIXES
- CONSTRUCTION
- MAINTENANCE, GENERAL

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. 1978

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

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The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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FOREWORD

By Staff
Transportation
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The results of this study will be of interest to all persons involved with environmental protection during construction and maintenance operations and in the preparation of environmental impact statements. For highway administrators, the extent of the on-site construction problem is put into perspective. Such persons as construction, maintenance, and materials engineers will find information of value in performing their operational duties within a highway administration. The report documents the principal sources of air pollution from highway construction, such as burning during the clearing phase, dust during the earth-moving phase, and hydrocarbons during the paving phase. It also synthesizes air pollution regulations existing in each state and the extent of air pollution from highway construction and maintenance compared to existing regulations. Seven projects in three states were studied in detail. For those responsible for controlling air pollutants during construction, mitigation techniques used by the various states are reviewed and evaluated.

This report evaluates the effect of air pollution regulations for fugitive particulates and hydrocarbons on the highway construction and maintenance industry. Research was limited to the on-site construction process. Surveys of air pollution control officials and highway officials determined the monitoring procedures used by the industry to identify possible violations and tabulated those activities likely to produce illegal emissions. Mitigation methods favored by construction officials were also determined. A testing program for fugitive particulates and hydrocarbons generated by highway construction was performed. It was found that fugitive particulate regulations have had little effect on the industry because they are primarily concerned with persistant, permanent sources rather than sporadic, temporary sources such as construction. Open burning can be adequately controlled through present technology. Fugitive dust particles tend to settle out within right-of-way limits and the industry has long undertaken adequate mitigation procedures in response to neighbors' nuisance complaints. The quantity of reactive hydrocarbons emitted from the more volatile cutbacks is small compared to that of vehicular exhaust and dissipates within a short distance of its source. Essentially no violations of the ambient air quality standards are attributed to highway paving and priming.

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Thanks also are extended to the individuals and agencies responding to the survey.

EFFECT OF AIR POLLUTION REGULATIONS ON HIGHWAY CONSTRUCTION AND MAINTENANCE

SUMMARY

This report deals solely with the air pollution effects of the on-site construction process itself rather than with off-site materials processing. In this context, air pollution regulations have had little effect on the highway construction and maintenance industry because most regulations are primarily concerned with persistent, permanent sources rather than sporadic, temporary sources such as construction.

Open burning can be adequately controlled through present technology. Although bans on open burning caused significant price escalation when first introduced, the development of high combustion burners and sophisticated chipping equipment has been reported to result in disposal costs approximately equal to the costs of open burning. Tests conducted during this research program have indicated that fugitive dust generated by construction traffic does not significantly contribute to the ambient particulate level because the particles tend to settle out within right-of-way limits. Furthermore, the industry has long undertaken adequate mitigation procedures in response to neighbors' nuisance complaints. Hydrocarbon test results have revealed that essentially no violations of the ambient air quality standards are attributable to highway paving and priming. The quantity of reactive hydrocarbons emitted from the more volatile cutbacks is small compared to that of vehicular exhaust; that which is emitted, in fact, is dispersed or diluted to trace concentrations within a short distance of its source.

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

INTRODUCTION

The Federal Environmental Protection Agency promulgated primary and secondary ambient air quality standards for major pollutants under provisions of the Clean Air Act (P.L. 88-206 as amended) (*1*). The primary standards, to be met by July 1, 1975, were to define levels "requisite to protect the public health." Secondary standards, set at stricter levels "requisite to protect the public welfare from any known or anticipated adverse effects . . .," were to be met in a reasonable time after July 1, 1975. Two of the pollutants for which standards were set, particulate matter and hydrocarbons, are associated with highway construction and maintenance.

Each state was required to submit air quality control plans to the EPA for approval in order to implement the air quality standards. The states were permitted wide latitude in devising strategies (implementation plans) to conform with the Federal mandate. The EPA often exercised its power to reject portions of the plans found unacceptable and imposed stricter Federal controls. To attain the required ambient air quality standards for a given region (the United States is divided into 247 air quality control regions), the implementation plans included particulate emission limitations on various "stationary sources" such as incinerators, wood pulp mills, asphalt plants, and concrete batching plants (*2*). The highway construction and maintenance industry was not specifically cited as a stationary source.

In two areas, however, the EPA established models or suggested strategies related to this industry upon which the states could base their implementation plans. In the control of air pollution episodes, the EPA published a sample program—complete with alert stages and appropriate source controls—that could be directly applied to the industry.

Further, fugitive dust control measures were specified in a model for abatement that is offered to the states as a guide to the attainment of Federal standards. This model does not specify limitations on dust, but offers methods of abatement predicated on the use of "reasonable precaution" (*3*). The EPA also established air quality standards for hydrocarbon emissions, but provided no models that could be used by the industry as an aid in attaining the standards.

This report examines the contribution of on-site processes (hauling, paving, sweeping) of the highway construction and maintenance industry that might prevent attainment of the ambient air quality standards for particulate matter and hydrocarbons. The investigation of asphalt and concrete batching plants has been excluded from the research because of extensive studies by others. The scope of this report also excludes vehicular exhaust emissions.

A research program was developed to identify, evaluate, and recommend procedures for highway construction and maintenance that will enable compliance with ambient air quality standards and regulations. Specific research objectives were:

1. To perform a literature review.
2. To conduct a survey that would determine the highway construction and maintenance industry's perception of their contribution to the air pollution problem, review air quality regulations, assess the monitoring procedures utilized to identify offenders, tabulate citations or violations relating to the air pollution laws or regulations, identify construction and maintenance practices producing potentially illegal emissions, and record the current mitigation methods for these emissions.
3. To conduct field tests that would quantify particulate and hydrocarbon emissions.
4. To infer from the data those highway construction and maintenance processes likely to result in violations of regulations and to assess the value of mitigation techniques.
5. To set forth conclusions and, if necessary, alternative mitigation techniques whereby the construction and maintenance practitioner can be guided to avoid conflict with existing regulations.
6. To recommend a program of research.

RESEARCH APPROACH

Literature Review

A standard literature search was performed. Manual searches were made of the Public Health Service and the Environmental Protection Agency and Transportation Research Board documents, bibliographies, and abstracts; computerized searches were made by the Smithsonian Science Information Exchange, Inc., and the Highway Research Information Service.

Survey

The survey was comprised of two questionnaires (copies of the questionnaires, lists of recipients, and summaries of responses are included in Appendixes A and B). The first questionnaire was sent to 53 air quality officials representing 50 states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands. This questionnaire requested copies of the respondents' approved implementation plan and air quality regulations and standards currently in effect; it also asked for completion of a series of questions designed to aid in defining the range of air pollution problems associated with highway construction. As a follow-up to the first questionnaire, series of informal telephone contacts were conducted to solicit representative opinions of selected state and Federal agencies. Twenty-seven state air quality officials, representing states in each region of the United States, were consulted.

The second questionnaire was sent to 71 highway maintenance and construction officials from all states, to many turnpike authorities, and to other agencies. This questionnaire asked respondents to identify procedures that have caused air pollution problems and to evaluate the various dust mitigating procedures that are presently used by them. As with the first questionnaire, series of telephone and personal interviews were conducted with highway construction and maintenance officials to supplement the information gained from the questionnaire itself.

Fugitive Particulate Testing Program

Since the highway construction and maintenance industry performs a number of operations that generate airborne particulates (principally fugitive dust), one of the objectives of this research was to study the presence of fugitive dust in the following ways:

1. By measuring the ambient air quality concentrations.
2. By determining the particle size distribution of the fugitive dust emissions.
3. By assessing the influence of meteorological parameters on ambient air quality concentration.
4. By observing the settleable range of fugitive particulate emissions.
5. By considering the effectiveness of control measures.

Table 1 lists the many activities in highway construction that are potential sources of fugitive dust. The effect of particulate emissions on the ambient air quality in the area of the work site depends not only on these activities but also on the following: the intensity of the activity within each task, the number of concurrent operations, the weather, the meteorology, the type of soil, the mitigation methods employed, the nature of the haul road or roads adjacent to the work site, the local traffic on those roads, the traffic volumes and speeds, the type of construction equipment, the distance from the dust source, the terrain, and the characteristics of adjacent property.

A matrix of all these variables and all possible operations would lead to a testing program with several hundred possible combinations. Since each test must be of 24-hr duration, all variable factors could not possibly be considered. Consequently, the results of the survey discussed earlier were used as a basis for formulating a more manageable testing program. A brief description of the testing procedures follows. Further details of the program are given in Appendix E.

The promulgated reference method of particulate determination was the High Volume Method (*4*). Briefly, the determination of particulate matter is made by filtering a large volume of air through a glass fiber filter that is enclosed in a specially constructed housing. The mass concentration is computed by measuring the mass collected on the glass filter and relating it to the volume of flow.

For the determination of particle size, a cascade impactor was used. This impactor collects particles on a series of collection stages according to the aerodynamic dimension of the particles. The collection plates are staggered with apertures decreasing in size to sequentially impact smaller particles on collection paper.

Microscopy of morphological analysis was used to identify the source of the particulate matter collected. Basically, this method employs certain microscopic techniques to study particles. In air pollution important applications are:

1. Determination of the composition of a given air pollutant and, as a result, the source of the pollutant.
2. Identification of the general types and sources of air pollution over a given area.
3. Determination of the concentration of a given pollutant.
4. Determination of the dispersion of "tracer" emissions.

Morphological characteristics (such as size, shape, surface marking, transparency, translucency, opacity, occlusions, color, birefringence, refractive index, and conoscopic observations), which are not readily apparent by normal vision but are accented when making observations under a microscope, are used to identify the air pollutants.

In this testing program, the basic objective of the microscopic analysis was to identify a given source (i.e., the highway construction activity), and do a comparative analysis with ambient samples. Characteristics such as shape, color, surface marking, and transparency were the prime identifying factors.

In order to determine the influences of certain meteorological factors, pertinent data were obtained through the National Weather Service and by an on-site wind recording system. Two air-monitoring trailers were used during the research. These units housed all the necessary equipment to perform the field testing.

The original research plan called for fugitive dust samples to be taken from construction projects in five states. In two states, however, the research team was denied access to the construction sites in the belief that the presence of the testing apparatus would create suspicion that "something must be wrong"—or, worse, that violations would be found and penalties imposed. A revised plan then focussed on seven projects in three states. Three projects were chosen for study in the Orlando, Fla., area; two projects in the Richmond, Va., area; and two in the Newark, N.J., area. In order to determine general ambient air quality concentration, sites where the general public had access were chosen. A breakdown of the sampling locations and types of work being performed is given in Table 2.

The area of influence of highway construction was determined by selecting sampling sites at various distances from the source (the figures in Appendix E illustrate the distances to construction and existing roadway). Also, sampling at various heights gave an indication of the settleability of the fugitive dust generated by highway construc-

TABLE 1

HIGHWAY CONSTRUCTION ACTIVITIES

EARTHWORK

a. excavation
b. loading
c. hauling
   1. paved
   2. non-paved
d. dumping
e. spreading
f. grading
g. compacting
h. wind erosion control
   1. water
   2. chemical
   3. oil
   4. topsoil, seed, sod
   5. membrane

PAVEMENT

i. hauling
   1. paved
   2. non-paved
   3. limestone
   4. sand
   5. asphalt
   6. P.C. Concrete
j. grading
k. dumping
l. spreading
m. compacting
n. oil prime
o. sand cover
p. sweeping
q. stabilizing bases
   1. cement
   2. asphalt
   3. limestone
   4. clay
   5. flyash
   6. wax or resin
r. asphalt pavement
s. portland cement

MISCELLANEOUS

t. painting
u. sand blasting
v. mowing, seeding, mulching
w. demolition
x. grinding, chipping
y. line stripping
z. traffic only - no specific const. in sample area

TABLE 2

SAMPLING LOCATIONS

Site No.	
1	Aloma Avenue, Near an Intersection, Winter Park, Fl
2	Aloma Avenue, Directly North of Site No. 1, Winter Park, Fl
3	Aloma Avenue, Parking Lot, Winter Park, Fl
4	Aloma Avenue, Variety of Construction Activities, Winter Park, Fl
5	State Route 436, Sweeping of Asphalt, Forest City, Fl
6	State Route 436, Variety of Construction Activities, Forest City, Fl
7	Aloma Avenue, Distance from Construction, Winter Park, Fl
8	Aloma Avenue, Distance from Construction, Winter Park, Fl
9	Aloma Avenue, Additional Documentation, Winter Park, Fl
10	Interstate-4, Unpaved and Paved Haul Road, Maitland, Fl
11	Douglasdale Road, Paved Haul Road, Richmond, Virginia
12	French Street, Excavation Activities, Richmond, Virginia
13	New Jersey Turnpike, Jackhammer Operation, Newark, NJ
14	Contractors Yard, Maintenance and Storage, Jersey City, NJ

tion and traffic on the roadway. Sampling heights were chosen at 3.5 ft (1 m) and 10.1 ft (3 m) to conform with the High Volume reference method housing height, trailer stand limitations, and EPA recommended sampling heights (*5*).

Hydrocarbon Testing Program

Various operations in the highway construction and maintenance industry produce gaseous atmospheric pollution other than that from equipment or vehicular exhaust. Air quality standards for hydrocarbons are based almost entirely on their role as precursors of other compounds formed in the atmospheric photochemical system and not on the direct effects of the gaseous hydrocarbons themselves. The more significant operations emitting hydrocarbons include asphalt paving operations and the use of cutback asphalts for highway construction in operations such as the application of seal and prime coats.

The national primary and secondary ambient air quality standard for hydrocarbons, measured and corrected for methane by the reference method described or by an equivalent method, is 160 $\mu g/m^3$ (0.24 ppm) maximum 3-hr concentration (6 to 9 a.m.) not to be exceeded more than one per year (*4*). The reference method described specifies that hydrocarbons measured by gas chromatography will be in terms of methane (CH_4) concentrations (i.e., the signature generated by ethane (C_2H_6) and higher carbon compounds will be measured as though it were a methane signature). It is therefore unnecessary to examine the hydrocarbons in the air by the individual compound identification (to determine molecular weight) and concentration. The 6 to 9 a.m. measuring period derives from the fact that the photosynthesis (photochemical) process has had little time to operate on the hydrocarbons in the atmosphere and their concentration is, therefore, greatest during this period—even though hydrocarbon production is greatest later in the day.

Parts per million by volume (ppm_v) is used throughout this report to describe hydrocarbon (H-C) and methane concentrations. These values can be converted to milligrams per cubic meter as follows:

$$\text{mg H-C (as } CH_4)/m^3 = ppm_v\text{H-C (as } CH_4)/1.53$$

The term "corrected for methane" is used to ensure that hydrocarbon values given and used as quality standards do not include the methane concentration that must be subtracted from any total hydrocarbon (THC) concentration measurement. Methane is photochemically unreactive and is therefore not a harmful pollutant in air (it can be dangerous as an explosive at high concentration approaching stoichiometric quantities with the oxygen in the air). For this reason, the standards are directed solely to those hydrocarbons, C_2+ and above, that will react photochemically in sunlight and are therefore designated as "reactive hydrocarbons" (RH-C) herein.

A brief description of the hydrocarbon testing program that was undertaken follows. Further details of the program, data, and results are given in Appendix F.

The testing program was performed to evaluate the hydrocarbon emissions from two major asphaltic products. The first phase of testing was performed on air samples in the vicinity of asphaltic paving operations, and the second phase was performed on air samples taken during the application of cutback asphalt in a prime coating operation. These two products were chosen because of their extensive use in the highway construction and maintenance industry and because of their relative volatility. Table 3 summarizes information provided by the Asphalt Institute. These data indicate that the two products tested represent more than 63 percent of the total petroleum asphalts sold and about 86 percent of the asphalt paving products.

The RC-70 cutback asphalt sampled in the second phase of testing is known to give off the highest concentration of hydrocarbon fumes of commercially available asphalt products because it has the lowest viscosity and the highest dilution with a volatile solvent.

All of the data for the hydrocarbon testing program were recorded in the vicinity of Orlando, Fla. Throughout each phase, ambient air measurements and various samples were taken during different stages of each operation.

Samples of the asphalt paving operation primarily were taken directly adjacent to the paving machine to ascertain (1) the reliability of measuring the fumes emitted from new paving, (2) their contribution to atmospheric concentrations, and (3) their decay factors. Operations including an idling, nonloaded paving machine during its morning warm-up and the THC contribution from auto traffic flow during paving operations and nonpaving times were also sampled (see Appendix E). The majority of the samples of paving operations, as shown in Figure 1, were taken in the vicinity of heavy traffic, and only a small number were taken in nonurban areas.

Samples of the RC-70 fumes were taken during the prime coating of compacted limestone aggregates base for both a single lane of roadway and a parking lot. In addition to the ambient measurements, samples were taken of the hand application of the cutback asphalt over curbing and other irregular areas and of the spray truck as it primed the base aggregate (see Fig. 2).

At least two samples were taken for each condition, but at different locations. When noticeable fumes were observed, a sample was taken at nose height for comparison purposes. Further samples were taken from two RC-70 storage tanks, as shown in Figure 3.

TABLE 3

PERCENT SALE OF PETROLEUM ASPHALT AND ROAD OIL IN U.S. FOR 1973

Paving Products	
Asphalt Cements	56.58%
Cutback Asphalts	11.83
Emulsified Asphalts	7.25
Road Oil	3.97
Sub Total:	79.63%
Roofing Products	
A. C. and Fluxes	15.82%
Emulsified Asphalts	0.03
Sub Total:	15.85%
Miscellaneous Products	
A. C. and Fluxes	4.10%
Emulsified Asphalts	0.42
Sub Total:	4.52%
TOTAL:	100.00%

Figure 1. Paving operations on US 50 at SR 436.

The samples of air taken during the two operations previously described were, for the most part, captured with a modified, small "propane tank." This inexpensive, rugged portable air sampling container was devised as a part of this research. Each reusable tank was evacuated and opened in the field with the hose inlet located at the desired sampling position. Each grab sample was then returned to the laboratory and analyzed for hydrocarbon content on a modified gas chromatograph. Details of the tank and testing apparatus are given in Appendix F, and are shown in Figure 4. Sample output from the gas chromatograph is depicted in Figure 5.

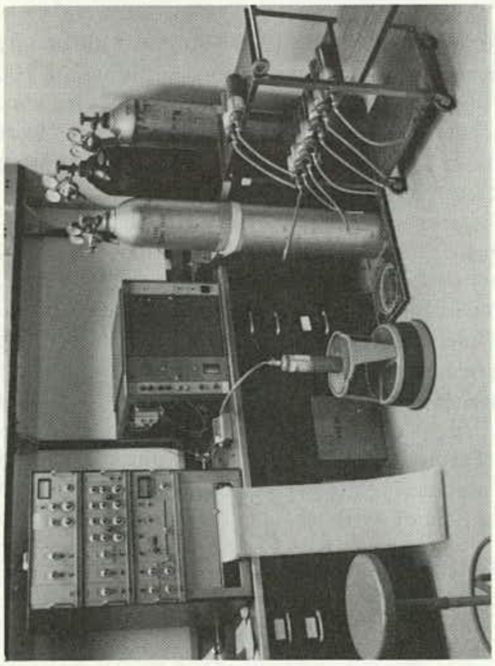

Figure 4. Gas chromotograph and sample bottles.

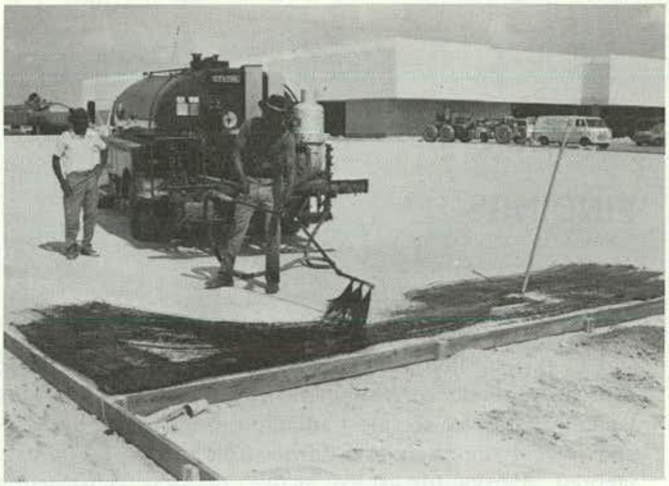

Figure 2. Hand spray RC-70.

Figure 3. Two 4000-gal RC-70 storage tanks.

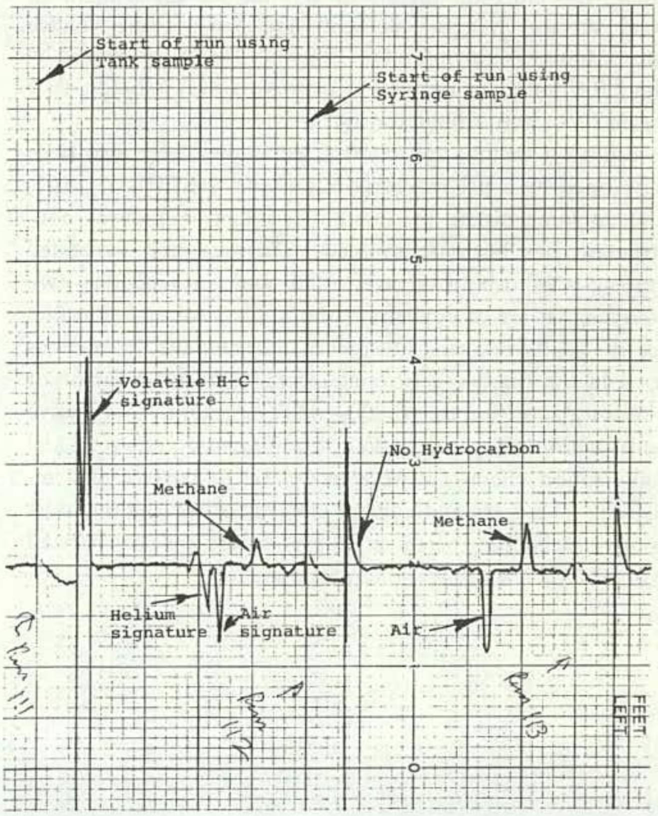

Figure 5. Sample recording from tank and syringe.

CHAPTER TWO

FINDINGS

LITERATURE REVIEW

The existing literature is virtually barren with regard to construction-induced dust and hydrocarbons. Open-burning techniques receive the most attention, whereas fugitive dust and solvent fumes emitted during construction are largely ignored. Except for asphalt plants, highway construction and maintenance have been the subject of few specific inquiries, but studies and publications concerning closely related construction and industrial processes include relevant and useful information on fundamental air quality problems.

Recent awareness of ambient air violations caused by fugitive particulate emissions has led to investigations that quantitatively define the contribution of highway systems to the problem. The EPA has developed emission factors for various fugitive dust sources by atmospheric isokinetic sampling (*7*). The sources relating to the highway industry include unpaved roads and air strips, construction sites, and aggregate storage piles. The emissions from unpaved roads most closely parallel the effects of highway construction. The equation developed by the EPA for estimating the total amount of road dust emissions with a drift potential greater than 25 ft (8 m) (i.e., particles smaller than 100 μm in diameter) is as follows:

$$e(\text{roads}) = 0.81s \times (S/30) \tag{1}$$

where e = emission factor, lb/veh-mi; s = silt content of road surface material, percent; and S = average vehicle speed, mph. An air pollutant emission factor developed by the EPA for open burning is expressed at 17 lb/ton (8.5 kg/MT) of refuse material burned (*8*).

Emission factors and control techniques have also been developed by a private corporation and the EPA (*9, 10*), and, to some extent, the qualitative effect of highway construction has been determined. This research evaluated emissions from both unpaved roads and construction—two sources that are of concern in this study. An emission factor of 3.7 lb/veh-mi (1.9 kg/km) for unpaved roads was used in the fugitive dust emission survey, and a factor of 1.4 tons/acre/month (0.0004 $MT/m^2/month$) of active construction was used. About 40 different commercial soil stabilization chemicals were evaluated as part of this research. The costs and control efficiencies for fugitive dust control techniques pertinent to this report are summarized from the EPA's publication as follows:

CONTROL METHOD	CONTROL EFFICIENCY (%)	COST UNIT ($)	UNIT
Paving (no curbs) 3″ bituminous surface	85	20,000-26,000	Mile
Single chip seal on prepared roadbed	50	8,500-14,000	Mile
Surface treatment with chemical stabilizers			
prepared surface	50	2,000- 3,000	Mile
unprepared surface		1,000- 2,000	Mile
worked into roadbed		5,000-12,000	Mile
Speed control	25	Negligible	
Construction site watering	50	2- 5	Acre/Day
Stabilization of cuts and fills	80	150- 400	Acre
Vegetation (hydroseeding)	65	200- 450	Acre
Chemical (vegetation)	90	100- 150	Acre

In Seattle, a fugitive dust study performed on unpaved gravel roads found that emissions ranged from 4 lb (1.8 kg)/veh to 22 lb (10 kg)/veh when speeds were from 10 mph to 30 mph, respectively (*11*). Ambient air quality sampling indicated geometric mean concentrations of 100 $\mu g/m^3$ when the recording station was under the influence of unpaved roads. Concentrations up to 3.73 $\mu g/m^3$ were found. Only unpaved roads were studied, and no data were available on construction and maintenance.

Using ZnS tracer particles, Sehmel studied particle resuspension caused by surface stresses from vehicular traffic (*12*). The particles were placed on a one-lane asphalt road. By weight, 50 percent of the particles had a diameter of 8 μ or less. The fraction of particles resuspended per vehicle passage increased with vehicle speed—greater for a drive through the tracer test area than adjacent to the test area and less with height of sampler above roadway—and was independent of wind velocities. The tracer particles do not completely simulate highway-related fugitive dust conditions or reflect type of earth, specific gravities, particle size distributions, and turbulence conditions. However, guidelines for field sampling were formulated from this work.

A study in Saskatchewan, Canada, evaluated selected dust palliatives on unpaved secondary highways with respect to ease of application, maintenance durability, effective life, cost, and performance (*13*). Calcium chloride was found to provide the most satisfactory results when compared with sodium chloride, a combination of calcium chloride and sodium chloride, emulsified asphalt, and calcium lignosulfonate.

A program for the Iowa State Highway Commission investigated means to provide low cost surface improvement and dust control on unpaved secondary roads and streets (*14*). This program evaluated 6 asphaltic products and elastomers, 5 lignosulfates and secondary additives, and 11 soil chemical additives. Although no specific cost data were presented in this report, the criterion of $5,000 per mile maximum cost was established. Paving and seal coats virtually eliminated dust concentration, but at a cost substantially greater than $5,000 per mile. During the field testing, dust emissions were reduced from 30 percent to more than 80 percent those of untreated surfaces. The greatest control of dust was achieved with MC-800 and cationic emulsified asphalts.

A recent report by the Asphalt Institute studied the emissions (referred to as "blue smoke") from hot asphalt mixing plants. Although this type of emission was specifically excluded from the current project, the results of that study are presented because they very closely parallel those achieved from the present investigation of asphalt paving and cutback asphalt application. Detailed laboratory analyses of eight samples lead to the following findings with regard to EPA standards; "Under the shrouded, concentrated sampling conditions, the amount of volatile organic hydrocarbons occasionally exceeded the 0.24 ppm limit set forth in the Ambient Air Quality Standards. . . . However, it is inconceivable that this limit would ever be reached at the "fence line" of a hot-mix asphalt plant" (*15*).

Much of the literature obtained as part of this research was a result of the survey questionnaire to air pollution control officials. This information, relating to Federal and state regulations, implementation plans, etc., is presented next under "Survey Results."

SURVEY RESULTS

The results included in this section are based on the two questionnaires described in Chapter One and presented in Appendixes A and B. The results of the first questionnaire to air pollution officials are discussed under "Regulations." The results of the various questions to the construction and maintenance officials are summarized under "Monitoring Procedures," "Construction and Maintenance Activities Producing Emission," and "Mitigation Methods Used."

The first questionnaire was completed by 47 of the air pollution offices contacted. Fifty jurisdictions provided copies of their regulations. Although only eight jurisdictions sent copies of their implementation plans, complete plans were available for inspection at the EPA's Freedom of Information Center, Washington, D.C. Specific results of this first questionnaire are included in Appendix A. With few exceptions, respondents conveyed the impression that they regard problems associated with highway construction and maintenance as minor.

Telephone contacts produced remarkably similar responses, reflecting widely shared attitudes about the problem of air pollution from highway construction and maintenance. Most officials did not hesitate to pronounce the problem insignificant, relative to other highway construction-related problems such as asphalt or concrete batching. All those contacted felt that adequate control measures are taken and that these controls are enforced by contract specifications and current state regulations. When complaints of dust nuisances are received, the cause is usually abated by informal negotiation with the offender. In most instances, air quality officials rely on personal contacts to solve problems as they arise; as reflected in the questionnaire responses, citations are rarely issued. Questions concerning new, or especially effective, control measures yielded very little response. Fugitive dust is controlled primarily by water, secondarily by calcium chloride, and occasionally by oils and other coatings. Open burning is controlled to some degree in all jurisdictions. Hydrocarbons evaporated from asphalt paving, cutbacks, and seal coats are rarely controlled.

Responses to the second questionnaire generally reflected lack of concern for air pollution problems generated by construction and maintenance. (Specific responses are summarized in Appendix B.)

Follow-up interviews both in person and by telephone with several of the respondents disclosed that officials tend more to react to nuisance complaints rather than to actively pursue prevention before complaint. As one state official put it, "We tell our contractors they can use open burning until someone complains . . . then we'll make them stop." These comments indicated an awareness of the state regulations and a further awareness that there was little threat of conviction for a possible violation. (The researchers were unable to discover a single case where a contractor was fined for creating dust.) Officials felt little legal pressure to control violations, but remained sensitive as a matter of public relations.

As explained by the EPA, Office of Air Programs, Division of Air Quality and Planning, the contribution of the highway construction industry to the attainment of the ambient air quality standards was miniscule in the context of other pollutors. The Federal EPA dust abatement model only specifies that "reasonable precautions" should be used by contractors during construction operations. This approach is taken primarily because construction is a relatively short term source of pollution. At the Federal level, the expense of a monitoring program to identify potential violations would not be justified by measurably improved air quality.

Regulations

State implementation plans do not directly affect highway construction and maintenance techniques, but establish the regulatory context in which specific regulations function. Regional air quality goals and strategies outlined in implementation plans are result oriented rather than methodological. Consequently, contractors appear to be far more influenced by traditional specifications than by state or regional goals.

As discussed in Chapter One, the two major pollutants associated with the highway construction and maintenance industry are particulates and hydrocarbons. The following is a discussion of the regulations for each pollutant.

Particulates

Particulates may be divided according to size (i.e., whether settleable or not), because such a breakdown is useful in controlling nuisance and health problems. (Further details regarding particulate characteristics as they relate to the ambient air quality standards and various health problems are given in Appendix E.) However, particulates related to highway construction are most often divided by source—process emissions, emissions from internal combustion engines, incinerators and fuel burning equipment, fugitive dust, and emissions from open burning. Fugitive dust and open burning, the principal sources of particulates studied in this report, are usually influenced by state and local standards. Process emissions are frequently governed by measurements of particulate concentrations in the exhaust gas or by measurement of the opacity of the exhaust gas—criteria not easily applied to highway construction sources.

The Federal particulate standards in Table 4 represent Federal primary and secondary ambient air quality standards for particulates that must be met by each state. These standards may be difficult to meet because of natural background and fugitive dust sources. Even in "clean" environments there are annual geometric mean concentrations of between 30 and 35 $\mu g/m^3$, which is one-half the standard (*16*). The EPA does not regulate fugitive dust, but the model offered as a guide in Part 51, Title 40, Code of Federal Regulations (see Table 5) calls for reasonable precautions to be taken to control dust and recounts standard methods of abatement.

Especially applicable to highway construction and maintenance are the EPA model requirements for the use of water and hygroscopic chemicals. The model also suggests the application of temporary surfaces to heavily used haul roads, the covering of trucks hauling materials that are liable to give rise to airborne dust, and the prompt removal of earth spilled during transportation.

The states have attacked the fugitive dust problem in four distinct ways:

1. Setting specific maximum concentrations of suspended particulates.
2. Insisting that certain abatement measures be taken, often those suggested by EPA.
3. Limiting visible emissions.
4. Limiting dustfall resulting from industrial or construction activities.

Fugitive dust and dustfall standards for each jurisdiction are given in Appendix C. A summary of the procedures employed is as follows.

States commonly employ two or more strategies in combination. Only Arkansas, Hawaii, Indiana, Kansas, and Pennsylvania have designated maximum permissible fugitive dust concentrations. Of these, Arkansas stipulates that measurements be made on the property, and Hawaii permits the inspector to choose the sampling point. Indiana, Kansas, and Pennsylvania measure at the property line, and employ a line of reasoning very prevalent among state air quality officials—namely, that polluting processes do not become their concern until a danger or nuisance is created somewhere off the premises.

TABLE 4

FEDERAL PARTICULATE STANDARDS

NATIONAL PRIMARY AMBIENT AIR QUALITY STANDARD FOR PARTICULATES:

75 micrograms/cubic meter, annual geometric mean.

260 micrograms/cubic meter, maximum 24-hour concentration, not to be exceeded more than once per year.

NATIONAL SECONDARY AMBIENT AIR QUALITY STANDARD FOR PARTICULATES:

60 micrograms/cubic meter, annual geometric mean, as a guide in assessing implementation plan progress.

150 micrograms/cubic meter, maximum 24-hour concentration, not to be exceed more than once per year.

TABLE 5

FUGITIVE DUST ABATEMENT MODEL

"Reasonable precautions can be taken to prevent particulate matter from becoming airborne. Some of these reasonable precautions include the following:

(a) Use, where possible, of water or chemicals for control of dust in the demolition of existing buildings or structures, construction operations, the grading of roads or the clearing of land;

(b) Application of asphalt, oil, water, or suitable chemicals on dirt roads, materials tockpiles, and other surfaces which can give rise to airborne dusts;

(c) Installation and use of hoods, fans, and fabric filters to enclose and vent the handling of dusty materials. Adequate containment methods can be employed during sandblasting or other similar operations;

(d) Covering, at all times when in motion, open bodied trucks, transporting materials likely to give rise to airborne dusts;

(e) Conduct of agricultural practices such as tilling of land, application of fertilizers, etc., in such manner as to prevent dust from becoming airborne;

(f) The paving of roadways and their maintenance in a clean condition;

(g) The prompt removal of earth or other material from paved streets onto which earth or other material has been transported by trucking or earth moving equipment, erosion by water, or other means."

Forty of the 53 jurisdictions surveyed in the first questionnaire stipulated working procedures to be employed to control dust. Only 7 states have adopted the Federal model without modifications, while 11 others use some portion of that model. Most frequently deleted are the requirements that dust from agricultural operations be controlled and that all roads be paved. Several officials contacted indicated that these two requirements are either politically or practically infeasible in their states. Each of the 18 states borrowing from the Federal model retains the requirements for use of water, oil, and chemicals to control dust during road-building and related activities. An additional 12 jurisdictions require that measures essentially equal to the requirements of the Federal model be taken, often with particular attention on materials handling and haul roads.

Ten states do not require specific dust abatement techniques. They demand, instead, that such "reasonable precautions" be taken as may be required to meet standards and avoid creating a nuisance, or be required by special order to an air quality official. In such cases, "reasonable precautions" may be taken to mean standard remedies, many of which are included in the Federal model.

Every jurisdiction surveyed controls the opacity of emissions from certain types of stationary sources. A number of jurisdictions apply the same control idea to fugitive emissions by prohibiting (7 states) or limiting (2 states) dust emissions beyond the property line in visible quantities. Of the latter, Illinois forbids fugitive dust across the property line in quantities visible when looking straight up, and Tennessee permits visible dust to pass the property line during 5 min/hr or 20 min/day.

Nine states set numerical limits of dustfall permitted from an activity. Hawaii, Mississippi, and Arkansas apply a single requirement statewide; New York, North Dakota, and Wyoming apply different standards in areas of different development levels. Thus, construction work in rural areas must produce less dustfall than similar work carried out in an industrial area.

Several jurisdictions require no special fugitive dust measures, in which case only the ambient air quality standard for particulates applies. Thirty-five jurisdictions require that the Federal primary and secondary standards be met. Nine are more stringent, requiring that the Federal secondary standards be achieved and maintained as primary standards. Other jurisdictions apply particulate standards more stringent than Federal primary standards, but not the same as Federal secondary standards. It is within the context of these standards that particulate control regulations have been devised.

Land clearing operations are inseparable from highway construction. Vegetable wastes generated during land clearing may be burned in 40 of the jurisdictions surveyed, but conditions placed on such burning vary widely (see Appendix D). Most jurisdictions permit burning on-site only those materials removed from that site, and most specifically prohibit the burning of tires, heavy oil, or other smoke-producing materials. Eleven states permit burning only when other practical means are unavailable. A variety of other conditions may be placed on burning operations. Many states permit burning only in rural locations and when wind and other meteorological parameters are favorable to avoid fire or safety hazards. Eight jurisdictions permit burning only within periods of the day when dispersal conditions are good. Only four states are specific about the method to be used; they recommend stacking and the use of air curtain destructors to encourage complete combustion.

Several states—including Montana, South Carolina, and Virginia—have adopted a requirement that merchantable wood products be salvaged during right-of-way clearing operations.

The EPA's model for control of air pollution episodes is copied by many states (*17*) (see Table 6). The Federal model provides an objective guide to the seriousness of pollutant accumulations, and suggests tactics to reduce such build-up. An "air pollutant forecast" is declared within the state Department of Air Pollutant Control when the National Weather Service advises that stagnant atmospheric conditions are foreseen. The Federal model outlines criteria for three levels of public warning; "alert," "warning," and "emergency" may be declared as actual air pollutant levels increase. This standard three-stage criterion is used as a basis for comparison in Table 6. To counter such pollutant accumulations, certain sources may be required to curtail or suspend operations until the episode is officially terminated. Under the provisions of the Federal episode model, contract construction work may be suspended at the "emergency" level of alert; this provision is included in many state episode control plans as well.

Hydrocarbons

There is much less variety in standards applied by jurisdictions to hydrocarbon emissions than to particulate emissions. As may be seen from Table 7, the Federal primary and secondary ambient air quality standard—160 $\mu g/m^3$, maximum once-yearly 6 to 9 a.m. concentration—is simply affirmed by most jurisdictions, with four states applying a stricter standard (*4*). The Federal standard is set only as a guide to achieving oxidant standards. For this reason, and because harmful hydrocarbons are predominantly a product of internal combustion engines, only a few jurisdictions have devised control standards for organic materials in the quantities used in highway construction and maintenance. As indicated in Table 8, 18 jurisdictions control evaporation of nonphotochemically reactive organics. Of these, 11 jurisdictions require control measures for tanks of 3,000-gal (11,500-liter) capacity or less. Thirteen states set specific limits on the amount of such organics that may be permitted to evaporate from a construction or maintenance site each day.

No indication was given by any of the air quality officials interviewed that this latter requirement is enforced on highway construction sites. There appears to be no mechanism for judging the rate of solvent evaporation and thus no way of applying such standards in the field. No standard exists that would limit evaporation hydrocarbons measured at the property line or elsewhere.

State air quality officials show little interest in the problem of highway construction-related hydrocarbons. Any discussion of such hydrocarbons invariably focusses on automotive emissions as being overwhelmingly more significant.

TABLE 6

BREAKDOWN OF STATE AIR POLLUTION EPISODE CONTROLS

Respondents	No Regulations Received	No Provision Found In Regulations Received	Standard Three-Stage Criterion Or Better	Specific Reference To Federal Model	Additional Control Measures
Alabama			X		
Alaska			X		
Arizona			X		X
Arkansas		X			
California		X			
Colorado		X			
Connecticut			X	X	X
Delaware			X		X
Washington, D.C.					X
Florida			X		X
Georgia			X		
Hawaii			X		
Idaho			X	X	X
Illinois			X	X	X
Indiana			X	X	
Iowa			X	X	X
Kansas			X	X	X
Kentucky			X	X	X
Louisiana			X	X	X
Maine		X			
Maryland			X	X	X
Massachusetts			X	X	
Michigan			X		X
Minnesota		X			
Mississippi			X	X	X
Missouri			X	X	X
Montana		X	X	X	
Nebraska			X	X	X
Nevada	X				
New Hampshire			X	X	X
New Jersey			X	X	X
New Mexico			X	X	
New York		X			
North Carolina			X	X	X
North Dakota			X	X	X
Ohio		X			
Oklahoma		X			
Oregon			X	X	X
Pennsylvania			X		X
Puerto Rico					X
Rhode Island			X	X	X
South Carolina			X	X	X
South Dakota			X		
Tennessee			X	X	
Texas			X	X	X
Utah			X		
Vermont					X
Virginia			X	X	X
Virgin Islands			X		
Washington			X	X	
West Virginia			X	X	
Wisconsin			X	X	X
Wyoming			X		

Monitoring Procedures

The survey investigated the monitoring and enforcement of construction activities as they relate to the attainment of the ambient air quality standards. A review of Appendix A shows that questionnaire responses on monitoring were diverse and inconclusive. The frequency of monitoring programs varies from random to daily. The monitoring of particulates created by highway construction is done by a variety of official bodies with a majority being performed by either the state Department of Transportation or the state environmental protection agency. Surveillance methods as found in the questionnaire responses generally include just visual examinations.

Monitoring authorities command many different types of enforcement provisions—including fines, notices, criminal penalties, hearings, and permit revocations. There is as little consistency among the states in the handling of a potential violation as there is in identifying a violation.

Many of the air pollution officials responded to the survey by citing the number and frequency of violations of the ambient air quality standards. These numbers were generally quite nominal. However, 6 states listed violations ranging from 36 to 120 per year—an extraordinary number compared with the average. And yet no violations or citations could be identified that resulted in conviction of the violator.

Construction and Maintenance Activities Producing Emissions

The survey suggested 31 operations likely to produce fugitive dust under the 4 major headings of earthwork, paving, bridge construction, and miscellaneous activities (see Appendix B). Respondents were also encouraged to list additional operations. A subjective ranking of each operation from "no problem" to "occasional complaint" to "severe problem" was requested. By assigning values of 1 to 3 in the order of severity (3 indicating no problem), weighted averages for each operation were obtained.

Of the 10 earthwork operations listed, "hauling on unpaved roads" (2.1) and "traffic on dirty roads" (2.2) were listed as producing the greatest amounts of dust, followed by "wind erosion" (2.3) and "excavation" (2.5).

Of the 11 categories listed under paving operation, "hauling over unpaved roads" (2.1) received the same relative ranking as it did under the earthwork operation. "Sweeping" (2.4) associated with paving was found to be less objectionable in the amounts of dust produced.

Bridge construction operations were not considered significant contributors to the emission problem. Among several miscellaneous operations presented, "maintenance sweeping" (2.3) was felt to be a relatively large dust producer.

The research survey results are consistent with impressions gained from many independent professionals in the construction industry. The dust problem created by traffic on soil-covered roads during all phases of construction and maintenance is certainly worse than that of any other operation.

TABLE 7

STANDARDS FOR CONTROL OF HYDROCARBON EMISSIONS

National Primary and Secondary Ambient Air Quality Standard for Hydrocarbons.

The hydrocarbons standard is for use as a guide in devising implementation plans to achieve oxidant standards.

The national primary and secondary ambient air quality standard for hydrocarbons corrected for methane, is:

160 micrograms per cubic meter

(maximum 3-hour concentration, 6-9 a.m., not to be exceeded more than once per year).

Jurisdictions Accepting This Standard:

Alabama
Alaska
Arizona
Arkansas
California
Colorado
Connecticut
District of Columbia
Florida
Georgia
Idaho
Illinois
Indiana
Iowa
Kansas
Kentucky
Louisiana
Maine
Maryland
Massachusetts
Michigan
Minnesota
Mississippi
Missouri
Montana
Nebraska
Nevada
New Hampshire
New Jersey
New Mexico
New York
North Carolina
North Dakota
Ohio
Oklahoma
Oregon
Pennsylvania
Puerto Rico
Rhode Island
Tennessee
Texas
Utah
Vermont
Virginia
Virgin Islands
Washington
West Virginia
Wisconsin
Wyoming

Jurisdictions Applying Different Standards:

Delaware

131 ug/m^3 (maximum 3-hour concentration, 6-9 a.m., measured as carbon)
196.5 ug/m^3 (maximum 3-hour concentration, 6-9 a.m., measured by volume)

Hawaii

100 ug/m^3 (maximum 3-hour concentration, during any 3-hour morning period)

South Carolina

130 ug/m^3 (maximum 3-hour concentration, 6-9 a.m.)

South Dakota

125 ug/m^3 (maximum 3-hour concentration, 6-9 a.m.)

Mitigation Methods Used

An approximate proportion of reliance on each mitigant was estimated by the respondents; however, since detailed back-up information was seldom available, the data cannot be considered precise (see Appendix B).

It was found that 54 of 55 respondents used watering as a dust mitigant some of the time; 6 states used watering all of the time. The total respondent usage rate for water was more than 80 percent of the time. About 30 percent of the states used a combination of water and calcium chloride.

Mixing types of asphalt emulsions were employed by 11 respondents about 7 percent of the time. The remaining 9 mitigants, comprised mostly of various asphalt products, were applied by 60 percent of the respondents about 20 percent of the time. Seven of these products were used in only one responding state each.

Watering is the most widely used mitigant, probably because it is the least costly, it is the easiest to apply, and the secondary pollution effects are most controllable. Also, water can be employed on short notice and can produce instant and obvious results.

However, water is perhaps the least effective mitigant because its effect is temporary. This creates a tendency to overwater, which produces mud and causes the soil to be continually tracked away from the construction site, thereby spreading the problem. As the length of construction time is increased, the soil is tracked still further from the site and, consequently, the potential for dust pollution is greatly extended.

The allaying of dust is paid for in one of three ways: a lump sum item may cover all temporary pollution control; no separate payment may be made, but the contractor is expected to distribute the cost in all other items of the contract; or each pollution control item may be paid for separately.

Many jurisdictions such as Virginia, West Virginia, Connecticut, and the New Jersey Turnpike Authority have included in their contract specifications separate pay items for watering. More efficient dust control often results because the contractor is offered monetary incentive to place water. Opponents of this method, however, charge that it is too difficult to measure the quantity of water placed. During the 1971 New Jersey Turnpike Widening project, the cost of dust abatement procedures, where watering was paid for separately, accounted for more than 0.5 percent of the project construction cost of about 50 million dollars. On the other hand, recent projects in West Virginia and a percentage of construction cost range from 0.1 percent to 0.4 percent. Both used a factor of 2 gal/yd^3 of earthwork for estimating purposes.

The survey indicated that, although many states utilize calcium chloride as a dust palliative, most use it as a secondary or back-up method. The criteria for use of calcium chloride are seldom clearly specified, and are usually left to the discretion of the resident engineer.

Calcium chloride is generally used for more permanent dust abatement, such as on haul roads or for slope stabilization. It has been reported by construction personnel on New Jersey Turnpike projects that, when calcium chloride is used on pavement prior to rain, the surface becomes very slippery. With sandy soil conditions, rain may wash away the calcium chloride. On well-compacted, unpaved haul roads or access roads, however, calcium chloride has been reported effective (*13*). Both weather and traffic weigh heavily on the efficiency of this mitigant.

Lastly, many states use various asphalt products ranging from emulsions to cutbacks. As with calcium chloride, the location and time of their use are not clearly defined in most contract specifications. They are most often used for long-term installations because of the high initial cost. Emul-

TABLE 8

HYDROCARBON CONTROL METHOD REGULATIONS

Respondents	Accept Federal Standards	Include Control Measures	Control Measures Relating to Small Tank Storage or Transfer[1]	Limit Amount Allowable Discharge[2]
Alabama	X	X	X	X
Alaska	X			
Arizona	X	X	X	X
Arkansas	X			
California	X			
Colorado	X	X		X
Connecticut	X	X	X	X
Delaware				
Washington, D.C.	X			
Florida	X			
Georgia	X			
Hawaii		X	X	
Idaho	X			
Illinois	X			
Indiana	X	X	X	X
Iowa	X			
Kansas	X	X		
Kentucky	X	X	X	X
Louisiana	X	X	X	X
Maine	X			
Maryland	X	X		X
Massachusetts	X	X		
Michigan	X			
Minnesota	X			
Mississippi	X			
Missouri	X			
Montana	X			
Nebraska	X			
Nevada	X			
New Hampshire	X			
New Jersey	X			
New Mexico	X			
New York	X			
North Carolina	X	X		X
North Dakota	X	X	X	X
Ohio	X			
Oklahoma	X	X	X	X
Oregon	X			
Pennsylvania	X			
Puerto Rico	X			
Rhode Island	X			
South Carolina				
South Dakota				
Tennessee	X			
Texas	X	X	X	X
Utah	X			
Virginia	X	X	X	X
Virgin Islands	X	X		
Washington	X			
West Virginia	X			
Wisconsin	X	X	X	X
Wyoming	X	X		

[1] Tanks of 3000 gallons or less.

[2] From highway construction or maintenance activities.

sions have been reported as successful mitigants on embankment slopes where a crust is formed on the soil, thus preventing wind erosion. Various cutbacks have been efficiently used on haul roads and access roads that remain in use for long periods of time. The Iowa State study discusses extensive tests that were performed on secondary roads that seem applicable to a haul road situation (*14*).

Only three states responded positively to the question requesting information on any experimental methods being used, and these indicated the use of commercial petroleum resin products. Although new products are known to exist, very little research other than that in Iowa and by the EPA could be identified that evaluated the performance of various mitigants.

There are additional methods of dust mitigation in the highway construction and maintenance industry that were not evaluated by the survey. For example, some construction equipment today is designed to reduce the dust raised during operation. Jackhammers, rock drilling equipment, mechanical sweepers, and other similar devices have been fitted with hoods, vacuum systems, and water hoses that are intended to reduce dust. Conveyor systems and pipelines (hydraulic fill) are used in lieu of trucks for hauling materials over long distances. Air curtain destructors, as shown in Figure 6, have been employed quite successfully to reduce the smoke and particulates created by the open-burning process (*18, 19*). This device passes a curtain of air downward over a fire within a deep, narrow trench about 20 to 40 ft (6 to 12 m) long. This recirculates smoke and flying ashes back through the fire while furnishing a forced draft. The resultant fire is extremely hot, and nearly complete combustion is achieved.

Air curtain destructors have been most successfully employed in Pennsylvania. Soon after the state placed a "no burning" edict on construction projects, cost increases for "clearing and grubbing" work (which included the disposal of previously burned materials) were between 30 and 700 percent for a series of five projects. Experimentation with the air curtain destructor found that it increased both the speed and efficiency of burning, and the cost of the device approximately equalled the labor saved in the burning operation. Hence, it was found that no increase in the normal contract bid price is necessary through use of the air curtain destructor.

Both landfill disposal and chipping have been successfully employed as alternatives to open burning. Two of the most successful methods of reducing dust are speed control on haul roads and rerouting traffic from the area of construction.

Construction officials responded during interviews and on the questionnaire that their construction specifications seemed to adequately cover any potential air pollution problems resulting from construction operations. Most of the specifications reviewed direct the contractor to comply with the existing air pollution regulations, thereby placing all responsibility with the contractor. Two of the states require the submission to, and acceptance by, the client of proposed pollution control plans prior to construction. This plan must be coordinated with the over-all construction schedule. Two items required in this plan by Nevada are

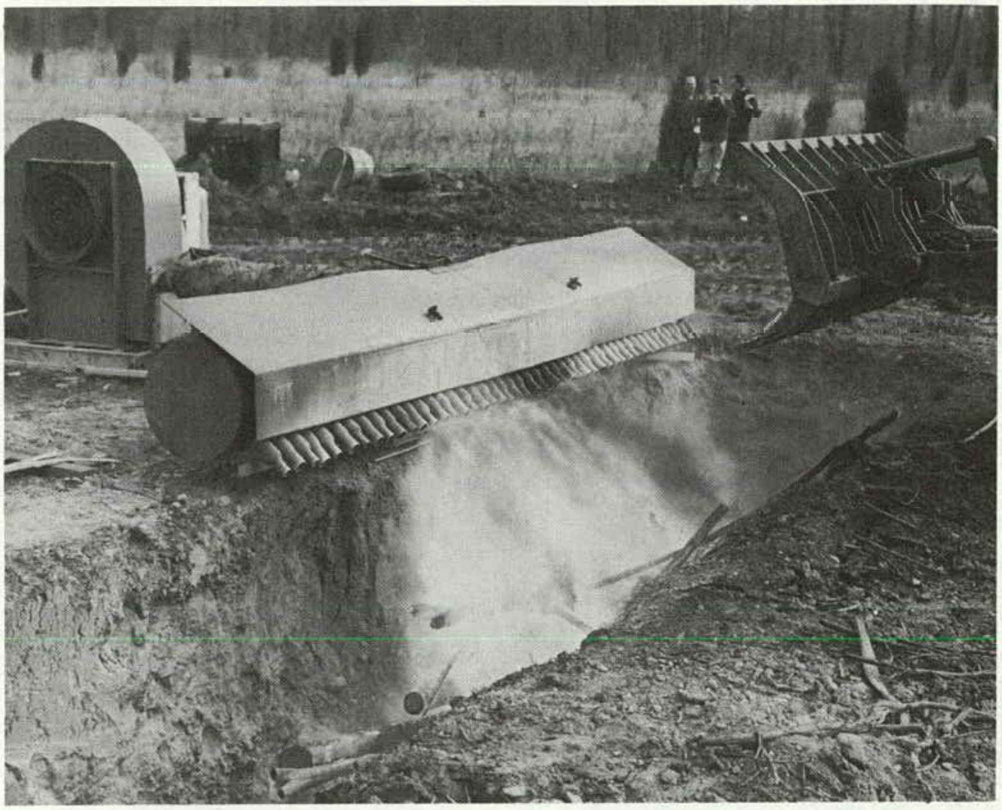

Figure 6. Air curtain destructor.

that dust palliatives be placed on all completed embankment and excavation areas and that a maximum erosible area be set at 750,000 ft² (70,000 m²). Some states restrict the vertical exposed area of an excavation or embankment slope. Prior to continuation of work, this slope is seeded to prevent erosion and potential air and water pollution.

Cost comparisons of various dust mitigation methods have not been made as part of this study. There are too many variables involved in each circumstance requiring dust mitigation to fairly evaluate comparative costs. For example, it is certainly the best approach, from a minimization of dust aspect, to pave a haul road; however, if the total environmental impact of the situation is evaluated, watering may be the "best" solution.

Reference is made to the "Literature Review" section of this report for further discussion of cost studies previously performed.

FUGITIVE PARTICULATE TEST RESULTS

During the period from April 10, 1974 through August 2, 1974, 151 samples were collected at the 14 locations delineated in Table 2. The sampling data taken during the testing program at projects in Orlando Fla., Richmond Va., and Newark N.J. are summarized in Tables E-2 through E-15. These data included concentration, physical location, average wind speed and direction, construction activity, and general meteorology. The general meteorology data were obtained from the National Weather Service and are listed in Tables E-16 and E-17.

The range of concentrations varied from 28 $\mu g/m^3$ to 1400 $\mu g/m^3$ under various meteorological conditions, source influences, and physical locations, except in the jackhammer operation in Newark N.J., when concentrations reached 16,670 $\mu g/m^3$.

In order to determine if a specific source caused a certain ambient air influence, one of two methods was used. In the first method, the distance between a major source of particulate matter and the receptor was evaluated. Since no such source existed in the vicinity of the sampling site, no exceptional ambient air influence was found.

The second method of source identification was microscopy. Figures E-41 through E-52 are reports of the particles found in High Volume samplers in the vicinity of the project. Comparisons with samples of the road base material support the conclusion that the High Volume samplers were influenced to a major extent by highway construction.

Table 9 is a complete statistical summary of the particulate concentration data obtained from the 14 sampling locations. Geometric means, geometric standard deviations, distances, and numbers of large concentrations are included.

As described earlier, the standards compared are the Federal primary and secondary air quality standards for particulate matter. These standards have both a 24-hr average (not to be exceeded more than once per year) and an annual geometric mean. The comparative values for this testing are 260 $\mu g/m^3$ maximum 24-hr concentration for the primary standard and 150 $\mu g/m^3$ for the secondary standard.

The average of all data obtained (not including that for the jackhammer operation) is 216 $\mu g/m^3$. The number of values required for a valid annual geometric mean under

TABLE 9

PARTICULATE CONCENTRATION DATA ANALYSIS

Sample Location	Sample Height (ft)	No. of Samples	Geometric Mean (µg/m3)	Geo. Std. Deviation	Distance From Edge of Road	Distance From Const. Activities	No. Values Greater Than 150 µg/m^3	No. Values Greater Than 260 µg/m^3
#1	3.5	5	801	1.53	43	5	5	5
#1	10.1	7	521	1.65	43	5	7	6
#2	3.5	6	580	1.88	46	19	5	5
#2	10.1	7	249	1.94	40	13	6	3
#3	3.5	22	109	1.53	51	78	6	0
#3	10.1	23	100	1.54	60	86	4	0
#4	3.5	5	109	1.53	83	109	1	0
#4	10.1	5	89	1.53	86	112	1	0
#5	3.5	2	63	1.34	22	85	0	0
#5	10.1	2	51	1.1	22	85	0	0
#6	3.5	6	221	1.85	64	16	6	1
#6	10.1	7	146	1.39	66	18	2	1
#7	3.5	4	55	1.55	206	232	0	0
#7	10.1	3	63	1.33	198	224	0	0
#8 FR*	3.5	3	52	1.57	39	65	0	0
#8 FR*	10.1	2	94	1.11	42	68	0	0
#8 BK*	3.5	4	58	1.89	83	109	0	0
#8 BK*	10.1	2	97	1.10	86	112	0	0
#9 FR*	3.5	9	127	2.12	30	56	2	1
#9 BK*	3.5	8	88	1.99	64	90	2	1
#10	3.5	5	169	1.19	44	23	3	1
#11	3.5	3	328	1.01	7	--	2	2
#12	3.5	5	454	1.00	80	14	5	4
#13	3.5	4	---	----	--	--	4	3
#14	3.5	2	---	----	--	--	2	1

* FR = Front Location; BK = Back Location ** DPC Data

TABLE 10

AMBIENT STATISTICAL ANALYSIS

State-Area:10-3280 ; Florida ; Orange County
State:Florida Pollutant:Total Suspended Particulate Method:Hi-Vol Gravimetric Period 73/ 1/ 1 To 73/12/31
Location:Orlando Sampling Interval: 24 Hours Units:Micrograms/Cubic Meter

			Percentiles												
Site* Num	Num Obs	Min Obs	10	30	50	70	90	95	99	99.9	Max Obs	Arith Mean	Std. Dev	Geom Mean	Geom Std
3	21	32.6	42.0	59.4	71.4	78.7	104.0	138.6	141.4	141.4	141.4	73.06	28.57	68.22	1.46
3	5	40.8	40.8	44.0	72.6	76.1	83.4	83.4	83.4	83.4	83.4	63.38	19.58	60.75	1.40
4	28	38.8	38.8	57.0	63.7	69.7	86.4	87.1	124.3	124.3	124.3	63.10	19.69	60.26	1.36
4	9	33.4	33.4	41.6	44.9	44.9	55.2	55.2	55.2	55.2	55.2	43.52	7.08	43.00	1.18

* Site 4-595 N. Primrose
3-West Central and Parramore

Source: Reference #16

Richmond Virginia and Newark, New Jersey Area

Location	No. Obs.	Min Value	Percentiles 10	30	50	70	90	95	99	Max Value	Arithmetic Mean	Arithmetic Std. Dev.	Geometric Mean	Geometric Std. Dev.
Richmond-002	16	49	56	64	72	79	99	137	137	137				
Richmond-003	33	29	40	58	69	83	101	116	119	119				
Newark-001	29	23	37	52	73	82	99	124	137	137	71	25.29	66	1.48
Newark-003	54	43	78	115	144	172	206	253	285	285	144	53.58	134	1.49
Jersey City-001	29	30	36	57	84	91	122	123	168	168	78	31.36	72	1.53
Jersey City-003	53	33	52	67	84	102	135	141	232	232	89	34.13	83	1.45
Jersey City-004	58	27	47	60	75	98	128	133	149	149	81	30.77	75	1.47

* Source: Air Quality Data - 1972 Annual Statistics, Environmental Protection Agency, March 1974.

ambient concentrations (*20*) is 61. By using a weighted average between the fugitive dust samples and the normal ambient average of particulate matter in the Orlando area from Table 10 with the following relationships, a time of construction versus annual geometric mean can be predicted (*16*). Thus,

$$\sigma_g = e^{\{1n^{0.5}[(\sigma^2/\mu^2)+1]\}} \qquad (2)$$

$$\mu_g = \frac{M}{e(0.5\ 1n^2\ \sigma_g)^2} \qquad (3)$$

where σ = the standard deviation, μ = the arithmetic mean, σ_g = the geometric standard deviation, μ_g = the geometric mean, and M = time in months.

Figure 7 shows a result of these calculations. As can be seen, after 2 months of highway construction it is predicted that the annual geometric mean primary and secondary standards would be exceeded. In order to validate this prediction, the data from site #3 (3.5-ft sampler) was chosen for comparison because the length of time for this site was almost 2 months. If, at the end of 2 months, highway construction stopped at site #3, it would be expected that values would be similar to ambient air as measured for Orlando in 1973. Following the previously described analysis, the predicted annual geometric mean would be 80 µg/m^3, which compares favorably with the observed 75 µg/m^3.

Particle Size

Particle size data were taken during 9 sampling intervals. From these data, log normal probability plots were made. From these plots, shown in Figures E-32 through E-40, the mean (geometric) particle size and standard geometric deviation were calculated.

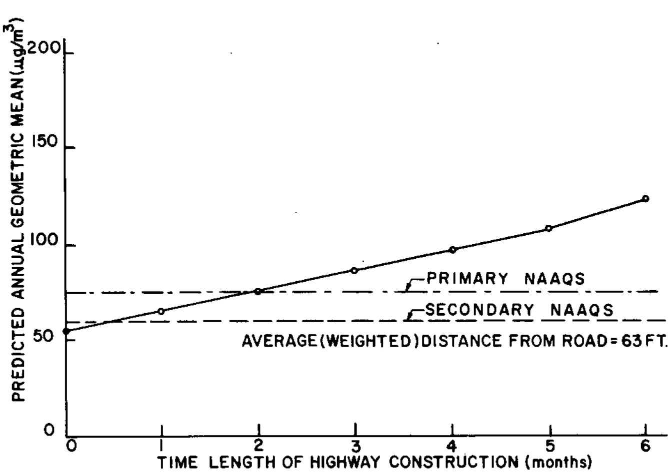

Figure 7. Predicted annual geometric means vs. time length of highway construction.

Table 11 is a statistical summary of the particle data collected. For these data, the average mean particle size was 5.3 µ and standard geometric deviation was 2.29. The resultant particle size distribution is shown in Figure 8. (Microscopic examination verifies this particle size range.)

The soils in the area of the Florida testing sites can generally be classified as sandy. The material in the area of the Virginia construction sites consisted of about 20-percent to 30-percent clay. Lastly, the jackhammer operation in New Jersey created very fine concrete dust particles.

The relationship of mean particle size versus concentration is shown in Figure 9. Normal mean particle sizes in urban environments center around 1 μ (*21*). It can be seen from Figure 9 that, as concentrations approach normal urban concentrations, the particle size decreases.

The particle size standard geometric deviation has significance in determining source influence. Figure 10, developed from test data, is an analysis (by least squares) of the standard geometric deviation as a function of concentration. The lower the standard geometric deviation, the lower the influence from other sources, because generally a source emits particulates within a certain range. Thus, the resultant negative slope indicates the influence of highway construction with high concentrations.

Another indicator of source influence is shown in Figure 11. Here, it can be seen that, as the distance from the source increases, the standard geometric deviation increases towards normal ambient concentrations.

As a result of the particle size analysis it can be concluded that highway construction dominates the air quality in the vicinity of such activities.

Meteorological Influence of Fugitive Dust Concentrations

Three meteorological parameters influencing particulate matter concentrations are wind speed, wind direction, and precipitation. In a review of the data for concentrations at various wind speeds, no distinct correlation was noted. Wind speeds occur generally within a narrow range, and any definite conclusions concerning wind speed versus concentrations may be erroneous.

Wind deviation, on the other hand, was observed to have a definite relationship to particulate matter concentrations. Wind direction data taken along with particulate matter samples were analyzed and averaged over a 24-hr period. All values for wind direction and concentrations were used to determine frequency of values greater than 100 μg/m³ at different degrees from the roadway (see Fig. 12). The value of 100 μg/m³ was chosen because the highest ambient concentration observed in the Orlando area during sampling was 99 μg/m³. No ambient data were available for the Virginia or New Jersey sites.

The results shown in Figure 12 indicate that the chart readings of wind direction may be biased as have been found by the National Weather Service (*22*). Because data were analyzed as directional—using N, NNE, NE, etc.—the tendency to introduce human error by recording the 8 principal directions (N, NE, E, etc.) rather than the secondary directions (NNE, ENE, etc.) would occur if the principal frequencies exceed the secondary ones by 10 to 20 percent. A procedure for removing the biased result is discussed in Appendix E.

The highest frequency of values greater than 100 μg/m³ occurs at 67.5° from a straight-line direction from sampler to the road. This is what would be expected because the source of fugitive dust is a line source. A straight line from source to sampler (90° deviation) would not allow reinforcing of concentrations by all sources along the line source, whereas an angle of deviation around 67.5° would allow the "addition" of concentrations downwind (provided the distance from the source to the sampler is within the area affected by the source).

TABLE 11

PARTICLE SIZE ANALYSIS

Sample Date	Mean Particle Size (microns)	Std. Geo. Deviation	Sample Height (ft)	Sample Distance (ft)	Sample Concentration (μg/m³)
4-10-74	7.5	1.93	3.5	5	1103
4-13-74	6.3	1.85	3.5	19	1255
4-17-74	5.3	1.89	10.1	13	155
5-1-74	4.9	1.71	10.1	86	158
5-31-74	5.9	2.63	3.5	51	197
6-20-74	4.8	2.71	3.5	51	94
6-30-74	3.7	2.16	3.5	30	66
7-10-74	4.5	3.00	3.5	30	85
7-18-74	4.9	2.76	3.5	30	135

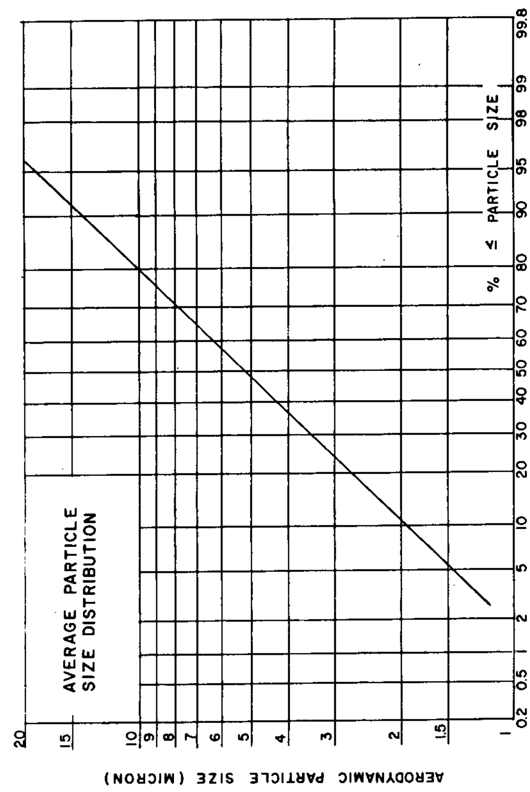

Figure 8. Average particle size distribution.

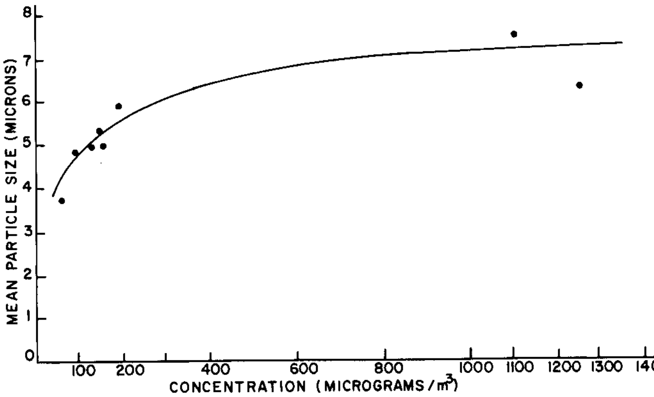

Figure 9. Mean particle size vs. concentration.

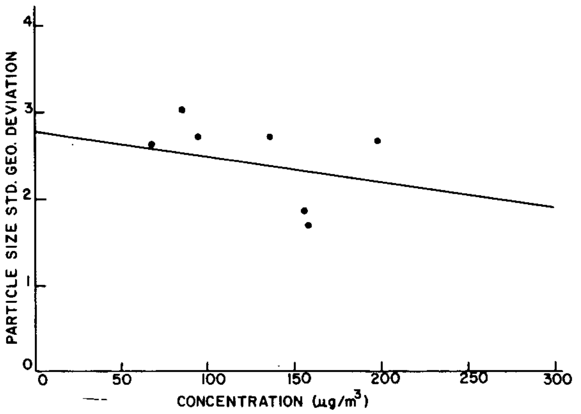

Figure 10. Particle size standard geometric deviation vs. concentration.

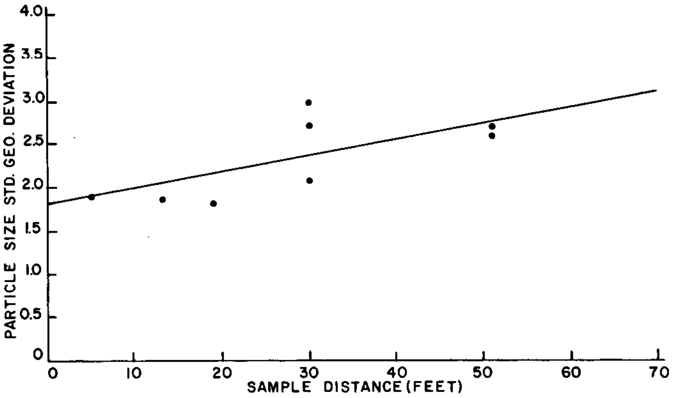

Figure 11. Particle size standard geometric deviation vs. sample distance.

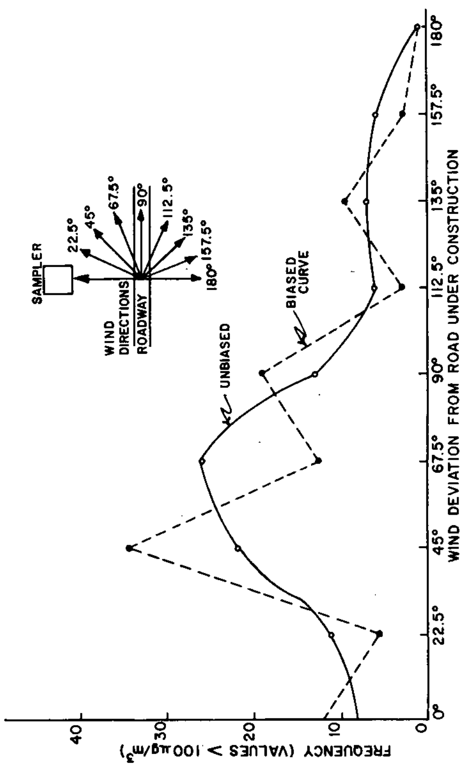

Figure 12. Concentrations greater than ambient vs. wind deviation.

The influence of precipitation was also analyzed. During the total of 132 samplings for the particulate matter summarized in Tables E-2 through E-15, rain fell to some extent during 70. The geometric mean of all values taken when rain fell was 99.5 μg/m³. For samples when no rain occurred, the geometric mean was 212.5 μg/m³. To ensure no bias in these results, the sampler height was taken into account. Fifty-three percent of the "rain" concentrations and 52 percent of the "no-rain" concentrations were taken at 3.5 ft (1 m). Also, the average weighted sampling distances were 59 ft (18 m) and 65 ft (20 m), respectively, for "no rain" and "rain" concentrations.

From the foregoing analysis, an estimated 53.2-percent reduction may be expected during rainfalls. This is similar to the 50-percent control expected for construction site watering; however, because rain applications are more intense, no conclusions can be made (*9*).

Influence of Construction Activities on Fugitive Dust Concentration

During the period of sampling many types of construction activities took place, as can be seen from Tables E-2 through E-15. Since the data were not sufficient to have confidence in the analyzed values, the analysis of all data was based on whether construction activities occurred with traffic or if traffic was the only source. In addition, the influence of precipitation was used to limit any bias.

The results summarized in Table 12 are based on the data from the 14 sampling sites presented in the tables noted earlier.

Of the data obtained, 60 percent had traffic, but no construction activities in the general area. Construction activities occurred with traffic for 40 percent of the data points. A minimum of 20 values was used in the determination of the geometric mean.

Precipitation, as noted previously, does have significant influence in reducing concentrations. The major influence in the concentrations observed without rain was due to traffic since ambient concentrations observed in Orlando are around 60 μg/m³.

The sand, limestone, and other road base material spilled and tracked on the roadway would be considered the major source of emissions.

Area of Impact of Highway Construction

The area of impact can most readily be determined by analyzing the concentrations presented in Tables E-2 through E-15 as a function of distance from the source. Also, the variations of concentrations with height can be an indication of the settleability of the fugitive particulates.

The geometric mean concentrations as a function of distance from construction and roadway were analyzed for the foregoing data and are plotted in Figures 13 and 14. The plots indicate that the air quality impact is markedly reduced by distance over 50 ft (15 m). Concentrations at greater distances approach the 60 μg/m³ ambient urban "background" concentrations for Orlando in 1974. In 1972, the average of urban particulate concentrations was 82 $\mu g/m^3$ (*2*).

To evaluate the effects of distance on short-term 24-hr values, values greater than the air quality standard were plotted as a function of distance from construction (Figs. 15 and 16). It is noted from Figure 15 that it is unlikely that the 24-hr Federal primary air quality standard of 260 $\mu g/m^3$ would be exceeded at a distance of 50 to 150 ft (15 to 45 m) with normal ambient concentrations of about 60 $\mu g/m^3$. Under similar conditions, the Federal secondary standard of 150 $\mu g/m^3$ would be exceeded at distances of 100 to 250 ft (30 to 75 m) from construction activities. Although actual distances of dust dissipation are difficult to establish because of the variables having a direct effect thereon, it is clear that the dust in potential violation of the ambient standards settles out very quickly.

Testing at sampling location 9 (see Table E-10) included simultaneous samples at different distances. An analysis of the results shown in Figure 17 shows the intersection of the regression line with the determined natural background concentrations (i.e. concentrations not influenced by man). In addition, a decrease of 45 percent is effected by increasing the distance about 34 ft (10 m).

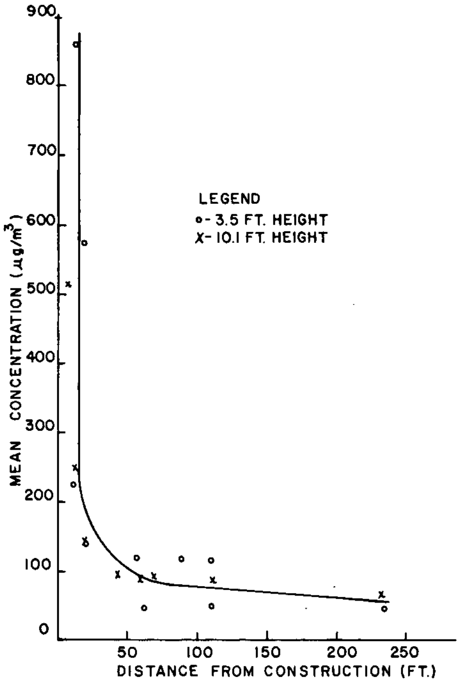

Figure 13. Geometric mean concentration vs. distance from construction.

TABLE 12

GEOMETRIC MEAN CONCENTRATION ($\mu g/m^3$)

	With Rain	Without Rain	Total
Construction	119	257	184
No Construction	87	177	142

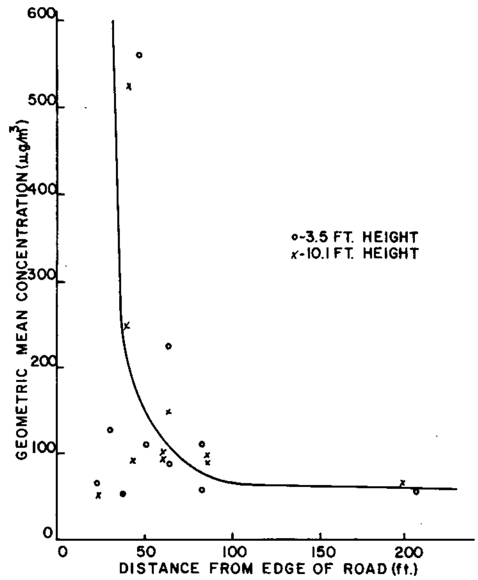

Figure 14. Geometric mean concentration vs. distance from edge of road.

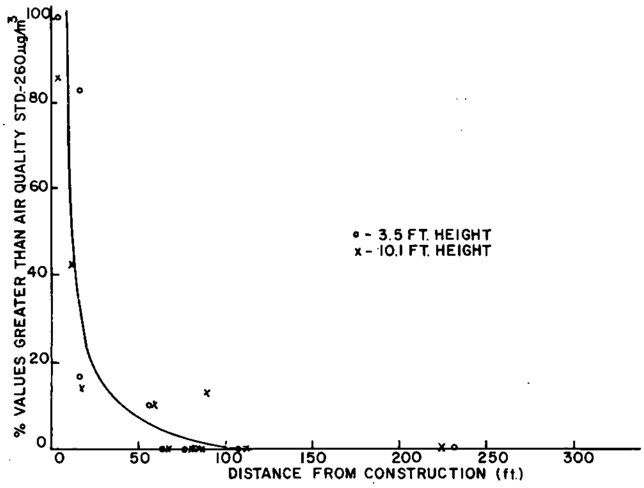

Figure 15. Violations of primary standard vs. distance.

Results of analyzing the effects of sample height are shown in Figures 18 and 19. Figure 18 shows the relationship obtained from individual samples taken at 10.1 ft (3 m) and 3.5 ft (1 m) during the same time period. The slope of 0.521 would indicate that a large portion of the particulate matter would be settleable. Concentration differences normally encountered in urban ambient air at such heights are not as large (*23*).

The geometric mean concentrations for the 3.5-ft (1-m) sampler and the 10.1-ft (3-m) sampler are plotted in Figure 19. The curve drawn is as expected—that is, the higher the sample, the nearer to "normal" ambient air concentrations; and the lower the sample, the nearer to collecting heavy concentrated particulate matter.

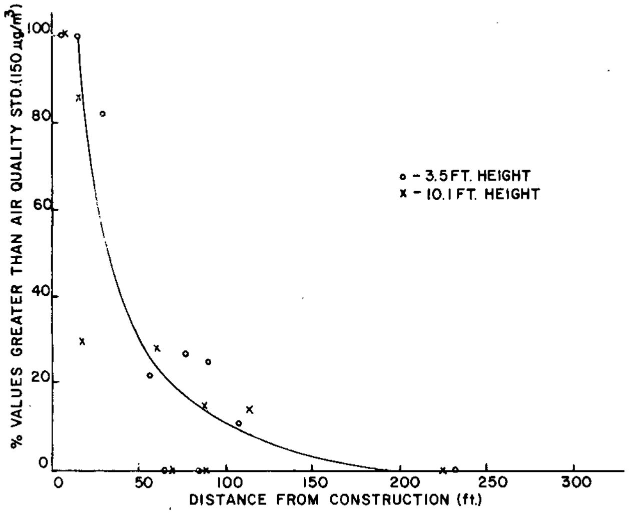

Figure 16. Violations of secondary standard vs. distance.

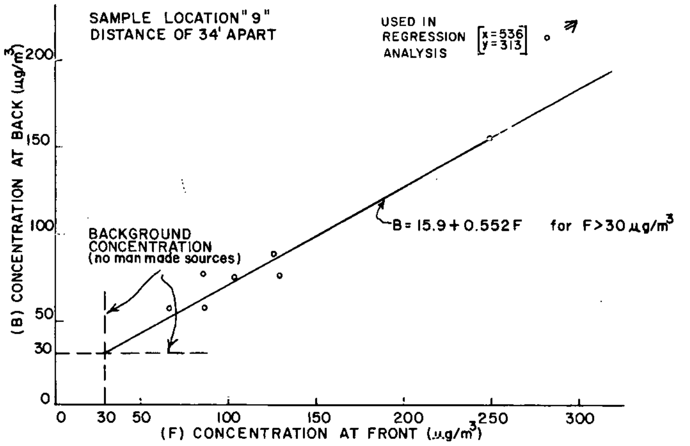

Figure 17. Concentration differences between two samplers 34 ft apart.

Consideration of the high readings obtained adjacent to the jackhammer operations (see Table E-14) points up that, although the particulates dissipate rapidly, the concern for the worker must not be ignored in many cases. This responsibility falls within the jurisdiction of the Division of Health, Occupational Safety and Health Administration (OSHA) (*24*). OSHA applies specific standards to the exposure of workers for certain particulates at construction sites. Dust at each site is analyzed by OSHA for content of certain minerals—including silica, mica, soapstone, fibrous talc, graphite, and coal dust. Airborne dusts containing certain proportions of these minerals must not be breathed by workers in greater than specified concentrations, averaged over an 8-hr day. Typically, the cumulative exposure from 8-hr work shift for total inert or nuisance dust would be 15 mg/m³. This can be compared to the NAAQS secondary standard for particulates of 150 µg/m³ for a 24-hr period. The OSHA controls are therefore less restructive by a factor of about 100. This is justified because the OSHA regulations are based on the effect on healthy workers involved in 8-hr shifts as opposed to EPA regulations, which concern the general public and the spectrum of health situations covered 24 hr per day.

Control Measures

A small portion of the testing, as will be shown, was performed during periods of site watering. Although site watering was beneficial, it appeared to be neither long lasting nor a solution to the fugitive particulate problem. At sampling location 2, watering was used and compared to a similar day when no water was used. The fugitive particulate was reduced from 551 µg/m³ to 457 µg/m³ at a sample height of 3.5 ft (1 m) for a 17-percent reduction. Other site watering led only to the conclusions that the reduction of fugitive particulate levels persisted for 1 or 2 hr and that the wet materials were "tracked" to other areas. These observations prompted an evaluation for fugitive particulate on an hourly basis at sampling location 3. The results in Table E-4 indicated that watering was beneficial, but only for a short time. Water was applied shortly before 9:00 a.m.

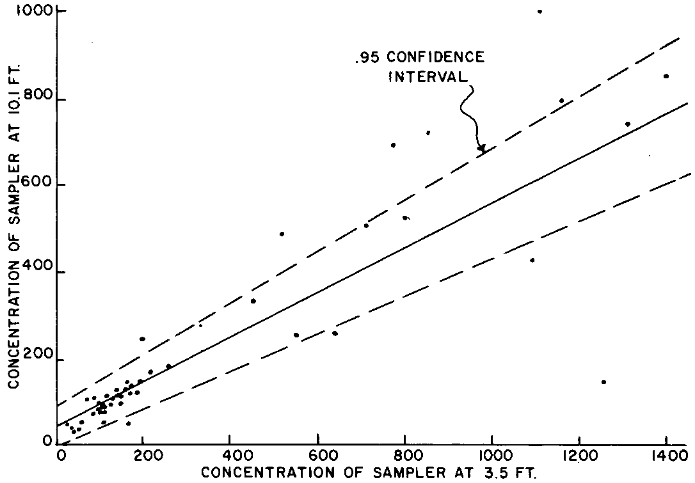

Figure 18. Concentration of samples at 10.1 ft vs. concentration at 3.5 ft.

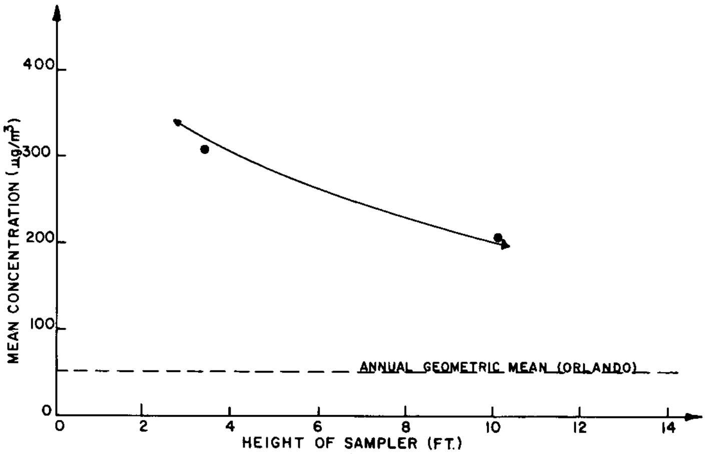

Figure 19. Mean concentrations vs. height of sampler.

and the fugitive concentration was 80 $\mu g/m^3$ for the next hour, but was elevated to 132 $\mu g/m^3$ from 11:00 a.m. to noon. Traffic on the road increased slightly around noon. It is believed that no specific conclusion can be drawn from this one sampling day and that there are many other meteorological variables that need to be controlled before meaningful results can be expected.

HYDROCARBON TEST RESULTS—DATA ANALYSIS

A detailed data analysis is presented in Appendix F. The analysis of data has shown instances where unexpected characteristic results can be related to the lack of statistically sufficient data. The increased number of samples taken in a single sampling day during the second phase of testing improved the confidence level in the data obtained over the first phase of testing. The findings are summarized as follows.

An evaluation of the 20 ambient air measurements taken during the first phase of testing indicates that there is a great variability in the data and that the average ambient values exceed the EPA standards. In these tests, many of the high reactive hydrocarbon (RH-C) concentrations can be explained possibly by locally heavy traffic. As expected, the ambient values measured in the morning were found to be greater than those in the afternoon. More reasonable data were provided by the 12 ambient air measurements made during the cutback asphalt application than the measurements made during the paving operations because there was less adjacent traffic. It is noted that these ambient readings in each case were used as a means of determining the relative contribution of the construction operation.

Eleven of the 13 valid samples taken in the immediate vicinity of operating paving machines showed an increase in the reactive hydrocarbon concentrations over the ambient level. The variability in these concentrations was caused by changes in such factors as wind, turbulence, temperature, location, and type of paving machine. The concentrations were found to depend on the proximity of the sampling inlet to point sources.

The relative contribution of the two hydrocarbon sources tested is indicated by the fact that the reactive hydrocarbon emitted to the atmosphere by RC-70 sprayer operations at points 5- to 30-ft (1.5- to 9-m) downwind were considerably greater than those 1 ft (0.3 m) from the paving machine. In all cases, wind and distance were found to attenuate the concentrations through dilution.

The concentration increase over the ambient level measured approximately 25-ft (8-m) downwind from paving operations averaged about 9 ppm, with a standard deviation of about 1.5 ppm. Those downwind measurements would tend to be increased because of the traffic flow on the highway being paved. The downwind measurements from the RC-70 application indicated that a large proportion of the solvent had been evaporated within 1 hr of application.

Measurements taken at different moments of time after a paving operation indicated that the emission of RH-C from new paving is halved in 20 min and ceases after 45 min. The same type of test on the cutback asphalt application indicated that a 90-percent reduction in emission concentrations of RH-C occurs within the first 15 min. The reduction is highly dependent on wind, temperature, distance from the source, and the volatility of the solvating agent. Normal use of asphaltic cements provides emissions that are rapidly diluted to levels indistinguishable from concentrations caused by local automobile traffic.

Samples taken adjacent to paving machines and spray trucks that are parked with their engines on prior to operation indicated concentrations of RH-C about 2 ppm above the average ambient conditions.

Through testing. many of the measurements that obtained a measureable RH-C concentration exhibited a signature "tail-off" that was designated during the research as "heavy hydrocarbon." It is hypothesized that this tail-off is caused by solvent vapors condensing on the gas chromatograph column material and eluting more slowly from the column than the reactive hydrocarbon gases that have a lower boiling point.

It is possible that solvating agents containing a high proportion of aromatic hydrocarbons may emit toxic fume concentrations during operations involving cutback asphalts. However, normal use of uncut asphalt cements provides relatively low emission concentrations of reactive hydrocarbons that are nontoxic (although photochemically active).

In order to provide comparative results on the magnitude of the RH-C contribution to air pollution resulting from asphaltic paving operations and cutback asphalt application, various other sources were tested. The following is a selection of test results that provide a relative comparison of volatility of petroleum products; these concentrations were measured in an almost closed container wherein the vapor pressures had stabilized for the ambient temperature. The values indicated should be used for qualitative comparisons only.

REACTIVE HYDROCARBONS (PPM)	METHANE (PPM)	SOURCE
17.51	3.1	Asphalt Tanker Truck (AC Temp. 320 F)
208-280	11.5	RC-70 @ 76 F
845	50.0	#6 Fuel Oil @ 85 F
1071	23.8	Diesel Fuel Tank
1250	23	RC-70 @ 95 F
2310	84	RC-70 @ 150 F
4250	124	RC-250 @ 150 F
24,100	97.6	Auto Gasoline Tank

The values give some indication that the quantity of hydrocarbons emitted into the atmosphere by the construction industry is minor when compared to even that of an open auto gas tank. Consequently, care should be taken that the problem addressed is considered in its proper context.

CHAPTER THREE

INTERPRETATION, APPRAISAL, AND APPLICATION

GENERAL

Air pollution is believed to be harmful because of its effect on health (respiration, toxicity, eye irritation) and welfare (reduced visibility, nuisance factors). Air pollution regulations presumably reduce the occurrence of air pollution incidents and thereby lessen any harmful effects. On the other hand, regulations can be presumed to affect costs either by requiring elaborate control equipment, which itself would be costly, or by imposing restrictions that would supposedly increase costs by limiting the available construction processes. Ideally, then, one could compare these costs with the benefits gained (reduced health care costs, reduced housekeeping and maintenance costs) and create an index whereby the effect on an industry could be foretold.

The highway construction and maintenance industry appears to contribute to air pollution by creating smoke from open burning during clearing and demolition operations, by creating dust during various construction operations, and by emitting hydrocarbons during paving and priming operations. If the amount of pollutants from these operations could be quantified and satisfactory mitigation techniques identified, then the costs of maintaining a desirable reduction could be determined. However, on the basis of the preliminary studies described in this report, it appears that the fundamental assumption may be in error. Although there is, of course, some contribution of particulate matter introduced into the ambient air by construction, this contribution is of such short duration and so easily controlled that it does not form a significant part of a community-wide air pollution problem. As for hydrocarbons, the quantity emitted during paving operations is so small as to be practically unmeasurable against normal ambient quantities at the construction sites studied.

In summary, it can be said that, although both particulate matter and hydrocarbons are created by highway construction and maintenance, generally their effect is one of being a localized nuisance rather than being in violation of the National Ambient Air Quality Standards.

SMOKE

Smoke from open burning is potentially the most serious of three construction-generated problems because of the gross amounts and large variety of pollutants emitted. This occurs primarily because the low temperature usually associated with open burning results in incomplete combustion. Furthermore, because of the updraft created by the fire, the fine particles are readily elevated and hence widely dispersed.

However, few cases justify open burning. Many jurisdictions have been able to effect a total ban on open burning and numerous others have had little difficulty in postponing the burning operation during periods of temperature inversions when the harmful effects of smoke would be most seriously felt. Although the clearing of the land may be a vital step in the progress schedule of a construction project, the disposal of the cleared materials rarely is. Consequently, time is available to either await favorable weather or to undertake alternative procedures. The trend in alternative procedures seems to be toward reducing the wood products by chipping machines (and salvaging the product as mulch) or increasing the temperature of combustion by the use of air curtain destructors and, thus, eliminating the most harmful effects of open burning. Indeed, one state found that the use of air curtain destructors was actually less expensive than open burning, because the cost of the equipment needed for forced air combustion was less than the cost of the labor and equipment involved to tend the open fires.

DUST

Embankment construction primarily involves three steps: excavation, hauling, and compaction. The excavated earth normally contains sufficient moisture, so that little, if any, dust results. The compaction process, under most state specifications, requires a certain optimum moisture content to achieve maximum compaction, so that this operation, too, is not a dust generator. The hauling process can generate dust, because the top surface is subject to drying and, when dried, offers a dust-producing source to passing vehicles. Winter months and days during and after rainfall constitute a significant portion of the year, such that the opportunities for drying are only a fraction of the construction season in many regions. Where dust production is likely, traffic can be banned, speeds can be reduced, or the hauling road or detour road can be watered. During extended periods of drying, water appears to be inefficient because the effects may only last a few hours. Consequently, use of hydrophilic materials, such as calcium chloride, is more sensible. Further, on heavily traveled haul roads, cutback asphalts and emulsions may be used for dust mitigation. On the basis of the recent trend in the cost of asphalt products, emulsions have become the more favored choice. Where dust results from the spillage of embankments onto paved roads, frequent cleaning through scraping, sweeping, and hosing is the best method for eliminating the potential for dust.

HYDROCARBONS

Hydrocarbons emitted from paving with asphaltic concrete are quickly dispersed, are apparently nontoxic, and may constitute a smaller contribution to the ambient air than the machine transporting the paving materials. More volatile cutbacks emit considerably more hydrocarbons than asphalt cements, but they constitute only a small percentage of the total asphalt products used in the highway industry. In fact, the use of cutback products is declining even further because of the need to conserve both gasoline and naptha (usually used in cutback production) for more urgent energy requirements.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The specific conclusions that follow pertain to the results obtained from studies of the fugitive particulate and hydrocarbon regulations and their effect on the highway construction and maintenance industry.

Fugitive Particulates

1. State regulations for fugitive particulates are rarely applied to construction sites.
2. Enforcement of state regulations is difficult because of the requirement for a 24-hr test and because of the conspicuousness and cost of the equipment presently used for testing.
3. Open burning, potentially the worst violator of the air pollution regulations, can be adequately controlled through present technology.
4. Fugitive dust from highway construction and maintenance is a local, short-term problem, hence an insignificant contributor to ambient particulate levels.
5. Construction activity has an influence on concentrations. The dominant source causing high readings is traffic on unpaved surfaces. Public access along construction sites should be reduced through detouring and particulates controlled by speed control.
6. Wind direction is more significant than wind speed in its effect on fugitive particulate concentrations.
7. Precipitation reduces mean concentrations by about 50 percent. Site watering is less effective than rainfall in reducing particulate levels and generally lasts for only a few hours.
8. Both rain and site watering cause soil to be "tracked" from construction sites, thereby spreading the potential for dust.
9. Watering is probably overused as a mitigant and should be replaced by more efficient dust mitigation methods such as oil-based products and temporary pavements.
10. Concentrations of fugitive particulates measured at 10.1 ft (3 m) are about 45 percent less than at 3.5 ft (1 m). This settleability is not observed in urban concentrations of particulates.
11. At 50 ft (15 m), a sharp discontinuity in dust levels is found. Without dust mitigation, it is unlikely that the 24-hr Federal primary air quality standard of 260 $\mu g/m^3$ would be exceeded at a distance of 50 to 150 ft (15 to 45 m) with normal ambient concentrations of 60 $\mu g/m^3$. Under similar conditions the secondary standard of 150 $\mu g/m^3$ would not be exceeded at distances of 100 to 250 ft (30 to 75 m) from construction activities. Through the use of dust mitigation techniques, these distances would be reduced.
12. Additional measures that should be considered to reduce the industry's contribution to air pollution include restriction of public access to work site, restriction of exposed graded area, and topsoiling and seeding such that vertical exposed faces of excavation or embankment are limited.

Hydrocarbons

1. The reactive hydrocarbons emitted by normal asphaltic paving operations and equipment are well below concentrations that could be harmful to health.
2. Hydrocarbon emission from freshly paved asphalt and prime coat is highly sensitive to wind, turbulence, and temperature. The hydrocarbons dissipate very rapidly with distance from the source. Within no more than 50 ft (15 m) from the source (for the more volatile cutbacks), essentially all hydrocarbons above the ambient level are reduced to trace concentrations.
3. Emissions of hydrocarbons generated by paving operations are difficult to differentiate and measure because of their low concentrations and the emissions from vehicular traffic normally found in the vicinity of such operations.
4. Aggregate priming (stabilizing) with RC-70 provides higher emission concentrations of reactive hydrocarbons (RH-C) than do uncut asphalt cements.
5. The primary parameters determining the amount of RH-C emitted during asphaltic paving operations are the amount of solvating agent remaining with the asphalt cement, the solvent composition, and the temperature during and after application.
6. RH-C emission concentrations from RC-70 priming operations are reduced to approximately 10 percent of their initial values 15 min after application under normal wind and temperature conditions experienced in Florida in October.

RECOMMENDATIONS

Fugitive Particulates

The following lists several suggested areas of research that could be undertaken that may help in identifying possible methods of improving the highway industry's role in the attainment of the ambient air quality standard for fugitive particulates.

1. In order to control short-term (less than 5 min) dustfalls, it is necessary to quantify them. This could best be done by means of a "quick and dirty" test, whereby a resident engineer may objectively evaluate the need for mitigation procedures. Such a test could be accomplished by simply capturing dust on a sticky tape or cheese cloth for a certain period of time and comparing the results to a preestablished color or opacity chart. A potential nuisance level could be established relative to this chart that could be used to trigger preventive measures.
2. Air pollution regulations could be related to the OSHA regulations to determine if one method of control and testing of the worker would be sufficient to protect the public.
3. The additional construction costs caused by the ban on open burning could be evaluated.

Hydrocarbons

While the contribution of hydrocarbons from the highway industry (exclusive of vehicular exhaust) is small, several areas of suggested research have arisen from the testing program undertaken as part of this research.

1. Future work could be performed to define compounds as they affect workers. This would, by necessity, have to be performed in a more controlled environment.
2. Although much data exist on the "tons of fuel per year" or hydrocarbon emission (production) quantities put into the atmosphere per time period, data could not be found on increases in atmospheric RH-C concentrations resulting from these emissions under various atmospheric conditions. Such data might prove highly useful for practical control application and city planning processes.

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APPENDIX A

QUESTIONNAIRE TO AIR POLLUTION OFFICIALS

The questionnaire presented in this appendix was sent by letter to the 53 air pollution officials that follow. The letter requested that the questionnaire be completed and returned; it also requested copies of approved implementation plans and air quality regulations and standards currently in effect. A second follow-up letter was later sent to serve as a reminder.

The answers of the 47 respondents are summarized in Table A-1.

QUESTIONNAIRE

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP Project 20-12: EFFECTS OF AIR POLLUTION REGULATIONS ON HIGHWAY CONSTRUCTION AND MAINTENANCE

Your Name: ____________________

Title: ____________________

Organization: ____________________

Mailing Address: ____________________

1\. Do your current regulations explicitly control highway construction and maintenance impacts on air quality? Yes ____ No ____

1a. If no, do you think there is a need for such regulations? Yes ____ No ____

1b. If yes, are existing regulations effective for control of pollutants associated with highway construction and maintenance? Yes ____ No ____

Comments: ____________________

____

2\. Does your organization monitor construction activities? Yes ____ No ____

2a. If not, who conducts this monitoring and how do they coordinate with your office?

Comments: ____________________

____

2b. How frequent does monitoring occur? Daily ____ Weekly ____
Monthly ____ Other ____

2c. What pollutants are monitored? Please list: ____________________

____

3\. What enforcement provisions, if any, exist in your present regulations?

Comments: ____________________

____

4\. Can you provide any data on the type and number of violations that occur in a given time frame? (e.g., Dust; 3; per month.)

Type of Violation	Number	Time Period
____	____	____
____	____	____
____	____	____

5\. We would welcome any critical comments you would care to send on the effectiveness of existing regulations.

Please return completed questionnaire to:

Howard Needles Tammen & Bergendoff
Attention: Mr. R. L. Judd
201 North Washington Street
Alexandria, Virginia 22314

QUESTIONNAIRE RECIPIENTS

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TABLE A-1

SUMMARY OF QUESTIONNAIRE RESPONSES

	Current Regulations				Monitoring			Enforcement Provisions	Violations		
	Existing	Applicability	Need	Effectiveness	Responsibility	Frequency	Pollutants		Type	No.	Period
Alabama	Chap. 3, Proclamation 3 and Chap. 4.2	Open burning & fugitive dust	-	Adequate	Commission. Cooperation of Highway Dept. which plans revision of specifications. Requirements are presently discussed at pre-construction meetings.	Other	Particulates, Mobile source pollutants after construction.	None	open burning	2	month
Alaska		Not specific	No		limited, by agency		dust and point sources	Fines by Dept. of Law	dust asphalt plant visible emissions	5 5-10	year year
Arizona	Questionnaire not completed.										
Arkansas	Questionnaire not completed.										
California	local air pollution control districts	No	Yes		Not by state, local APCD's monitor, coordinate informally with state.		Smoke using Ringelmann #1 and #2 criteria				
Colorado	Yes			Yes	No general monitoring program	Other	CO, NO_x, particulates HC	Projects that violate regulations can be shut down			
Connecticut	Yes			Complex source regulations not implemented until 10/1/74.	Field surveillance and nuisance investigation		Particulates and combustion products of open burning	If highway results in CO above standard, it may not be constructed.	visible emission fugitive dust (road) fugitive dust (open truck) open burning	5 5 20 1	month month month month
Delaware	No		Yes	Some provision for review of major highway construction with respect to long term air quality maintenance.	None			No enforcement in regulation. Statute provides fines up to $10,000.	None		
District of Columbia	Yes			Yes	Bureau of Air and Water Quality Control	Daily	Particulates dust		fugitive dust, Sec. 8-2: 712	2	month

	Current Regulations				Monitoring				Violations		
	Existing	Applicability	Need	Effectiveness	Responsibility	Frequency	Pollutants	Enforcement Provisions	Type	No.	Period
Florida	Not specifically related to highway construction, but as fugitive dust and open burning in accordance with construction regulations in state highway manual	Present regulations may be adequate		(No 2nd answer) Not specific enough.	No monitoring of significance, only as complex source.		HC, CO, O_x only under very special circumstances.	Complex source rule, backed by legal staff and enforcement section. Notice & order violations re: ambient air standards.	None available. Ambient air quality standard for 24 hour-particulate.	8	11/2/73 2/10/73
Georgia	No Do have ambient standards for CO, but no specific review or emissions standards.		Yes	Existing regs. don't cover traffic related pollutants adequately, CO primary interest and impact, plans for adopting indirect source review regs. by end 1974.	None. Section has worked with Ga. Dept. of Transportation in evaluating some road projects.			Fines, injunctions, and criminal penalties.			
Hawaii	Do not specifically address highway construction.		None	Air pollution problems related to highway construction are not major.	Division, Pollution Investigation & Enforcement Branch	Other	Particulate matter	Section 8, statute on Environmental Quality.	dust open burning	6 2	annual annual
Idaho	No	general regs. apply	No		No routine monitoring. State Highway Department is responsible for ensuring compliance with fugitive dust and open burning requirements.			misdemeanor $300/day civil penalty $1000/day			
Illinois	Questionnaire not completed.										
Indiana	No		No		No monitoring. Private individuals report cases of open burning to our Enforcement Section who then investigates.			Enforcement prescribed by general law, not regulation.	No record of violation due to highway activities kept, seldom a problem.		

	Current Regulations				Monitoring			Enforcement		Violations	
	Existing	Applica-bility	Need	Effectiveness	Responsibility	Frequency	Pollutants	Enforcement Provisions	Type	No.	Period
Iowa	Fugitive dust only		Yes	Requires formal complaint prior to initiation of fugitive dust enforcement procedures. No legislative authority to control indirect sources (highways). No noise control regulations.	Iowa State Highway Commission - their "Action Plan" contains procedures for evaluating the environmental effects of highway construction. No specific pollutant monitoring however.	None		For citizen complaints, Dept. may order corrective actions under the fugitive dust provisions of the Air Quality Commission's Rules.	dust dust	3 (reported complaints) 2 (reported)	month month
Kansas	None specifically, emissions from asphalt plants, rock crushing plants and ready mix plants associated with highway construction are controlled.		None		None			Regulation 28-19-45, open burning prohibited. Regulation 28-19-51, ground level particulate limitations.	None for highway construction.		
Kentucky	Yes	Fugitive dust and open burning	Yes		Division of Air Pollution.	Other	Particulates	Statute - maximum penalty $1,000/day per violation	dust open burning (both estimated, represents violations construction season (4/15-11/15), not necess necessarily total violation, since only periodic inspection.)	1 1	month month
Louisiana	Yes. All highway impact statements are evaluated by this agency for air quality. Current regulations pertain to process weight rate emission standards. Ambient air suspended particulates. Open burning regulations.			Adequate	Air Control	Weekly	Visual observations of asphalt and cement plant emissions, open burning of trees, etc.	Regulations	Suspended particulate from asphalt plants, problem arises when asphalt plant has scrubber failure and operator continues to run plant.		1 or 2 occasions per month
Maine	Yes, in general			"No, probably should have fugitive dust"	Federal and State D.O.T.			Revised Statutes			

	Current Regulations				Monitoring			Enforcement Provisions	Violations		
	Existing	**Applicability**	**Need**	**Effectiveness**	**Responsibility**	**Frequency**	**Pollutants**		**Type**	**No.**	**Period**
Maryland	Yes			Yes	Bureau. No routine monitoring, spot checks usually made by local health officials to insure control of fugitive dust.	Other	Fugitive dust	Orders to cease issued. Civil penalties.	dust	30	month (from April - October)
Massachusetts	Construction activities governed by general regulations prohibiting excessive dust, noise and nuisance, etc. Note regulations 1.1, 6.5.1, 6.6.1, 9.1, 10.1.					As necessary	Particulates, Noise	Regulations	dust	5	month
Michigan	Questionnaire not completed.										
Minnesota	Questionnaire not completed.										
Mississippi	Yes			Yes	Commission	Periodically	Visual				
Missouri	Yes			Unknown	Agency	Daily, special	CO, O_x, HC, SO_x, NO_x, Particulates Pb	Regulations			
Montana	Questionnaire not completed.										
Nebraska	No. Do have indirect controls by regulating location of asphalt plants.		No		Division. Inspection of asphalt plants.	Other	Particulates	Statutes provide for fines, injunctions and jail sentences.	None		
Nevada	Yes			Yes Additional regulations on land use planning would make existing regulations effective.	Department	Random	During construction dust, after construction random CO.	Based on expected ADT, predictive modeling is required for CO, fugitive dust during construction.	dust	4	Quarter

	Current Regulations				Monitoring			Enforcement Provisions	Violations		
	Existing	Applicability	Need	Effectiveness	Responsibility	Frequency	Pollutants		Type	No.	Period
New Hampshire	Air pollution regulations and regulations on indirect sources.			Yes	Agency	Occasionally	CO, particulates, visible emissions, NO_x.	Regulations			
New Jersey	None. Federal air quality guidelines for highway construction are used by State Dept. of Transportation		None no significant problem with highway construction, since imposition of general ban on open burning.		No monitoring by Bureau, State Dept. of Transportation is developing monitoring capability. Their air quality reports are reviewed by Bureau.		CO	None			
New Mexico	None		Yes	Only for asphalt batch plants. Fugitive dust emissions associated with construction are a problem and an area where regulations are needed.	Only monitoring is of emissions from asphalt batch plants EPA monitors construction sites.		Regulation 501-asphalt batch plant emissions				
New York	No		No		Dept. monitors background pollutant levels in areas of proposed highway construction in cooperation with State Dept. of Transportation.	14 Days 6 weeks (Occassionally)	Minor highways for CO Major highways (4 lane) - CO, NO_x, hydrocarbons. (Particulates smoke on existing construction. CO, NO_x, O_x, on proposed sites.)	None (Hearings & Penalties)			
North Carolina	Yes, but not explicitly				None by Dept.		Regulations for control of air pollution.				
North Dakota	Yes Sec. 5.100 & 5.400 of Reg. 23-25	Particulate emissions from asphalt plants, fugitive dust.		Yes. Adequate for N. Dakota predominantly rural, agricultural, low population density.	State Dept. of Health also by local health dept.	On request.	Hydrocarbons & Particulates	Air pollution law & regulation Sections 23-25-08, 23-25-09, 23-25-10, of State Law in Reg. 23-25.	Particulate (dust) Asphalt plant emissions (dust) gravel trucks (dust)	1 3-4 2-3	1974 year year

	Current Regulations				Monitoring			Enforcement Provisions	Violations		
	Existing	Applicability	Need	Effectiveness	Responsibility	Frequency	Pollutants		Type	No.	Period
Ohio	No		No		OEPA or local agent	response to nuisance complaint	Particulate matter	Enforced through courts as nuisance matter	None		
Oklahoma	No		Not at present	Service has close working relationship with Hwy. Dept. in establishing review procedures to determine consistency of proposed hwy. project with State Plan. Consultation re: present regulations has been effective in dealing with air pollution problems.	No monitoring of construction activities has been conducted in the past.			Reg. No. 9 most applicable to hwy. activities For enforcement provisions, see Section 2002, (I)-(K) of the Oklahoma Clean Air Act.	None		
Oregon	Yes			Yes	Air Quality Control Division by special monitoring projects, Highway Division Oregon Graduate Center & others.	Other	CO,Pb certain stations operate continuously	Air Quality standards civil penalty $500/day	Station 1. CO 2. CO 3. CO 4. CO	 108 178 178 3	 1973 1973 1973 1973
Pennsylvania	No		Yes	EPA's indirect source review program and FHWA's PPM 90-7 guidelines should be adequate	Bureau	Other	Smoke & fugitive dust. Not for CO as HC at this time.	Open burning & fugitive dust regulations	Not available		
Puerto Rico	For fugitive dust. Amendments are necessary				Monitoring of construction activities not required.			Revocation of permit, fines (Law # 9)	dust	10	month
Rhode Island	Indirect source regulations & NEPA regs. required detailed air pollution studies before construction		Yes		R.I. DOT contractors monitor before construction permit is issued	Daily	CO, NO_2, HC	Federal indirect source provisions	CO 8-hr stand	35 5	1973 1st quarter 1974

	Current Regulations				Monitoring			Enforcement Provisions	Violations		
	Existing	Applicability	Need	Effectiveness	Responsibility	Frequency	Pollutants		Type	No.	Period
South Carolina	None		Yes & No		No monitoring of construction or maintenance.			None			
South Dakota	No		No		None at present.			None			
Tennessee	Yes			Yes			Visible particulates only, and fugitive dust.	Administrative hearings, board hearings, court action	open burning dust	30-50 12-20	year year
Texas	Reg. I, Para. 104 and Para. 101	Control of particulates associated with material handling construction and roads. Open burning.	NA	Yes	Board, Monitored visually by Regional personnel, coordinated by complaint reports and/or source surveillance reports.	Random as necessary	Particulates, open burning.	Reg. I, Para. 101 and 104. Nuisance Provisions-General Rule 5. Possible civil penalties of $50-1,000 day per violation.	None available		
Utah	Questionnaire not completed.										
Vermont	Land Use and Development Act has authority to control air quality on highway construction and maintenance.			Yes	Air monitoring is not conducted in association with usual highway construction projects; however, construction CO monitoring may be carried out by the Agency.			$1,000/day			
Virginia	Virginia Air Board Regs.	Fugitive dust and open burning		Yes	Air Board; highway construction is not monitored.			$1,000 maximum			
Virgin Islands	Questionnaire not completed.										
Washington	No		No		Local agencies and Dept. of Highways monitor,	Other	Particulates, CO	Civil Penalties.	None available.		

	Current Regulations				Monitoring			Enforcement	Violations		
	Existing	Applicability	Need	Effectiveness	Responsibility	Frequency	Pollutants	Provisions	Type	No.	Period
West Virginia	No		Yes need for manual of good practice. Not specifically for W. Va. but other areas.	No. There should be no open burning.	Commission	Random	Particulates, smoke	Director's cease & desist authority			
Wisconsin	No. Proposed rules taken to final hearing June 1974, would regulate construction of highways & other indirect sources		Yes	No	Section	Review of initial construction plans.	Particulates, sulfur, oxides, CO, HC, Ozone.	Issue order to prohibit construction of certain direct sources; issue other orders, assess penalties of $10-5,000/ violation of rules. (NR 154.08)	Particulates Particulates HC (stationary sources)	97 20 27	7/71-7/73 8/73-7/74 8/73-7/74
Wyoming	Yes			Yes	Division	As required	See Reg.	See Reg.	None		

APPENDIX B

QUESTIONNAIRE TO CONSTRUCTION AND MAINTENANCE OFFICIALS

The questionnaire presented in this appendix was sent to those 71 construction and maintenance officials listed herein. A summary of the results of the 55 respondents is given in Tables B-1 and B-2.

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
Transportation Research Board
National Academy of Sciences - National Research Council
Project 20-12

Questionnaire on Emissions from Highway Construction and Maintenance Operations.

General Instructions:
Please enter appropriate checkmarks, numbers or percentages where indicated. Emissions to be considered include fugitive dust and hydrocarbons, but exclude vehicular exhaust.

Question 1. Operations that produce fugitive dust or other emissions (excluding vehicular exhaust).

Column A. Please indicate relative magnitude of problems or complaints resulting from each operational area listed by checking one (1) box only.

Column B. Please enter number indicating your best estimate of the number of notices of statutory violations or legal citations received by your state, agency or contractors during the past year resulting from each operational area listed.

Operations Area Instruction	Column A (Check one box each line) Relative Severity of Problem			Column B (Enter number)
Earthwork Operations	Severe Problem	Occasional Complaint	No Problem	Approximate Number of Violations
Excavation	( )	( )	( )	____
Loading	( )	( )	( )	____
Hauling (Paved Roads)	( )	( )	( )	____
Hauling (Unpaved Roads)	( )	( )	( )	____
Dumping	( )	( )	( )	____
Spreading	( )	( )	( )	____
Grading	( )	( )	( )	____
Compacting	( )	( )	( )	____
Wind Erosion	( )	( )	( )	____
Traffic on Dirty Road	( )	( )	( )	____
Other ____ (Specify)	( )	( )	( )	____
Paving Operations				
Hauling (Paved Roads)	( )	( )	( )	____
Hauling (Unpaved Roads)	( )	( )	( )	____
Grading	( )	( )	( )	____
Dumping	( )	( )	( )	____
Spreading	( )	( )	( )	____
Compacting	( )	( )	( )	____
Priming	( )	( )	( )	____
Application of sand cover	( )	( )	( )	____
Sweeping	( )	( )	( )	____
Road mixing	( )	( )	( )	____
Asphalt Concrete paving	( )	( )	( )	____
Other ____ (Specify)	( )	( )	( )	____
Bridge Construction				
Sawing	( )	( )	( )	____
Curing compounds	( )	( )	( )	____
Painting	( )	( )	( )	____
Other ____ (Specify)	( )	( )	( )	____
Miscellaneous Activities				
Burning (Smoke emissions)	( )	( )	( )	____
Mowing	( )	( )	( )	____
Seeding, grassing or mulching	( )	( )	( )	____
Sweeping	( )	( )	( )	____
Sandblasting	( )	( )	( )	____
Grinding, grooving, sawing, jackhammer	( )	( )	( )	____
Demolition	( )	( )	( )	____

Comments: ____________________

Question 2. Current Mitigation Methods Used.

Instructions: Please enter numerical percentage in one (1) box only on each line to indicate the approximate relative proportion of each dust mitigation method currently used by your state or agency. Checkmarks should be used in the last column to indicate experimental use.

Example:	Extensive Use	Moderate Use	Rare or No Use	Experimental Use
Applying water	(90%)	( )	( )	( )
Calcium Chloride	( )	(10%)	( )	( )
Polyethelene Sheets	( )	( )	( )	(✓)

Method	Extensive Use	Moderate Use	Rare or No Use	Experimental Use
Applying water	( )	( )	( )	( )
Calcium Chloride	( )	( )	( )	( )
Mixing type asphalt emulsion	( )	( )	( )	( )
Other asphalt products	( )	( )	( )	( )
Others (Specify)				
____	( )	( )	( )	( )
____	( )	( )	( )	( )
____	( )	( )	( )	( )
____	( )	( )	( )	( )

Comments: ____________________

State or Agency Completing this Form: ____
Person Completing Form: ____
Title or Office: ____
Telephone Number (if we are free to contact you): ____
Address: ____

Please return this completed questionnaire as soon as possible (no later than June 26, 1974) to:

Howard Needles Tammen & Bergendoff
Attention: R. J. McCready
387 Passaic Avenue
Fairfield, New Jersey 07006

QUESTIONNAIRE RECIPIENTS

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Construction Engineer
State of Alabama Highway Dept.
Montgomery, Alabama 36104

Mr. R. D. Shumway
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P.O. Box No. 1467
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Mr. E. F. Sandlin
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206 South 17th Avenue
Phoenix, Arizona 85007

Mr. John Tallant
Engineer of Construction
Arkansas State Highway Dept.
P.O. Box 2261
Little Rock, Arkansas 72203

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Construction Engineer
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Box 1499
Sacramento, California 95807

Mr. T. W. Smith
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California Division of Highways
Box 1499
Sacramento, California 95807

Mr. Reed M. Wilson
Chief Engineer
California Department of Aeronautics
Sacramento Exec. Airport
Sacramento, California 95822

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Staff Constr. Engineer
Colorado Department of Highways
4201 E. Arkansas Ave.
Denver, Colorado 80222

Mr. Orion L. Grunerud
Construction Engineer
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3311 W. State St.
Box 7129
Boise, Idaho 83707

Mr. Edward J. Kehl
Engineer of Maintenance
Illinois Department of Transportation
Springfield, Illinois 62764

Mr. Robert D. Schmidt
Engineer of Construction
Illinois Department of Transportation
Springfield, Illinois 62764

Mr. Michael J. Hartigan
Chief Engineer
The Illinois State Toll
Highway Authority
East-West Tollway
Oak Brook, Illinois 60521

Mr. R. L. Roath
Chief, Div. of Construction
Indiana State Highway Commission
State Office Building
Indianapolis, Indiana 46204

Mr. Lionel G. Roll
Chief Engineer
Indiana State Highway Commission
Management and Operations
State Office Building
Indianapolis, Indiana 46204

Mr. Robert H. McIntire
Construction Engineer
Iowa State Highway Commission
Highway Commission Bldg.
Ames, Iowa 50010

Mr. W. H. Wright
Engineer of Construction
State Highway Commission of Kansas
State Office Building
Topeka, Kansas 66612

Mr. William A. Sawyer
Construction Engineer
Michigan Department of State Highways
State Highways Bldg.
Lansing, Michigan 48904

Mr. Karl F. Crawford
Manager, Engineering Services
Connecticut Dept. of Transportation
24 Wolcott Hill Road
Wethersfield, Connecticut 06109

Mr. Raymond E. Tomasetti
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Delaware Dept. of Highways and
Transportation
Administration Building
Box 778
Dover, Delaware 19901

Mr. Earle M. Davis
General Manager
Delaware Turnpike Division
Box 566
Newark, Delaware 19711

Mr. Charles F. Williams
Construction Engineer
Department of Highways and Traffic
Presidential Building
415 - 12th St., N.W.
Washington, D.C. 20004

Mr. P. J. White
State Construction Engineer
Florida Department of Transportation
Haydon Burns Bldg.
604 Suwannee St.
Tallahassee, Florida 32304

Mr. Charles H. Breedlove
State Highway Construction Engineer
Georgia Department of Transportation
No. 2 Capitol Sq., S.W.
Atlanta, Georgia 30334

Mr. Calvin A. Tottori
Asst. Chief Constr. & Maintenance
Hawaii Department of Transportation
Highways Division
869 Punchbowl St.
Honolulu, Hawaii 96813

Mr. R. D. Fogo
Chief Engineer
Kansas Turnpike Authority
Wichita Interchange
Box 18007, S.E. Station
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Mr. C. S. Layson
Director of Construction
Kentucky Department of Transportation
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Mr. D. D. White
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Louisiana Department of Highways
Box 44245
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Mr. Ralph A. Stevens
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Maine Department of Transportation
State Office Bldg.
Augusta, Maine 04330

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State Highway Administration
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State Aviation Administration
Friendship Int'l Airport
Box 8755
Baltimore, Maryland 21240

Mr. Ralph Levine
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Massachusetts Department of Public Works
100 Nashua Street
Boston, Massachusetts 02114

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Massachusetts Turnpike Authority
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Mr. John C. Gibson
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1035 Parkway Ave.
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Mr. W. Stanley Ekern
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State Highway Building
St. Paul, Minnesota 55155

Mr. Richard W. Thomas
Constr. Engineer
Mississippi State Highway Department
Box 1850
Jackson, Mississippi 39205

Mr. W. H. Shaw
Division Engineer, Construction
Missouri State Highway Commission
Jefferson City, Missouri 65101

Mr. Clarence Mackey
Chief, Constr. Bureau
Montana Department of Highways
6th Ave. and Roberts
Helena, Montana 59601

Mr. Art Dederman
Construction Engineer
Nebraska Department of Roads
So. Junction of U.S. 77 and N-2
Lincoln, Nebraska 68509

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Construction Engineer
Nevada Department of Highways
State Highway Building
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Carson City, Nevada 89701

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Morton Office Bldg.
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Concord, New Hampshire 03301

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Bureau of Construction, Engr.
Ohio Department of Transportation
25 South Front St.
Columbus, Ohio 43215

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Ohio Turnpike Commission
682 Prospect Street
Berea, Ohio 44017

Mr. Delbert Carman
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Jim Thorpe Bldg.
Oklahoma City, Oklahoma 73105

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Olympia, Washington 98504

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New Mexico State Highway Commission
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1220 Washington Ave.
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South Carolina State Highway Dept.
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Pierre, South Dakota 57501

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Highway Building,
Nashville, Tennessee 37219

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Texas Highway Department
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Mr. W. O. Karpenko
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West Virginia Dept. of Highways
1900 Washington St., East
Charleston, West Virginia 25305

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Wisconsin Dept. of Transportation
4802 Sheboygan Ave.
Madison, Wisconsin 53702

Mr. E. H. Crowe
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Wyoming State Highway Department
Box 1708
Cheyenne, Wyoming 82001

TABLE B-1

OPERATIONS PRODUCING FUGITIVE DUST OR OTHER EMISSIONS

Operations Area	Earthwork												Paving													Bridge Const.					Misc. Activ.							
Legend 1-Severe Problem 2-Occasional Complaint 3-No problem Respondants	Excavation	Loading	Hauling (Paved)	Hauling (Unpaved)	Dumping	Spreading	Grading	Compacting	Wind Erosion	Traffic - Dirty Rd.	Other	Violations	Hauling (Paved)	Hauling (Unpaved)	Grading	Dumping	Spreading	Compacting	Priming	Appl. Sand Cover	Sweeping	Road mixing	Asph. Conc. Paving	Other	Violations	Sawing	Curing Compounds	Painting	Other	Violations	Burning (Smoke Emis.)	Mowing	Seeding or Mulching	Sweeping	Sandblasting	Grinding, etc.	Demolition	Violations
Alabama	2	3	3	2	3	3	3	3	3	3			3	3	3	3	3	3	3	3	2	3	3			3	3	2			2	3	2	2	3	3	3	
Alaska	3	3	3	2	3	3	3	3	3	2			3	2	3	3	3	3	3	3	3	3	3			3	3	3			3	3	2	3	3	3	3	
Arizona	2	2	2	2	2	2	3	3	2	2			3	2	3	3	3	3	2	2	2		3			3	3	3			3	3	3	2	3	3	2	
Arkansas	3	3	2	1	3	3	2	3	2	2			3	3	3	3	3	3	2	3	2	2	3			3	3	2			2	2	2	2	2	2	2	
California-Const.	2	2	2	2	3	3	2	3	2	2			3	1	3	3	3	3	2	3	3	3	3			3	3	1				3	2	2	1	3	2	
California-Maint															2		2			2	2	2									2	2			2			
California-Aer.																																						
Colorado	3	3	2	2	3	3	3	3	2	2			2	2	3	3	3	3	2	3	3	3	3			3	3	2			2	3	3	2	3	3		
Connecticut	2	2	2	2	2	2	2	3	2	2			3	3	3	2	3	3	3	3	2	3	3			3	3	2			3	3	3	2	2	2	2	
Delaware																																						
Delaware-Tpke.	3	3	3	3	3	3	3	3	3	3			3	3	3	3	3	3	2	3	3	3				3	3	3	3		3	3	3	3	3	3	3	
Washington D.C.																																						
Florida	2	3	3	2	3	2	2	3	2	2			3	2	3	3	3	3	3	3	3	3	3			3	3	3			2	3	3	3	3	3	3	
Florida Conslt.			1	1								9																										
Georgia	2	3	3	2	2	2	2	3	2	1			3	2	2	3	3	3	2	3	2	3	2			3	3	2			2	3	2	2	3	2	2	
Hawaii	2	2	2	2	2	2	2	2	2	2			3	2	2	2	2	2	2	2	2	2	2			2	2	2			3	3	3	2	2	2	2	
Idaho	2	3	3	2	3	3	2	3	3	2			3	2	2	2	2	3	3	3	2	3	2			3	3	2			2	3	3	2	3	3	3	
Illinois-Maint.	3	3	3	2	3	3	3	3	2	2			3	2	3	3	3	3	2	2	3	3	3			3	3	2			2	3	3	3	3	3	3	
Illinois-Const.	3	3	3	2	2	3	3	3	3	3			3	3	3	2	3	3	3	3	2	3	3			3	3	2			3	2		2	3	3	3	
Illinois-Toll																																						
Indiana-Const.	2	2	2	1	2	2	2	2	2	2			2	1	2	2	3	3	1	2	2	3	2	2		3	2	2			2	2	2	2	3	2	2	20
Indiana-Oper.																																						
Indiana-Toll	3	3	3	3	3	3	3	3	2	3			3	3	3	3	3	3	2	2	3	3	3			3	3	2	2		2	2	3	3	2	3	3	
Iowa	3	3	2	2	3	3	3	3	3	3	3		3	2	3	3	3	3	3	3	2	3	3	3		3	3	2	3		3	3	3	3	3	3	2	
Kansas	3	3	3	2	3	3	3	3	2	2	3		3	2	3	3	3	3	3	3	3	3	2	3		3	3	2	3		2	2	3	3	3	3	3	
Kansas-Tpke.																																						
Kentucky	2	2	3	2	2	2	2	3	3	2			3	2	2	2	2	3	3	3	2	3	3			2	3	2			3	3	3	2	2	2	2	
Louisiana	3	3	3	3	3	3	3	3	3	3			3	3	3	3	3	3	3	3	3	3	2	3		3	3	2			2	3	3	3	3	3	3	5
Maine	3	3	2	2	3	3	2	3	3	2			2	2	2	3	2	3	2	2	2	2	2			3	3	2			3	3	2	2	3	2	2	
Maryland	3	2	2	2	3	3	2	2	2	2			3	2	2	3	3	3	2	2	2	2	3			3	3	2			2		2	2	2	3	2	
Maryland-Aviat.																																						
Massachusetts	2	2	2	2	2	3	3	3	2	3			3	3	3	3	3	3	3	2	3	3				3	3	2			3	3	3	2	2	2	2	
Massachusetts Tpke.	3	3	3	3	3	3	3	3	3	3			3	3	3	3	3	3	3	3	3	3				3	3	3			3	3	3	3	3	3	3	
Michigan	2	3	3	2	3	3	3	3	2	1			3	2	3	2	3	2	2	2	2	3	3			3	3	2			2	3	3	2	2	2	3	
Minnesota	2	3	3	2	3	3	2	3	3	3			3	2	2	3	3	3	2	3	2	3	3	2		3	3	2	3		2	3	3	2	2	3	3	
Mississippi	3	3	3	2	3	3	3	3	3	3			3	2	3	3	3	3	2	3	3	3	2			3	3	3			3	3	3	3	3	3	3	
Missouri																																						
Montana	2	2	2	2	2	2	2	2	2	2			2	2	2	2	2	2	2	2	2	2	2	2		3	3	2			2	3	3	2	3	3	3	

Legend
1-Severe Problem
2-Occasional Complaint
3-No problem

Operations Area	Earthwork												Paving													Bridge Const.					Misc. Activ.							
Respondants	Excavation	Loading	Hauling (Paved)	Hauling (Unpaved)	Dumping	Spreading	Grading	Compacting	Wind Erosion	Traffic - Dirty Rd.	Other	Violations	Hauling (Paved)	Hauling (Unpaved)	Grading	Dumping	Spreading	Compacting	Priming	Appl. Sand Cover	Sweeping	Road mixing	Asph. Conc. Paving	Other	Violations	Sawing	Curing Compounds	Painting	Other	Violations	Burning (Smoke Emis.)	Mowing	Seeding or Mulching	Sweeping	Sandblasting	Grinding, etc.	Demolition	Violations
Nebraska	3	3	3	3	3	3	3	3	2	2			3	2	3	3	3	3	3	2	3	3	3			3	3	2			2	3	3	3	3	3	3	
Nevada	2	3	3	3	3	3	2	3	3	3			3	3	3	3	3	3	3	3	2	3		2		3	3	3	3		2	3	3	2	3	3	3	
New Hampshire	2	2	1	1	2	2	2	3	2	1			3	2	3	3	3	3	3	2	3	3	3			2	3	2			2	3	2	2	2	2	3	
New Jersey	2	3	2	3	3	3	3	3	2	1	1	1	2	1	3	3	3	3	3	3	3	3	3	2		3	3	3	2		2	3	3	2	2	3	2	5
New Mexico	2	2	2	2	3	3	3	3	1	2			3	2	3	3	3	3	2	2	2	3	3			3	3	3			2	3	3	2	2	2	3	
New York-Const.	3	3	2	2	3	3	3	3	2	2			3	2	3	3	3	3	3	3	2	3	3			3	3	2			3	3	3	2	2	3	2	
New York-Maint	3	3	3	3	3	3	3	3	2	3			3	3	3	3	3	3	3	3	3	3	3			3	3	3			3	3	3	2	3	3	3	
New York-Thruway																																						
New York-P.A.	3	3	3	3	2	3	3	3	2	3			3	3	3	3	3	3	3	3	3	3	3			3	3	2			2	3	3	3	2	2	2	
North Carolina	2	2	3	2	3	2	2	2	2	3			3	2	3	3	3	3	3	3	2	3	3			3	3	2			2	3	2	2	3	3	3	
North Dakota	3	3	3	2	3	3		3	2	2				2	3	3	3	3	3	3	3	3	2			3	3	3	3		3	3	3	3	3	3	3	
Ohio	3	3	2	2	3	3	3	3	3	2			2	2	3	3	3	3	3	3	2	3	3			3	3	3			2	3	3	3	3	2	3	
Ohio-Tpke.																																						
Oklahoma	3	3	3	2	2	3	3	3	2	2			3	2	3	3	3	3	3	3	3	3	3			3	3	2			3	3	3	3	3	3	3	
Okalahoma-Tpke.	2	3	3	2	3	3	2	3	2	3			2	2	3	3	3	3	3	2	3	3				3	3	2			3	3	3	2	3	3	3	
Oregon	3	3	3	2	3	2	2	3	2	2			3	2	3	3	3	3	3	3	2	3				3	3	2			3	3	3	2	2	3	3	
Pennsylvania																																						
Pennsylvania-Tpke.																																						
Puerto Rico																																						
Rhode Island	2	2	3	2	3	3	3	3	3	2			3	2	3	3	3	3	3	3	2	3				3	3	3			3	3	3	2	2	2	3	
South Carolina	2	3	3	2	3	3	2	3	3	3			3	2	3	3	3	3	3	3	2	3	3			3	3	3			2	3	3	2	3	3	3	
South Dakota	3	2	3	2																																		
Tennessee				2						2				2														2						2				
Texas-Const.	2	3	3	2	3	3	3	3	2	2			3	2	3	3	3	3	3	3	2	2	3	2		3	3	2			2	3	2	2	3	3	3	
Texas-Aer.																																						
Texas-Tpke.	2	2	3	2	3	3	3	3	3	2			3	1	3	1	3	3	3	3	1	2	3			2	2	2			3	3	3	2	2	2	3	
Utah	2	2	3	1	3	3	2	3	1	2			3	1	2	3	3	3	3	1	1	1	3			3	3	2			1	3	3	2	1	2	2	
Vermont	3	3	3	2	3	3	3	3	2	2			3	2	3	3	3	3	3	3	2	3	3	2		3	3	2			2	3	3	2	2	3	3	
Virginia	3	3	3	3	3	3	3	3	3	3			3	3	3	3	3	3	3	3	3	3	3			3	3	3			3	3	3	3	3	3	3	
Washington	2	3	3	2	3	3	2	3	2	2	2		3	2	3	3	3	3	3	3	2	3	3	2		3	3	2	2		2	3	3	2	3	3	2	
West Virginia	3	3	2	1	3	3	3	3	2	2			3	2	3	3	3	3	3	3	2	3	3			3	3	3			2	3	3	2	3	3	2	
Wisconsin	3	3	2	2	3	3	3	3	3	2	3		3	2	3	3	3	3	3	3	2	2	2			3	3	2			2	3	3	2	2	3	3	
Wyoming	2	3	3	2	3	3	3	3	2	2			3	2	3	3	3	3	3	3	3	3	2	2		3	3	3			3	3	3	3	3	3	3	
Average	2.5	2.7	2.6	2.1	2.8	2.8	2.6	2.9	2.3	2.2			2.8	2.1	2.8	2.8	2.9	2.9	2.7	2.7	2.4	2.8	2.7			2.9	2.9	2.3			2.4	2.9	2.8	2.3	2.5	2.7	2.7	

TABLE B-2
MITIGATION METHODS USED

Legend

20 = % of use

Respondants	Applying Water	Calcum Chloride	Mixing Type Asphalt Emul.	Other Asphalt Products	Dust Palliatives	Topping Oil	Lignin Sulfite	Paper Mill Waste	Proc. Reclaimed Oil	Mulching	Clean Rock Blanket	Wet Blast
Alabama	80	20										
Alaska		15				60	5		20			
Arizona	100											
Arkansas	85	10	5									
California-Const.	92	2	5				1					
California-Maint.	85		15									
California-Aer.												
Colorado	85		10	5								
Connecticut	50	50										
Delaware												
Delaware-Tpke.	95	5										
Washington D.C.												
Florida	90	10										
Florida-Pollut.												
Georigia	100											
Hawaii	95		5									
Idaho	95		3	2								
Illinois-Maint.	90	3		7								
Illinois-Const.	90	3		7								
Illinois-Toll												
Indiana-Const.	97	1	1	1								
Indiana-Oper.												
Indiana-Toll												
Iowa	40	60										
Kansas	95	1		4								
Kansas-Tpke.												
Kentucky	85	14		1								
Louisiana	90		10									
Maine	40	60										
Maryland-Const.	80	20										
Maryland-Aviat.												
Massachusetts	30	65		5								
Massachusetts-Tpke.	95	5										
Michigan	80	20										
Minnesota	90	7		3								
Mississippi	90		5	5								
Missouri												
Montana	99			1								

Legend 20 = % of use Respondants	Applying Water	Calcuum Chloride	Mixing Type Asphalt Emul.	Other Asphalt Products	Dust Palliatives	Topping Oil	Lignin Sulfite	Paper Mill Waste	Proc. Reclaimed Oil	Mulching	Clean Rock Blanket	Wet Blast
Nebraska	10	5		85								
Nevada	95			5								
New Hampshire	85	15										
New Jersey	99	1										
New Mexico	100											
New York-Const.	90	5								5		
New York-Maint.	20	80										
New York-Thruway												
New York-P.A.	60			30								10
North Carolina	95	5										
North Dakota	90	5		5								
Ohio	80	20										
Ohio-Tpke.												
Oklahoma	95			5								
Oklahoma-Tpke.	50			50								
Oregon	92			3								5
Pennsylvania												
Pennsylvania-Tpke.												
Puerto Rico												
Rhode Island	80	20										
South Carolina	100											
South Dakota	98				2							
Tennessee	85	15										
Texas-Const	80			20								
Texas-Aer.												
Texas-Tpke.	100											
Utah	80	4	10	6								
Vermont	95	5										
Virginia	97	2		1								
Washington	80		5	15								
West Virginia	80	19		1								
Wisconsin	90	8						2				
Wyoming	100											
TOTAL NO. OF USERS	54	34	11	23	1	1	2	1	1	1	1	1
AVERAGE % OF USE	83	17	7	12	2	60	3	2	20	5	5	10

APPENDIX C
STANDARDS FOR CONTROL OF PARTICULATE EMISSIONS

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Alabama	Federal	Federal	No fugitive dust beyond property line. Abatement: Reasonable precautions, plus first 3 paragraphs of Federal model.
Alaska	Federal	Federal	No visible dust past property line. Abatement: First 3 paragraphs of Federal model.
Arizona	Federal secondary	Air Quality Goal: 100 $\mu g/m^3$ maximum 24-hour average.	Fugitive dust from hauling, handling, crushing or conveying of materials must be controlled by reasonable means.
Arkansas	Federal	Federal	May not exceed 75 $\mu g/m^3$ for any 24-hour period or 150 $\mu g/m^3$ for any 30-minute period (measured on property and subtracting background). Abatement: Reasonable precautions. Dust fall: maximum 15 tons/mile^2/month. Particles larger than 60 microns may not exceed 120/cm^2/24 hours.
California	Nonvehicular standards and regulations are set by counties.		Fugitive dust regulations are devised by each county. Those with appliable regulations call for "reasonable precautions."
Colorado	Federal	Federal	If emissions are judged by a panel to be "objectionable," may require use of "best practical method" of control. Controls must be applied during non-working hours as required to control dust. No visible emissions may cross property line.
Connecticut	Federal	Federal	Reasonable precautions, plus Federal model, except paving of roads not required and agricultural operations need not suppress dust. No discharge beyond property line if: 1. visible near ground. 2. impinges on building or structure.
Delaware	70 $\mu g/m^3$ annual geometric mean of 24-hr. concentration. 200 $\mu g/m^3$ 24-hr. average concentration, not to be exceeded more than once per year. 500 $\mu g/m^3$ one hour average.	Federal	Water, chemicals or approved techniques must be used to control dust emissions during demolition, grading, land clearing, excavation and uses of unpaved roadways.
District of Columbia	Federal	Federal	Federal model, except that agricultural operations receive no specific mention.

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Florida	Federal secondary, except in Dade, Broward and Palm Beach Counties, where the following apply: 50 $\mu g/m^3$ annual geometric mean. 180 $\mu g/m^3$ maximum 24-hr. concentration.		Fugitive dust in excess of process emissions rate is prohibited. Reasonable precautions to abate fugitive dust are required.
Georgia	Federal	Federal	Federal model
Hawaii	100 $\mu g/m^3$ during any 24 hours 55 $\mu g/m^3$ annual arithmetic mean during any 12-month period.		No visible dust past property line. Ground level concentration at a point selected by the Department may not exceed 150 $\mu g/m^3$ above background. Dust fall may not exceed 3.0 grams per square meter per 14 days. Abatement by Federal model, except that Director may determine that "best practical" measures are sufficient.
Idaho	Federal	Federal	"All reasonable precautions" plus Federal model.
Illinois	Federal, plus no degradation of regional air quality permitted.	Federal	No emissions larger than 40 microns mean diameter. No emissions beyond property line visible when looking toward zenith. Not applicable in winds greater than 25 mph.
Indiana	Federal	Federal	No visible dust over property line. May not exceed 166 percent of upwind values, nor more than 50 $\mu g/m^3$ at ground level above background more than 60 minutes.
Iowa	Federal	Federal	No fugitive dust beyond property line. Federal model for abatement, except that no mention is made of agricultural dust suppression or paving of roads.
Kansas	Federal	Federal	Airborne particulates at ground level at property line may not equal 2.0 μg per cubic meter, above background, more than 10 min/hr.
Kentucky	Federal	Federal	No fugitive dust beyond property line, plus Federal model, except (1) no requirement that roads be paved, and (2) agricultural operations can create airborne dust if no nuisance created. Secondary dust fall standard: 15 ton/mi^2/month.

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Louisiana	Federal	Federal	Dust fall: 20 tons/square mile/month Coefficient of Haze: 0.6 coh/1000 lineal ft., annual geometric mean 0.75 coh/1000 lineal ft., annual arithmetic mean 1.50 coh/1000 lineal ft., 24-hr. average. Abatement by Federal model.
Maine	100 $\mu g/m^3$ 24-hour average 50 $\mu g/m^3$ annual geometric mean of 24-hour averages.		
Maryland	Primary: lowest concentrations attainable by reasonably available control methods, but not to exceed concentrations set forth as "secondary standards.	Annual arithmetic average: "More adverse": Lower Limit Upper Limit Serious 65 $\mu g/m^3$ 75 $\mu g/m^3$ 75 $\mu g/m^3$ daily average, once per year: 140 $\mu g/m^3$ 160 $\mu g/m^3$ 160 $\mu g/m^3$ dustfall, $mg/cm^2/mo$ 0.35 0.50 0.50	Federal abatement model, except no mention of agricultural operations.
Massachusetts	Federal	Federal	Reasonable precautions required. Fugitive dust from process industries, from transport or handling of materials, or from construction use and maintenance of roads may not "contribute to a condition of air pollution."
Michigan	Federal	Federal	Treated as a nuisance. Area of cut and fill open at one time is limited.
Minnesota	Federal	Federal	"Avoidable amounts" of dust must not become airborne. Director may order reasonable measures to be taken, including paving and frequent cleaning of roads, application of dust free surfaces, use of water and maintenance of vegetative ground cover.
Mississippi	Federal	Federal	Fugitive particulate matter must not become airborne as a result of handling, storage, or transport of any material. Dust fall may not exceed background levels by 5.25 grams/m^2/month on adjacent property.
Missouri			Reasonable precautions required. No fugitive dust or particles larger and 40 microns permitted beyond property line. Concentrations at property line: Suspended particulates 80 $\mu g/m^3$ 6-month geometric mean 200 $\mu g/m^3$ 2-hr arithmetic mean, for no fewer than 5 samples per year.

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Montana	Federal	Federal	Reasonable precautions must be taken; no "controllable" particulate matter may be emitted. Specific measures may be ordered by the Director.
Nebraska	Federal	Federal	No visible dust may pass over property line. Measures to control fugitive dust may include paving, frequent cleaning of roads, application of dust free surface, planting and maintenance of vegetation cover.
Nevada	Federal	Federal	Reasonable precautions are required. No visible airborne dust may cross property line.
New Hampshire	Federal Secondary		Roads, storage areas, etc. shall be controlled to confine dust.
New Jersey	Ambient air quality must be highest achievable at present state of the art, but in no case may it be worse than the Federal primary standard.	Federal	No standard or model.
New Mexico	*150 $\mu g/m^3$ 24-hour average 110 $\mu g/m^3$ 7-day average 90 $\mu g/m^3$ 30-day average * 60 $\mu g/m^3$ annual geometric mean * together comprise Federal secondary		No standard or model.
New York	State includes 4 "levels" from Level I: sparse population, to Level IV: Metropolitan. Short term (all levels) average 24-hr. concentration shall not exceed 250 $\mu g/m^3$. Long term: during 12 months, 50 percent of 24 hr. concentrations may not exceed: Level I: 55 $\mu g.m^3$ Level II: 65 $\mu g/m^3$ Level III: 65 $\mu g/m^3$		Dust fall: During any 12 months, 50 percent of 30-day values shall not exceed: ($mg/cm^2/mo$) Level I: 0.30 Level III: 0.40 Level II: 0.30 Level IV: 0.60 During any 12 months, 84 percent of 30-day values shall not exceed ($mg/cm^2/mo$): Level I: 0.45 Level III: 0.60 Level II: 0.45 Level IV: 0.90

Jurisdictions	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
	Level IV: 75 $\mu g/m^3$ and 84 percent of 24-hr. values shall not exceed: Level I: 45 $\mu g/m^3$ Level II: 85 $\mu g/m^3$ Level III: 100 $\mu g/m^3$ Level IV: 110 $\mu g/m^3$		
North Carolina	Federal Secondary		Asphalt plants must limit fugitive dust to stack outlet. Roads must be treated around plant. In road construction, use of dust control on haul roads and water sprays over crushers for stone and aggregate handling are required.
North Dakota	Federal Secondary		Dust fall: 15 tons/mi^2/mo, maximum 3-month arithmetic mean in residential areas. 30 tons/mi^2/mo, applies to heavy industry areas. 0.4 coefficient of haze/ 1000 lineal feet, maximum annual geometric mean. "Reasonable precautions" plus Federal model.
Ohio	Federal Secondary		Reasonable precautions plus Federal model.
Oklahoma	Federal	Federal	Reasonable precautions to control fugitive dust are mandatory.
Oregon	Highest and best technology must be applied. Standards measured at "primary stations:" 60 $\mu g/m^3$ annual geometric mean 100 $\mu g/m^3$ 24-hr concentration not to be exceeded by 15 percent of monthly samples. 150 $\mu g/m^3$ 24-hr concentration.		Abatement by Federal model, less mention of agricultural operations of paving roads. Stockpiles of materials should be enclosed where other means do not control dust.
Pennsylvania	Federal	Federal	Dust fall: annual average 0.8 mg/cm^2/mo. 30-day average 1.5 mg/cm^2/mo. In all roadwork and land clearing fugitive dust must be confined to property, and not exceed 150 particles per cubic centimeter at property line. Abatement by Federal model, except no call for hoods, fans, or covering of trucks.
Puerto Rico	Federal	Federal	No fugitive dust in visible quantities may be permitted to cross property line. Abatement by Federal model.

Jurisdictions	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Rhode Island	Federal	Federal	No emissions to air from handling, transportation or storage of materials. Abatement by reasonable precautions during construction.
South Carolina	60 $\mu g/m^3$ annual geometric mean 250 $\mu g/m^3$ 24-hr. average		Dust control measures must be used on premises and roads of mining, quarrying and other unenclosed operations.
South Dakota	Federal Secondary		
Tennessee	Federal	Federal	Visible dust emissions may not pass proper property line more than 5 min/hr or 20 min/day. Abatement by Federal model, first three paragraphs only.
Texas	Federal Emissions from any source may not exceed: 100 $\mu g/m^3$ average over 5 hrs. 200 $\mu g/m^3$ average over 3 hrs. 400 $\mu g/m^3$ average over 1 hr.	Federal	Materials-handling dust must be controlled by use of water or chemicals, use of hoods and fans, and covering or wetting truck-bed loads. During road construction, dust suppression is required on all haul roads.
Utah	Federal	Federal	
Vermont	45 $\mu g/m^3$ annual geometric average 125 $\mu g/m^3$ daily average		Reasonable precautions must be exercised in road construction activities.
Virginia	Federal, except in National Capital Air Quality Control Region, where Federal secondary standards must be met.	Federal	Federal model, except control of agricultural emissions not required.
Virgin Islands	Federal	Federal	All reasonable measures, including watering and coating of roads, must be used during road construction.
Washington	Federal Secondary		Reasonable precautions are required.
West Virginia	Federal	Federal	
Wisconsin	Federal	Federal	Abatement by Federal model.
Wyoming	Federal Secondary coh-0.4/1000 lineal ft. annual geometric mean.		Dust fall: 5 gm/m^2/mo for any 30-day period in a residential area. 10 gm/m^2/mo for any 30-day period in an industrial area. Abatement by Federal model.

APPENDIX D

OPEN-BURNING REGULATIONS

Respondents	Permitted For Land Clearing	Under Conditions Of Necessity Only	Under Conditions Of Location	Under Conditions Of Meteorology	Under Conditions Of Time Of Day	Under Conditions Of Method Used	Under Other Special Conditions	Other Conditions
Alabama	X							
Alaska	X							
Arizona	not permitted							
Arkansas	not permitted							
California	X							
Colorado	X	X	X	X		X		
Connecticut	X		X		X			
Delaware			X	X			X	Not permitted north of Chesapeake and Delaware Canal.
District of Columbia	not permitted							
Florida	X		X			X	X	Fuel in dry state
Georgia	X		X	X			X	Materials limited
Hawaii	not permitted							
Idaho	X	X					X	No fire or traffic hazard
Illinois	X						X	Certain airsheds are restricted.
Indiana	not permitted							Variances possible under "severe and extreme economic hardship."
Iowa	X						X	Variances may be granted by local jurisdictions.
Kansas	X		X		X		X	Frequency is limited
Kentucky	X	X				X		Visible emissions may not be darker than Ringelmann 2.
Louisiana	X		X	X	X			
Maine	X	X	X	X				
Maryland	X	X					X	Only permitted if absolutely necessary and meets strict standards.

Respondents	Permitted For Land Clearing	Under Conditions Of Necessity Only	Under Conditions Of Location	Under Conditions Of Meteorology	Under Conditions Of Time Of Day	Under Conditions Of Method Used	Under Other Special Conditions	Other Conditions
Massachusetts	X	X						
Michigan	X		X					
Minnesota	X		X	X				
Mississippi	X							
Missouri	X							
Montana	X						X	All materials >4" diameter must be salvaged.
Nebraska	X						X	Unless locally prohibited.
Nevada	not permitted							
New Hampshire	X							
New Jersey	not permitted							
New Mexico	X						X	Discretion of Director
New York	X							
North Carolina	X		X					
North Dakota	X		X	X	X			
Ohio	X		X			X		
Oklahoma	X	X	X	X	X		X	Fugitive dust control
Oregon	X						X	Except in special control areas.
Pennsylvania	X							Not permitted in any air basin. Visible emissions beyond property line forbidden.
Puerto Rico	X	X						
Rhode Island								
South Carolina	X		X	X	X	X	X	Salable wood must be salvaged.
South Dakota	X		X	X	X			

Respondents	Permitted For Land Clearing	Under Conditions Of Necessity Only	Under Conditions Of Location	Under Conditions Of Meteorology	Under Conditions Of Time Of Day	Under Conditions Of Method Used	Under Other Special Conditions	Other Conditions
Tennessee	X						X	Unless hazard created
Texas	X		X	X	X		X	Materials and frequency controlled
Utah	X						X	Fugitive dust control
Vermont	X						X	Not permitted in forest areas
Virginia	X						X	Timber >4" diameter must be salvaged.
Virgin Islands	X						X	
Washington								
West Virginia	X							
Wisconsin	X						X	Not permitted in S.E. A.Q.C.R.
Wyoming								

APPENDIX E

FUGITIVE PARTICULATE TESTING PROGRAM

DESCRIPTION

As summarized in Chapters One and Two of this report, a fugitive particulate testing program was performed as part of the research. This appendix provides additional technical information relating to the testing program, sampling site plans, photographs of test sites and operations, test data tables, and microscopy reports.

Particulate matter for which Federal ambient air quality standards have been promulgated *(4)* is defined as any solid or liquid aerosol that has a diameter between 0.0002 μ to 500 μ *(25)*. Such sized particles can remain suspended for a prolonged time or settled within a few minutes. The lifetime in a suspended state depends on the size, density, and meteorology.

Gravitational settling of particles larger than 1 μ is described by Stokes' Law:

$$v = gd^2\ (\rho 1 - \rho 2)/18\eta \qquad \text{(E-1)}$$

where v = settling velocity, cm/sec; g = acceleration of gravity, cm/sec^2; d = spherical diameter, cm; ρ_1 = density of particle; ρ_2 = density of fluid; and η = viscosity of air, poise.

Below 1 μ, particles are small enough that individual collisions with gaseous molecules take place, and Stokes' Law would underestimate settling velocity. However, the theory does little to describe the actions of particles in an open environment. Meteorological factors play an important role in the distribution of particulate matter. Also, the nonspherical shape of particles can cause greater retention time.

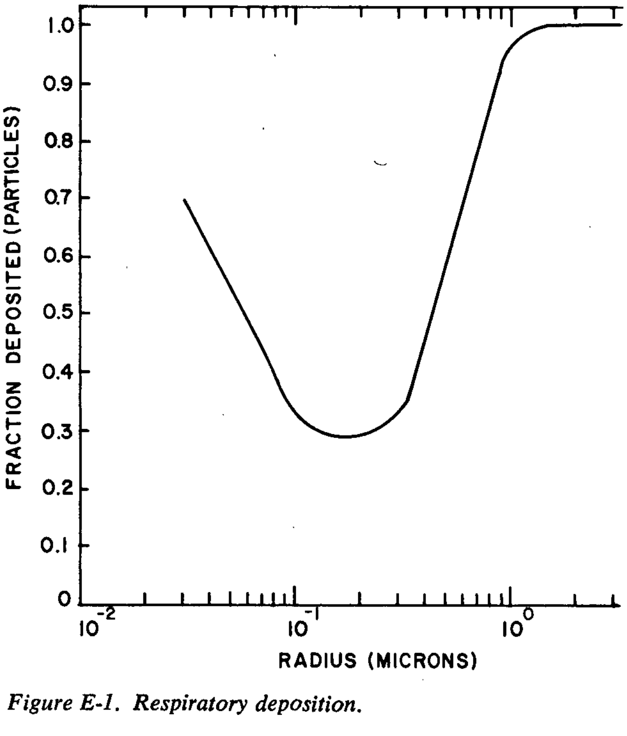


Figure E-1. Respiratory deposition.

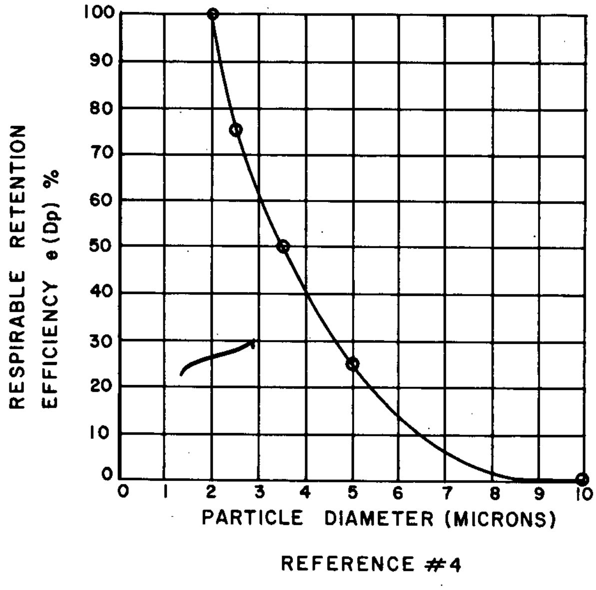
The significance of particle size may be determined from studies of deposition in the lungs. Deposition of particulate matter in the respiratory system is a function of particle size, as shown in Figure E-1 *(25)*.

The particular shape of the curve is caused by the different characteristics of the nasopharynoeal, pulmonary, and trachiobronchial compartments of the respiratory system. The particulate matter deposited is not always retained because of various clearing mechanisms. These mechanisms would include ciliary transport of mucus to the entrance of the gastrointestinal tract and transport to the ciliated region by macrophages. Clearing deposited particles is particle-size dependent, as shown in Figure E-2 *(26)*.

Whereas particle size is a direct functional relationship in determining deposition and retention of particulate matter in the lungs, toxic effects are not so easily defined. Health effects of particulate matter can be caused by one or more of the following mechanisms *(25)*:

1. The chemical and/or physical characteristics of the particle intrinsically may be toxic.
2. The particle may reduce the efficiency of the cleaning mechanism of the lung.
3. The particle may absorb toxic substances.

The actual toxicity effects cannot be readily determined because substances that may be inert could produce toxic responses under high concentrations. In addition, inert particles could act as carriers of toxic substances such as carcinogens. Epidemiological studies are the main deter-



REFERENCE #4

Figure E-2. Respirable retention.

mination of toxic effects of air pollutants. Such studies have determined a higher incidence of lung cancer in urban environments as compared to rural ones.

In addition to health effects, there are effects on climate, visibility, vegetation, materials, and odor (*25*). These effects are summarized as follows:

1. Visibility is reduced to as low as 5 mi with concentrations of particulate 150 $\mu g/m^3$ with size of 0.2 to 1 μ and relative humidity less than 70 percent.
2. Corrosion of steel and zinc occurs at an accelerated rate at concentrations from 60 $\mu g/m^3$ (annual geometric mean) in the presence of sulfur dioxide and moisture.
3. Sunlight can be reduced up to one-third and two-thirds with concentrations of particulates from 100 $\mu g/m^3$.

PARTICULATE MATTER SAMPLING

The promulgated reference method for particulate determination is the High Volume Method (*4*). The determination of particulate matter is made by filtering a large volume of air through a glass fiber filter that is enclosed in a specially constructed housing. The mass concentration is computed by measuring the mass collected on the glass filter and knowing the volume flow.

The glass filter media used was capable of measuring 99 percent of the particles greater than 0.3 μ in diameter. Each filter was given a specific number and tare weighted to the nearest tenth of a milligram.

The High Volume samplers were manufactured by General Metal Works, Inc. and Bendix Corporation. The design of the housing was similar (i.e. allowing shelter and providing clearance of 580.5 ± 193.5 cm^2 as required in the reference method). Figure E-3 shows a typical sampler housing. The physical characteristics of housing prevent particles having a diameter of 100 μ or more from being collected. The motor is capable of filtering 40 to 60 CFM for a normal sampling time of 24 hr (from midnight to midnight).

In order to assure accurate flow, the motor must be calibrated with a rotometer. This was accomplished with equipment specified in the reference method. The calibration equipment consisted of a calibrated orifice, a monometer, and restricting plates. A graph of the rotometer versus actual flow (as derived from the calibrated orifice) was made and used to determine all flows. Calibration occurred at frequent intervals (at least once per month) during the study.

The handling, collection, and preparation of filters were as specified in the reference method. Care was taken during collection and weighing, so that little human error was introduced.

The final determination of particulate mass concentration was made with the following equation:

$$\text{mass concentration } (\mu g/m^3) = \frac{\text{weight of sample (g)} \times (10^6\ \mu g/g)}{\text{volume flow } (m^3/\text{time}) \times \text{time sample}} \qquad \text{(E-2)}$$

Figure E-4 shows the worksheet used in sampling.

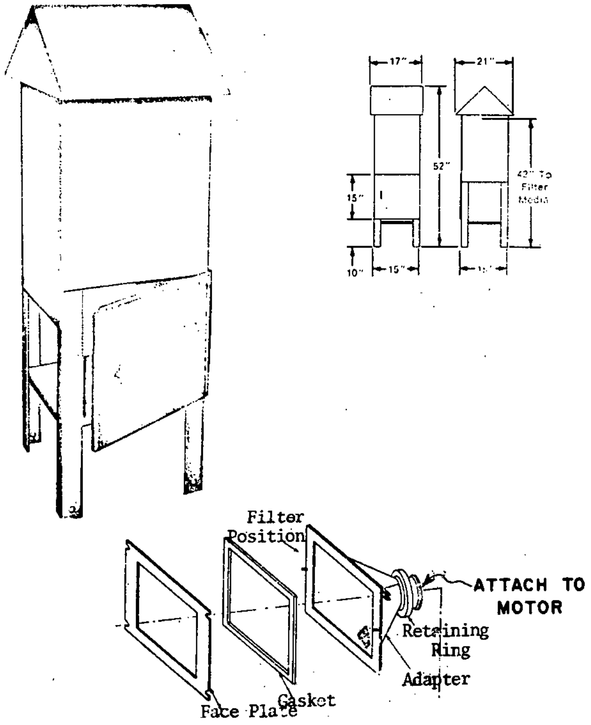


Figure E-3. High volume sampler and filter paper mount.

PARTICLE SIZING

For the determination of particle size, a cascade impactor (a Sierra Instruments Model 234 4-stage impactor adaptable to High Volume samplers) was used. The impactor collects particles on a series of collection stages according to the aerodynamic dimension of the particles. The collection plates are staggered with apertures decreasing in size to sequentially impact smaller particles on collection paper.

A significant parameter in collection is the cutoff diameter (i.e., the equivalent aerodynamic diameter at which 50 percent of the particles at that diameter are collected). The cutoff diameter, D_p, can be calculated from the following equation (*26*):

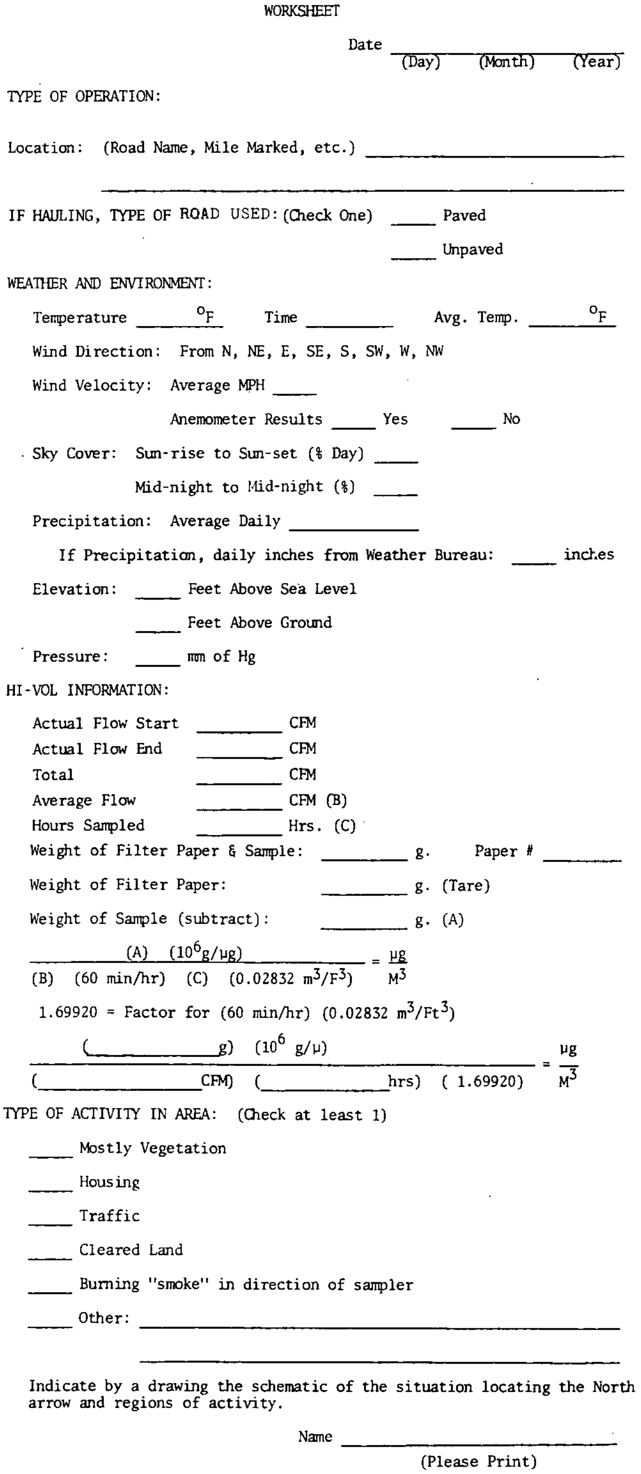
$$D_P = N_{DM} W \sqrt{9\eta L / C \rho Q} \qquad \text{(E-3)}$$

where N_{DM} = square of Stokes' number; W = slot width, cm; η = gas viscosity, gm/cm sec; L = slot length, cm; ρ = particle mass density, gm/cc; C = cunningham slip correction; and Q = flow rate.

For a flow rate of 40 SCFM at 25 C and 760 mm Hg, the cutoff diameter of a 1-gm/cc particle is as follows:

STAGE NO.	CUTOFF DIAMETER (μ)
1	10.0
2	4.9
3	2.7
4	1.3

Using the cutoff diameter equation, corrections can be made for particle density and flow.



WORKSHEET

Date ____ ____ ____
(Day) (Month) (Year)

TYPE OF OPERATION:

Location: (Road Name, Mile Marked, etc.) ____________________

____

IF HAULING, TYPE OF ROAD USED: (Check One) ____ Paved

____ Unpaved

WEATHER AND ENVIRONMENT:

Temperature ____ °F Time ____ Avg. Temp. ____ °F

Wind Direction: From N, NE, E, SE, S, SW, W, NW

Wind Velocity: Average MPH ____

Anemometer Results ____ Yes ____ No

Sky Cover: Sun-rise to Sun-set (% Day) ____

Mid-night to Mid-night (%) ____

Precipitation: Average Daily ____

If Precipitation, daily inches from Weather Bureau: ____ inches

Elevation: ____ Feet Above Sea Level

____ Feet Above Ground

Pressure: ____ mm of Hg

HI-VOL INFORMATION:

Actual Flow Start ____ CFM

Actual Flow End ____ CFM

Total ____ CFM

Average Flow ____ CFM (B)

Hours Sampled ____ Hrs. (C)

Weight of Filter Paper & Sample: ____ g. Paper # ____

Weight of Filter Paper: ____ g. (Tare)

Weight of Sample (subtract): ____ g. (A)

$$\frac{(A)\quad (10^6 g/\mu g)}{(B)\quad (60\ min/hr)\quad (C)\quad (0.02832\ m^3/F^3)} = \frac{\mu g}{M^3}$$

1.69920 = Factor for (60 min/hr) (0.02832 m^3/Ft^3)

$$\frac{(\underline{\qquad\qquad} g)\quad (10^6\ g/\mu)}{(\underline{\qquad\qquad} CFM)\quad (\underline{\qquad\qquad} hrs)\quad (\ 1.69920)} = \frac{\mu g}{M^3}$$

TYPE OF ACTIVITY IN AREA: (Check at least 1)

____ Mostly Vegetation

____ Housing

____ Traffic

____ Cleared Land

____ Burning "smoke" in direction of sampler

____ Other: ____________________

____

Indicate by a drawing the schematic of the situation locating the North arrow and regions of activity.

Name ____________________
(Please Print)

Figure E-4. Worksheet.

The collection paper placed between stages is a hi-volume filter paper manufactured specifically for the job. The impactor is placed on a High Volume sampler and used in conjunction with ambient particulate matter sampling. Figure E-5 shows the casade impactor. The total mass on all stages is summed and the percent less than the 50-percent cutoff is determined. Size, D_P, for each stage is plotted against percent less than cumulative frequency on log normal probability paper.

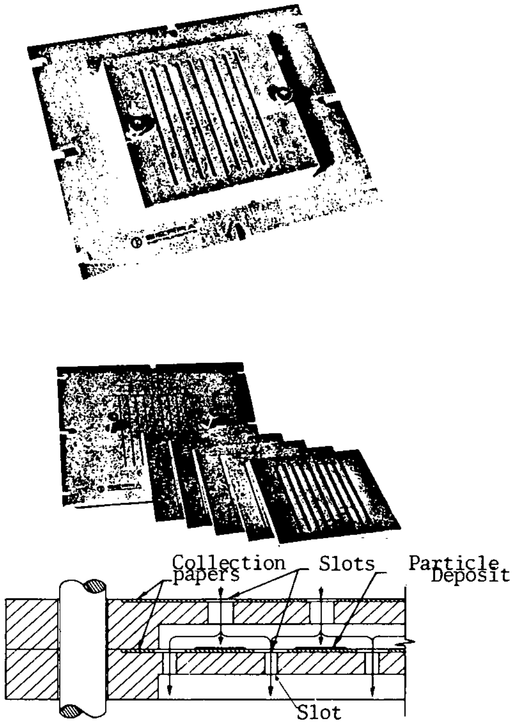


Figure E-5. Cascade impactor (source: Sierra Instruments, Bulletin No. 173-230).

MICROSCOPY

Microscopy, or morphological analysis, was used to identify the source of the particulate matter collected. Basically, microscopy employs certain microscopic techniques to study particles. In air pollution, important applications are:

1. Determination of the composition of a given air pollutant and, as a result, the source of the pollutant.
2. Identification of general types and sources of air pollution over a given area.
3. Determination of concentration of a given pollutant.
4. Study of "tracer" emissions to determine dispersion.

Characteristics not readily apparent by normal vision are accented when making observations under a microscope. Morphological characteristics such as size, shape, surface marking, transparency, translucency, opacity, occlusions, color, birefringence, refractive index, and conoscopic observations are used to identify the air pollutants.

The analytical procedures for this analysis were those specified in Refs. (*6*) and (*27*) for determination of particulate matter by physical characteristics. Analyses to determine refractive index were not made because of the complexity involved.

The basic objective of microscopic analysis in this testing program was to identify a given source (i.e., highway construction activity) and to do a comparative analysis with ambient samples. Characteristics such as shape, color, surface marking, and transparency were the prime identifying factors.

METEOROLOGICAL DATA

In order to determine the influences of certain meteorological factors, meteorological data were obtained through the National Weather Service and by an on-site wind recording system.

The wind recording system was an Ecowind III manufactured by Wong Laboratories. The instrument has a threshold of sensitivity of 0.75 mph and is accurate within 0.5 mph. The wind direction was damped, with low response time.

The data of wind speed and direction were recorded on special chart paper for analysis. As noted in Chapter Two, biasing occurred in spite of the precautions taken in analyzing the data from the charts. The following equations were used to develop the unbiased curve:

$$PF_c = PF - PF\,\frac{Ne - No}{2Ne}$$
$$SF_c = SF - SF\,\frac{Ne - No}{2No} \qquad \text{(E-4)}$$

where PF_c = principal frequency corrected; PF = principal frequency; SF_c = secondary frequency corrected; SF = secondary frequency; Ne = sum of principal frequencies; and No = sum of secondary frequencies.

AIR MONITORING TRAILERS

Two air monitoring trailers were loaned by the Florida Department of Pollution Control for use in the research. These trailers had an over-all length of 11 ft (3 m) and width of 3.3 ft (1 m) excluding wheels.

A housing to hold various instruments and equipment was constructed from ¾ in. (1.0 cm) and ⅜ in. (1 cm) plywood and had dimensions of 2 ft × 4 ft × 3.3 ft (0.6 × 1.2 × 1 m). Aluminum sheeting was used for weather protection on the sides and top. The interior was painted to protect against moisture.

The High Volume sampler stands were constructed from ⅛ in. × 2 in. × 2 in. (0.3 × 5.1 × 5.1 cm) aluminum angle fastened to a front portion of ¾ in. (1.9 cm) plywood. The stand height made the filter paper height 10.1 ft (3 m) above grade.

The wind measuring instruments were placed on a tripod between the housing and the High Volume sampler stand. The height of measurement was 13.5 ft (4 m) to give representative wind measurements.

Housed in the trailer were the timer and wind recorder. The timer was a 7-day type made by Paragon Electric Co. (Model 7008-0). Other miscellaneous tools, rotometer, etc. were also kept in the trailer.

Each trailer was equipped with two samplers, one attached to the sampler stand and the other placed on the ground near the trailer. Many of the figures that follow show trailers in field use.

SAMPLING SITES

For determining the impact of fugitive dust from highway construction and maintenance operations on the ambient air, three projects were chosen for study in the Orlando, Fla., area; two projects in the Richmond, Va., area; and two projects in the Newark, N.J., area.

The major location of study was Aloma Avenue (State Road 426) located in Winter Park, Orange Co., Fla. This project encompassed the expansion of a heavily traveled major arterial road from two lanes to four lanes over a distance of about 1.5 mi. Seven of the 14 sampling locations were selected here. The road handles heavy urban traffic during normal rush hours and has a variety of adjacent land uses that include light residential, heavy residential, and commercial. The speed limit of this roadway is 35 mph.

State Road 436 was selected as a project for study for two sampling locations. Although this road has similar characteristics to Aloma Avenue, it is more open (i.e., distances from surrounding buildings are greater and the speed limit is higher, about 50 mph). The expansion to four lanes on this project was also more complete than that on Aloma Avenue.

The Maitland interchange on I-4 in Maitland, Fla., was used to illustrate the effects of unpaved haul roads and distance from the road.

In Richmond, Va., a paved haul road, Douglasdale Road, was selected because it received some watering for control of fugitive dust. Another Richmond project near French Road was selected because of excavation and unpaved and paved haul road effects. Other various construction activities were also being performed.

A "jackhammer" operation was measured on the New Jersey Turnpike. A contractors' maintenance and storage yard in Jersey City, N.J., provided data on these types of activities.

Table E-1 summarizes these locations. Maps, photo-

TABLE E-1

SAMPLING LOCATIONS

Site No.	
1	Aloma Avenue, Near and Intersection, Winter Park, Fl
2	Aloma Avenue, Directly North of Site No. 1, Winter Park, Fl
3	Aloma Avenue, Parking Lot, Winter Park, Fl
4	Aloma Avenue, Variety of Construction Activities, Winter Park, Fl
5	State Route 436, Sweeping of Asphalt, Forest City, Fl
6	State Route 436, Variety of Construction Activities, Forest City, Fl
7	Aloma Avenue, Distance from Construction, Winter Park, Fl
8	Aloma Avenue, Distance from Construction, Winter Park, Fl
9	Aloma Avenue, Additional Documentation, Winter Park, Fl
10	Interstate-4, Unpaved and Paved Haul Road, Maitland, Fl
11	Douglasdale Road, Paved Haul Road, Richmond, Virginia
12	French Street, Excavation Activities, Richmond Virginia
13	New Jersey Turnpike, Jack Hammer Operation, Newark, NJ
14	Contractors Yard, Maintenance and Storage, Jersey City, NJ

graphs, data tables, particle size data, and microscopy reports compiled during the fugitive dust testing program are presented in Figures E-6 through E-17, Figures E-18 through E-31, Tables E-2 through E-19, Figures E-32 through E-40, and Figures E-41 through E-52, respectively. The legend for the site plans locations of the High Volume samplers (Figs. E-6 through E-17) is as follows:

LEGEND:

T	TRAILER MOUNTED SAMPLER
G	GROUND SAMPLER
▨	BUILDING
░	CONCRETE (SIDEWALK, ROAD, ETC.)
▭	PAVEMENT
▭	GRASS AREAS
▭	CONSTRUCTION AREA (EXCAVATION, UNPAVED, ETC.)

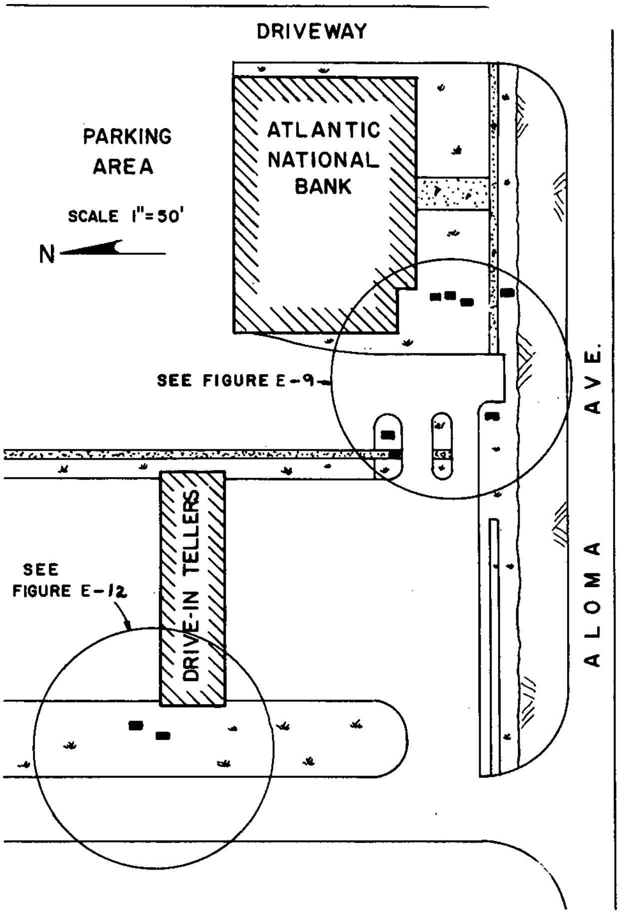


Figure E-6. Composite sampling sites.

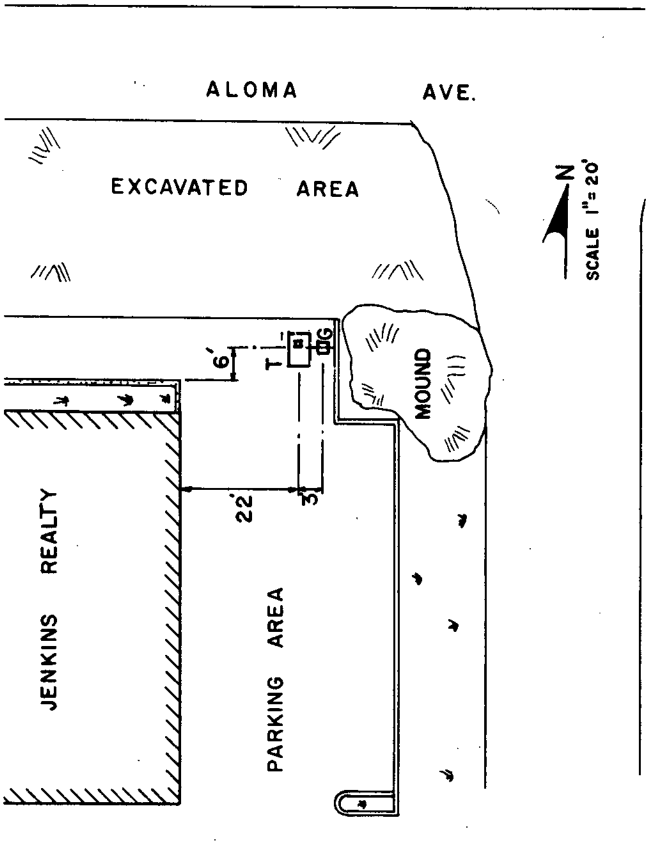


Figure E-7. Sampling site #1.

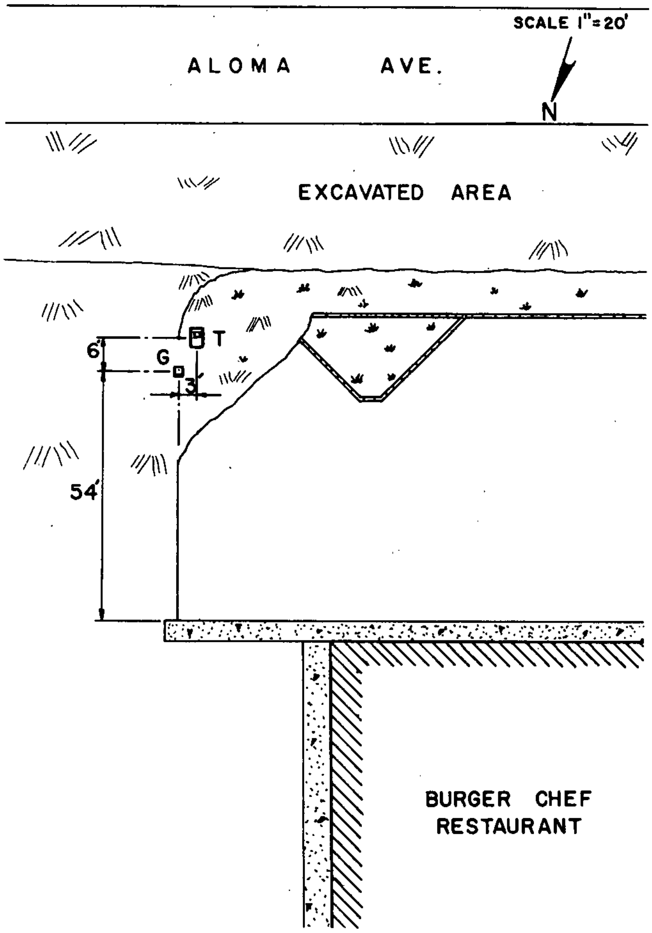


Figure E-8. Sampling site #2.

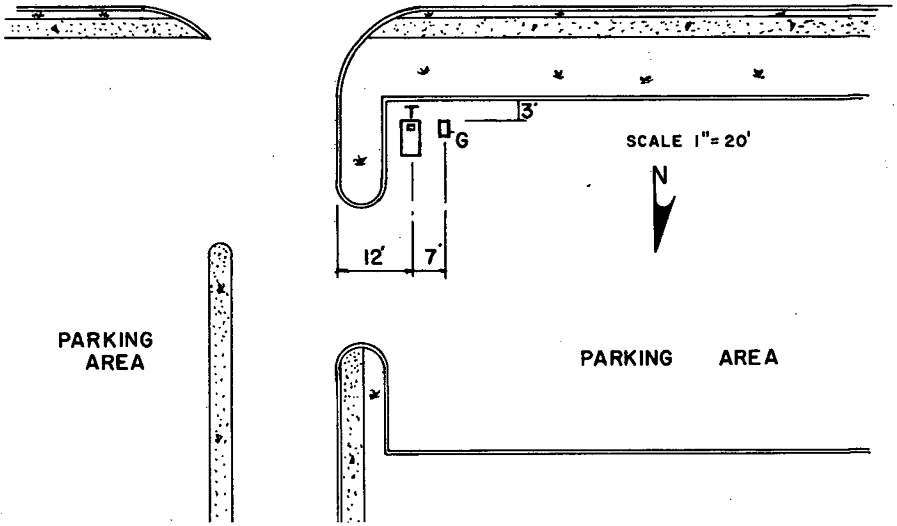


Figure E-10. Sampling site #5.

Figure E-9. Sampling sites #'s 3, 4, 8, 9.

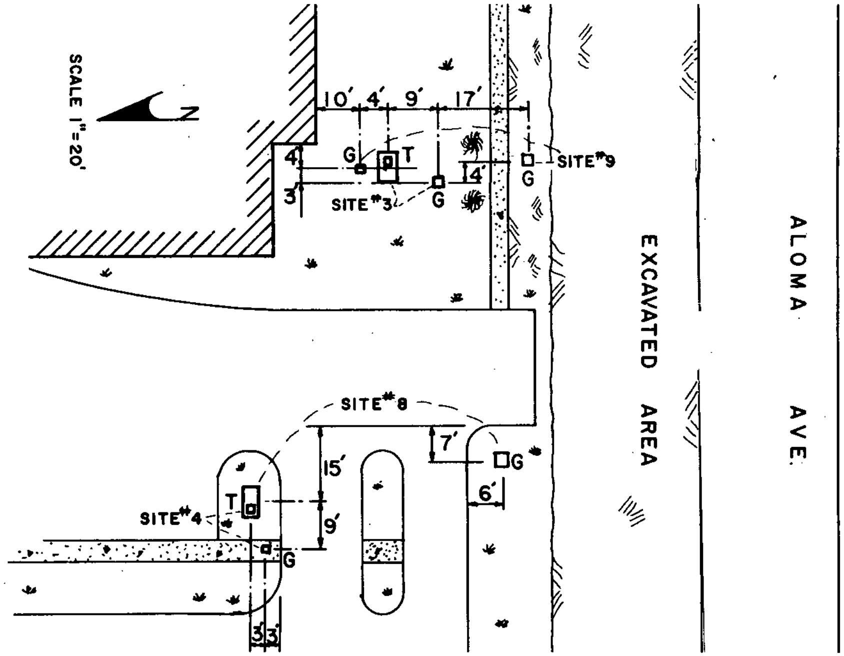
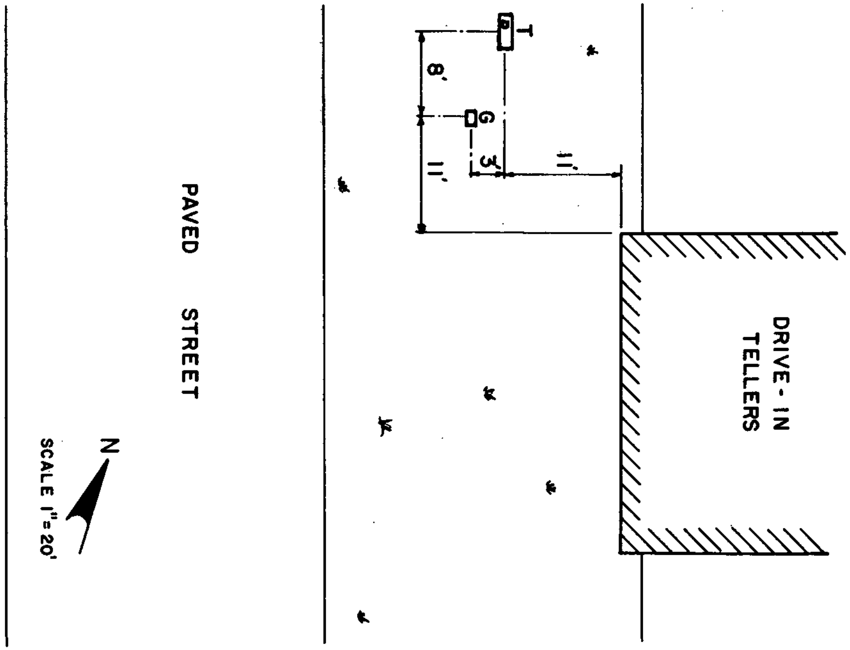


Figure E-12. Sampling site #7.



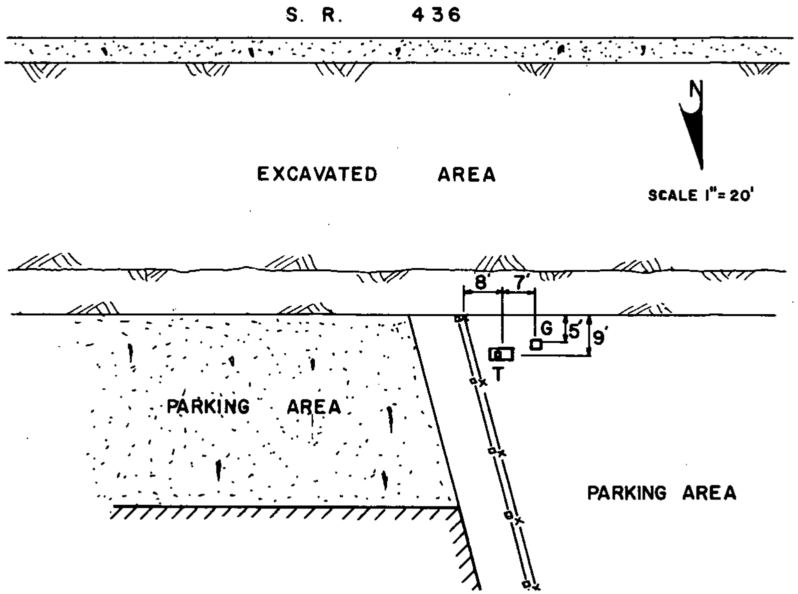


Figure E-11. Sampling site #6.

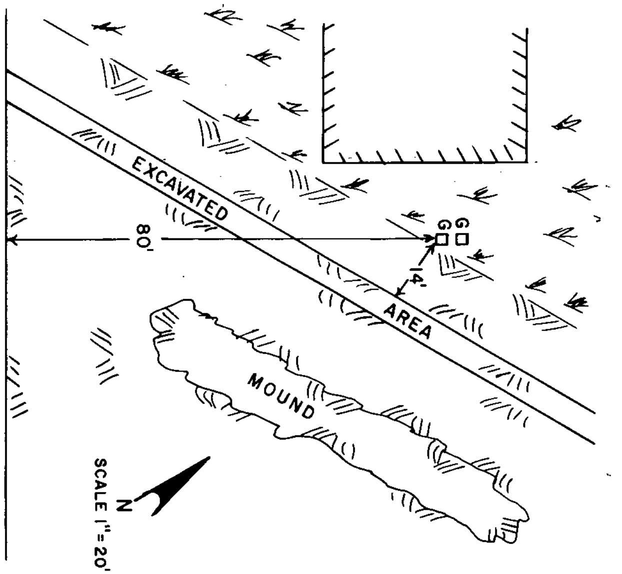


Figure E-15. Sampling site #12.

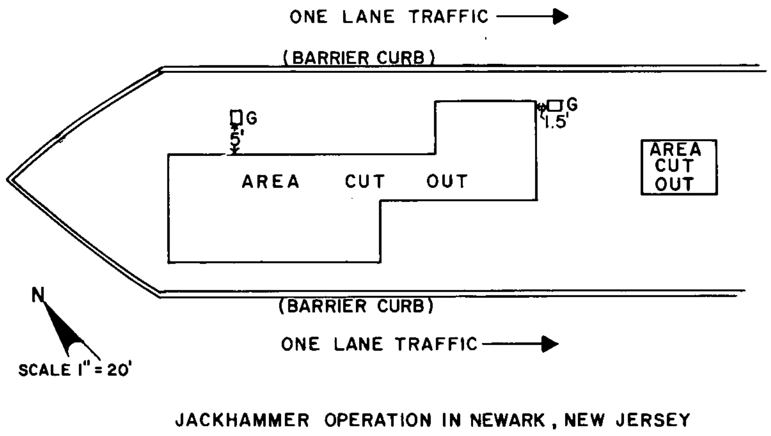


Figure E-16. Sampling site #13.

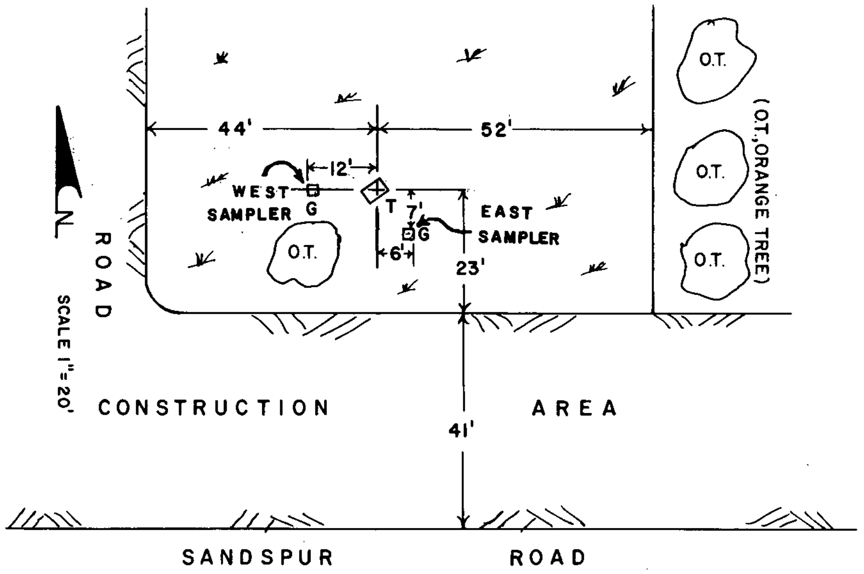


Figure E-13. Sampling site #10.

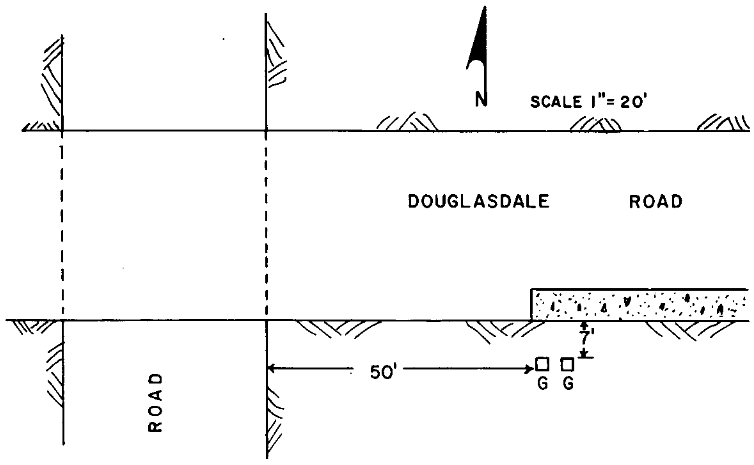


Figure E-14. Sampling site #11.

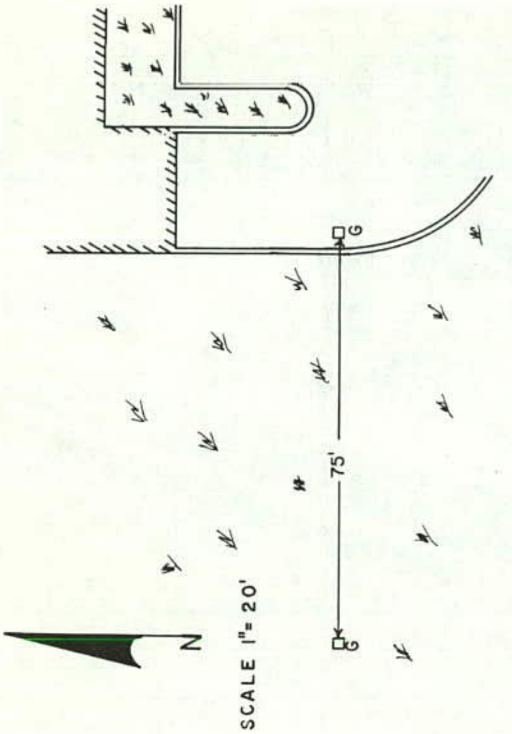


Figure E-17. Sampling site #14.

Figure E-18. Field location #1.

Figure E-19. Field location #2—nonconstruction traffic fugitive dust.

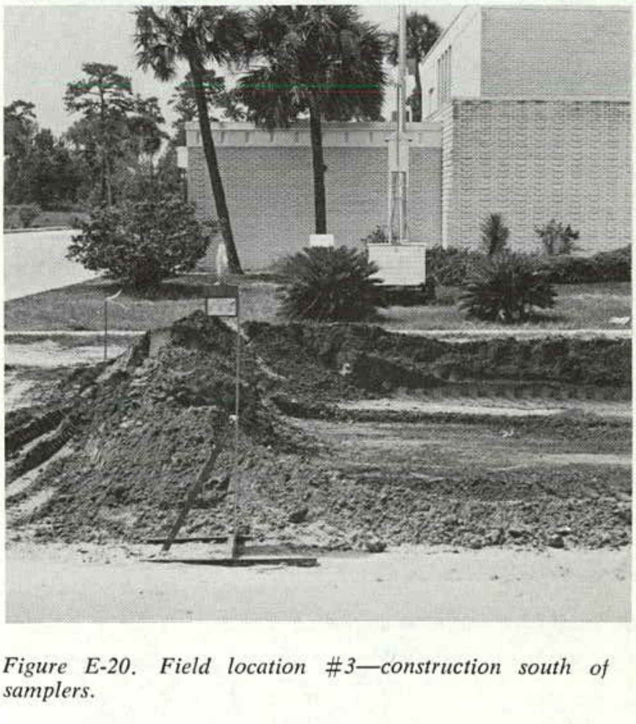


Figure E-20. Field location #3—construction south of samplers.

Figure E-21. Field location #4—over-all view.

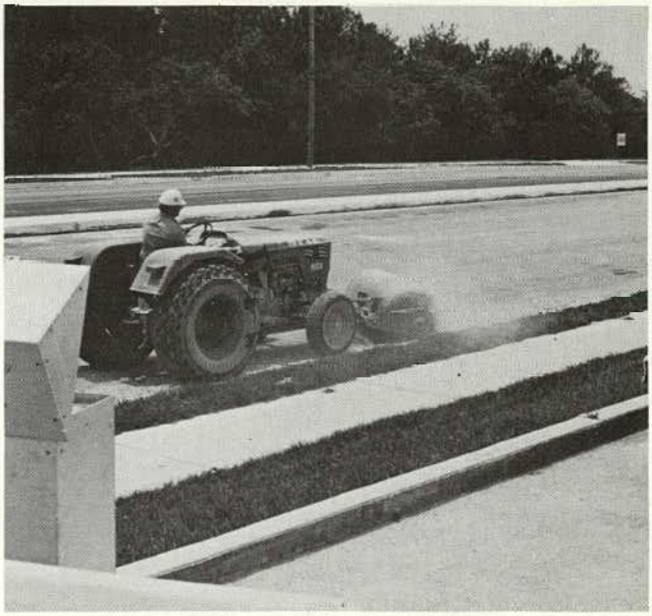


Figure E-22. Field location #5—mechanical sweepers.

Figure E-23. Field location #6.

Figure E-24. Field location #9.

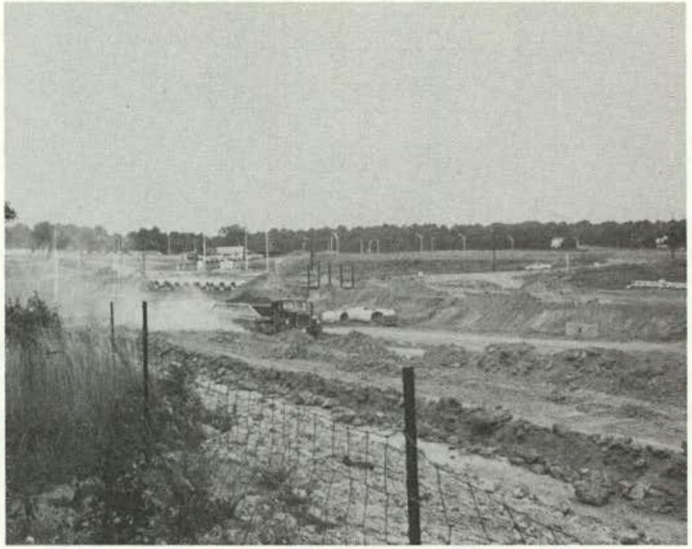


Figure E-27. Field location #12 construction and hauling.

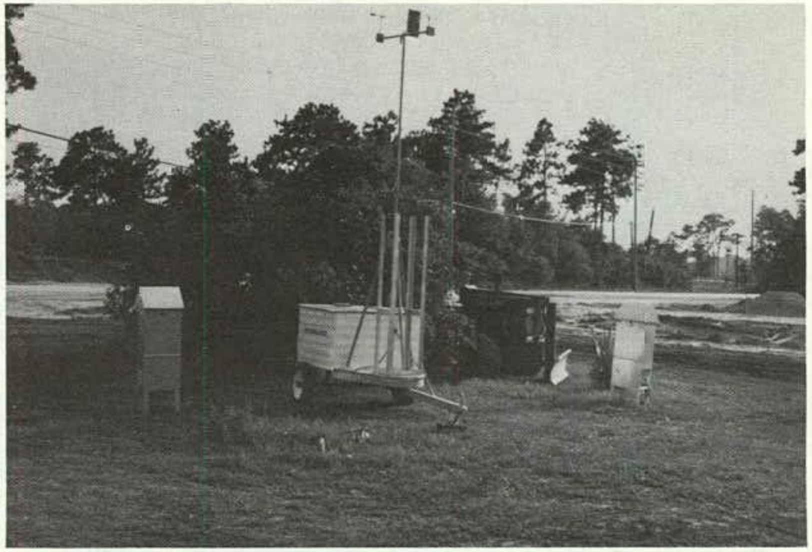


Figure E-25. Field location #10.

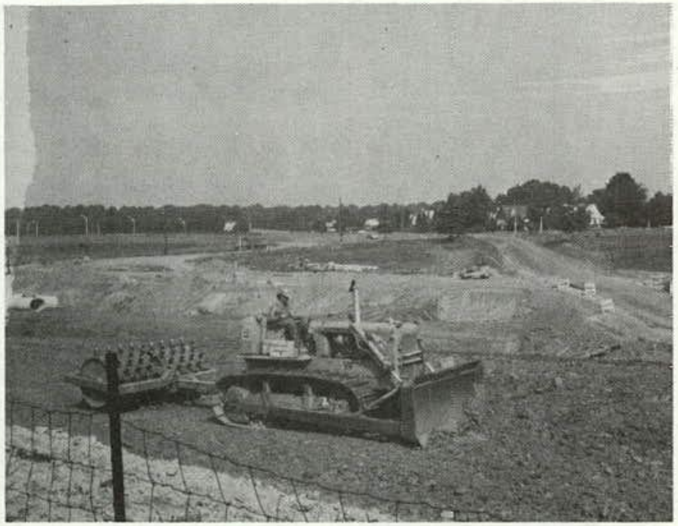


Figure E-28. Field location #12 compacting.

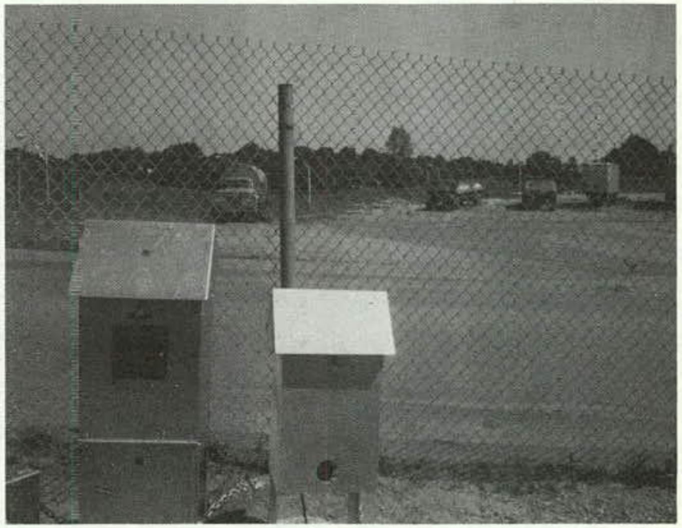


Figure E-26. Field location #11—north of samplers.

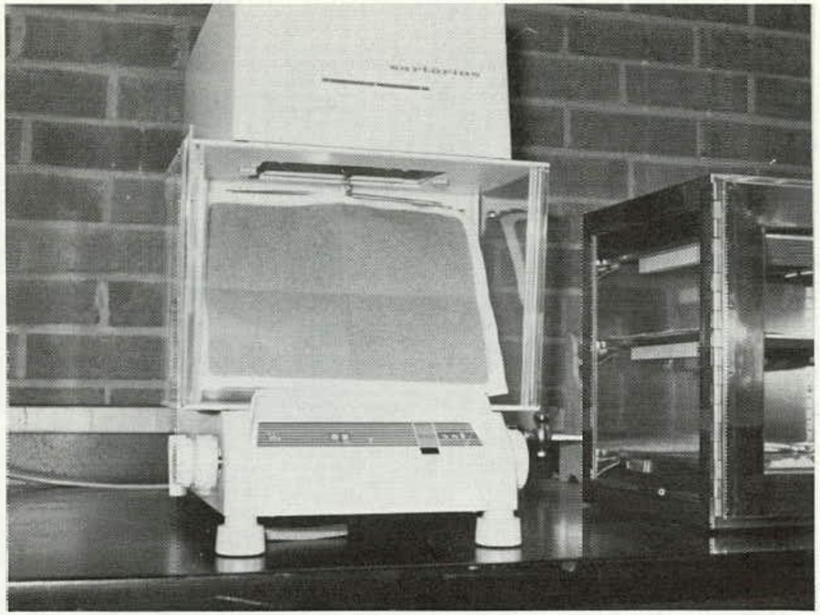


Figure E-31. Filter paper weighing.

Figure E-29. Field location #13.

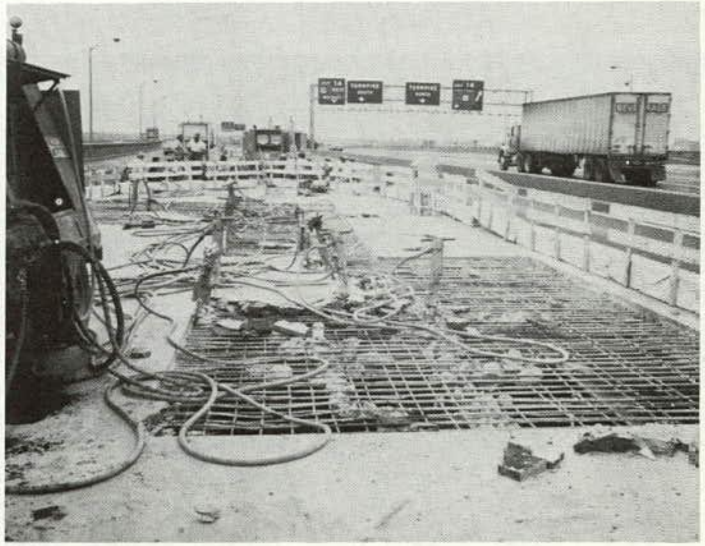


Figure E-30. Field location #13—no activity.

TABLE E-2

SAMPLING LOCATION #1—JENKINS REALTY

Distance from Edge of Road Bearing Traffic 43 Feet
Distance from Edge of Construction 3 Feet

Date	Height Above Ground (ft)	Concentration (μg m^{-3})	Avg. Flow Rate (CFM)	Avg. Wind Speed (MPH)	Avg. Wind Direction	Construction Activities Roadway Traffic and	General Meteorology (% Cloud Cover; Rainfall Avg. Temp. °F)
4/10	3.5 10.1	1108 1055	47.5 53.3	4.4	NE	Hauling,Dumping & Spreading	100%; 0; 64°F
4/12	10.1	232	64.5	6.3	SE	Grading & Watering	80%; 0; 54°F
4/16	10.1	391	60.5	2.9	NW	Compacting	80%;.25; 75°F
4/18	3.5 10.1	1163 800	51.0 53.0	3.5	NNE	Hauling,Dumping & Grading	20%; 0; 68°F
4/20	3.5 10.1	1400 862	51.0 50.0	5.3	E	No others	40%; 0; 70°F
4/22	3.5 10.1	336 281	52.0 58.5	3.1	SE	Watering	60%; +; 73°F
4/24	3.5 10.1	709 515	46.0 55.0	4.1	NW	No others	10%; 0; 73°F

	3.5 ft.	10.1 ft.	Combined
No. of Samples	5	7	12
Arith. Mean	943	591	738
Std. Deviation	421	317	390
Geo. Mean	801	521	633
Geo. Std. Dev.	1.53	1.65	1.54

TABLE E-3

SAMPLING LOCATION #2—BURGER CHEF

Distance from Edge of Road Bearing Traffic 43 Feet
Distance from Edge of Construction 16 Feet

Date	Height Above Ground (ft)	Concentration (μg/m3)	Avg. Flow Rate (CFM)	Avg. Wind Speed (MPH)	Avg. Wind Direction	Construction Activities Roadway Traffic and	General Meteorology (% Cloud Cover; Rainfall; Avg. Temp. °F)
4/11	3.5 10.1	1311 750	49.3 61.0	5.0	ESE	Hauling	80%; 0; 75°F
4/13	3.5 10.1	1255 155	48.5 57.8	4.5	SE	No others	40%; 0; 80°F
4/15	3.5 10.1	77 71	52.0 67.0	4.1	W	Compaction (51 ft. from site)	70%; 0; 80°F
4/17	10.1	155	56.0	2.9	N	Hauling,Dumping & Grading (51 ft. from site)	90%; +; 70°F
4/19	3.5 10.1	1089 439	49.8 62.5	2.5	NE	Hauling	10%; 0; 67°F
4/21	3.5 10.1	551 260	52.5 62.5	4.1	ESE	No others	30%; 0; 70°F
4/23	3.5 10.1	457 339	53.7 64.0	0.7	S	Watering	50%; +; 73°F

	3.5 ft.	10.1 ft.	Combined
No. of Samples	6	7	13
Arith. Mean	710	310	531
Std. Deviation	501	231	440
Geo. Mean	580	249	409
Geo. Std. Dev.	1.88	1.94	2.06

TABLE E-4

SAMPLING LOCATION #3—FRONT ATLANTIC BANK

Distance from Edge of Road Bearing Traffic 56 Feet
Distance from Edge of Construction 82 Feet

Date	Height Above Ground (ft)	Concentration (μg/m3)	Avg. Flow Rate (CFM)	Avg. Wind Speed (MPH)	Avg. Wind Direction	Construction Activities Roadway Traffic and	General Meteorology (% Cloud Cover; Rainfall; Avg. Temp. °F)
5/1	3.5 10.1	257 183	47.0 65.0	1.9	SW	Excavating & Grading	30%; 0; 74°F
5/3	3.5 10.1	153 100	49.0 70.5	3.1	W	Compacting Limestone	30%; 0; 76°F
5/5	3.5 10.1	113 90	59.5 71.5	3.9	SW	No others	70%;.12; 74°F
5/7	3.5 10.1	43 38	61.0 72.5	1.5	E	Dumping Limerock	70%;.02; 71°F
5/9	3.5 10.1	107 89	60.5 72.5	2.2	E	Hauling, Dumping & Compacting	10%; 0; 76°F
5/13	3.5 10.1	58 53	64.0 56.0	2.2	ENE	Compacting & Grading	70%; 0; 77°F
5/15	3.5 10.1	129 99	66.0 56.0	3.6	SSE	No others	70%;.46; 79°F
5/17	3.5 10.1	145 130	66.5 58.5	2.0	E	Compacting	70%;.23; 79°F
5/19	10.1	80	53.5	4.2	E	No others	50%; 0; 80 F
5/21	10.1	137	68.5	3.9	E	Hauling	50%; 0; 78 F
5/23	3.5 10.1	166 145	52.0 65.5	3.9	S	Compacting Limestone	90%; .35; 81 F
5/25	3.5 10.1	96 89	54.0 64.0	3.6	W	No others	40%; 0; 83 F
6/27	3.5 10.1	85 76	54.0 58.0	6.5	WSW	No others	90%; .06; 80 F
6/29	3.5 10.1	170 158	55.5 57.5	2.7	SE	No others	70%; + ; 80 F
5/31	3.5 10.1	197 259	54.0 61.0	2.3	NW	Grading & Compacting Clay	30%; 0; 85 F
6/2	3.5 10.1	106 97	57.0 62.0	3.2	SSE	No others	70% .07; 82 F
6/4	3.5 10.1	117 117	58.5 66.0	1.6	ESE	Excavating	60%; 0; 80 F
6/7	3.5 10.1	168 53	57.0 65.5	3.4	SSE	Compacting Limestone	40%; + ; 85 F
6/9	3.5 10.1	44 164	66.0 65.0	1.8	SE	None (Traffic only)	60%; + ; 82 F
6/11	3.5 10.1	111 109	62.0 62.5	2.9	S	No others	70%;.18; 81 F
6/13	3.5 10.1	109 116	73.0 62.0	0.9	SE	No others	60%; 0; 81 F
6/15	3.5 10.1	37 43	73.5 69.5	7.9	NE	No others	100%;.54;77 F
6/17	3.5 10.1	102 95	73.0 68.0	7.7	WNW	Dumping & Spreading Limestone	40%; .09; 81°F
6/20	3.5	94	56	6.3	NW	No others	60%; 0; 81°F
*8/20	3.5 3.5 3.5	80 125 132	64 64 64	--- --- ---	SE	Site-watering (9-10 am) No others (10-11 am) No others (11-12 am)	20%; 0; 80°F

	3.5 ft.	10.1 ft.	combined
No. of Samples	22	23	5
Arith. Mean	119	110	114
Std. Deviation	53	50	52
Geo. Mean	109	100	104
Geo. Std. Dev.	1.53	1.54	1.53

* Each one hour long, no watering on traffic bearing road

TABLE E-7

SAMPLING LOCATION #6—U-TOTEM

Distance from Edge of Road Bearing Traffic 62 Feet
Distance from Edge of Construction 14 Feet

Date	Height Above Ground (ft)	Concentration (μg/m^3)	Avg. Flow Rate (CFM)	Avg. Wind Speed (MPH)	Avg. Wind Direction	Construction Activities Roadway traffic and	General Meteorology (% Cloud Cover, Rainfall (in) Avg. Temp.)
5/17	10.1	142	66.0	2.2	NE	No others	70%; .23; 79 F
5/19	3.5	221	59.5	3.9	ENE	No others	50%; 0; 80 F
5/23	3.5	166	65.5	3.3	S	Dumping & Compacting Limerock	90%;0.35; 81 F
	10.1	138	60.5				
5/25	10.1	126	64.0	3.9	W	No others	40%; 0; 83 F
	3.5	192	60.5				
5/27	10.1	119	59.0	5.8	W	No others	90%;0.06; 80 F
5/29	3.5	219	64	*		Compacting & Sweeping	70%; + ; 80 F
	10.1	171	60				
5/31	3.5	639	60.5	*	NNW	No others	30%; 0; 85 F
	10.1	266	63				
6/2	3.5	172	68.5	*	SW	No others	70%;0.07; 82 F
	10.1	120	69				

* Meteorological Equipment Malfunctioned

	3.5 ft.	10.1 ft.	Combined
No. of Samples	6	7	13
Arith. Mean	268.3	154.6	207.1
Std. Deviation	183.3	52.4	137.3
Geo. Mean	221	146	173
Geo. Std. Dev.	1.85	1.39	1.83

TABLE E-8

SAMPLING LOCATION #7—SIDE ATLANTIC BANK

Date	Height Above Ground (ft)	Concentration (μg/m^3)	Avg. Flow Rate (CFM)	Avg. Wind Speed (MPH)	Avg. Wind Direction	Construction Activities Roadway Traffic and	General Meteorology (% Cloud Cover; Rainfall; Avg. Temp. $^{\circ}$F)
6/9	3.5	41	58.5	1.8	SE	No others	60%; + ; 82°F
	10.1	44	69.0				
6/11	3.5	88	58.5	2.9	S	No others	70%;.18 ; 81°F
	10.1	74	72.0				
6/13	3.5	81	58.0	0.9	SE	No others	60%; 0; 81°F
	10.1	80	72.0				
6/15	3.5	31.6	58.5	7.9	NE	No others	100%; .54; 77°F

	3.5 ft.	10.1 ft.	Combined
No. of Samples	4	3	7
Arith. Mean	60	66	63
Std. Deviation	28	19	23.1
Geo. Mean	55	63	59
Geo. Std. Dev.	1.55	1.33	1.42

TABLE E-5

SAMPLING LOCATION #4—ISLAND-ATLANTIC BANK

Distance from Edge of Road Bearing Traffic 84 Feet
Distance from Edge of Construction 111 Feet

Date	Height Above Ground (ft)	Concentration (μg/m^3)	Avg. Flow Rate (CFM)	Avg. Wind Speed (MPH)	Avg. Wind Direction	Construction Activities Roadway Traffic and	General Meteorology (% Cloud Cover; Rainfall; Avg. Temp. $^{\circ}$F
5/1	3.5	197	53.8	2.5	SW	Excavating & Grading	30%; 0; 74°F
	10.1	158	53.5	3.0			
5/3	3.5	129	55.8	4.1	W	Compacting Limerock	30%; 0; 76°F
	10.1	109	57.5				
5/5	3.5	116	57.5	4.3	SW	No others	70%;0.02; 71°F
	10.1	102	61.5				
5/7	3.5	50	53.3	2.1	E	Dumping Limerock	70%;0.02; 71°F
	10.1	38	64.0				
5/9	3.5	102	52.0	2.2	E	Hauling Limerock, dumping & Compacting	10%; 0; 76°F
	10.1	82	63.0				

	3.5 ft.	10.1 ft.	Combined
No. of Samples	5	5	10
Arith. Mean	119	98	108
Std. Deviation	53	44	47
Geo. Mean	109	89	99
Geo. Std. Dev.	1.53	1.53	1.51

TABLE E-6

SAMPLING LOCATION #5—NURSING HOME

Distance from Edge of Road Bearing Traffic 85 Feet
Distance from Edge of Construction 15 Feet

Date	Height Above Ground (ft)	Concentration (μg/m^3)	Avg. Flow Rate (CFM)	Avg. Wind Speed (MPH)	Avg. Wind Direction	Construction Activities Roadway Traffic and	General Meteorology (% Cloud Cover; Rainfall (in); Avg. Temp.)
5/13	3.5	52	51.0	4.3	NNE	No others	70%; 0; 77°F
	10.1	49	50.5				
5/15	3.5	80	49.0	4.0	S	½ hour of sweeping	70%;0.46; 79°F
	10.1	53	60.5				

	3.5' ft.	10.1 ft.	Combined
No. of Samples	2	2	4
Arith. Mean	66	51.0	58.3
Std. Deviation	20	2.8	14.6
Geometric Mean	63.2	51	56.6
Geo. Std. Dev.	1.34	1.06	1.28

TABLE E-10

SAMPLING LOCATION #9

Sampler Height above Ground 3.5 ft.

Date	Location	Concentration (µg/m³)	Avg. Flow Rate (CFM)	Avg. Wind Speed (MPH)	Avg. Wind Direction	Construction Activities Roadway Traffic and	General Meteorology (% Cloud Cover; Rainfall; Avg. Temp. °F)
6/30	Front	66	56.5	7.2	*	No others	100%; .17; 79°F
	Back	56	73.5				
7/2	Front	130	71.5	6.9	SE	No others	100%; .88; 74°F
	Back	74	73.0				
7/4	Front	86	71.5	4.7	SE	No others	90%; .53; 77°F
	Back	56	69.5				
7/6	Front	128	75.0	4.9	ESE	No others	60%; .17; 78°F
	Back	87	70.5				
7/8	Front	104	68.5	5.5	SW	No others	50%; .01; 81°F
	Back	74	69.5				
7/10	Front	85	59.0	6.5	W	No others	70%; 0; 83°F
	Back	77	71.5				
7/12	Front	250	69.0	9.2	W	Compacting	70%; .05; 82°F
	Back	155	73.0				
7/16	Front	536	65.5	5.7	SW	Compacting	30%; 0; 81°F
	Back	313	69.5				
7/18	Front	135	63.0	3.5	*	Compacting (half day)	60%; .30: 80°F

* Meteorological Instruments Malfunctioned

	3.5 ft. Front	3.5 ft. Back	Combined
No. of Samples	9	8	17
Arith. Mean	169	112	142
Std. Deviation	148	87	123
Geo. Mean	127	88	107
Geo. Std. Dev.	2.12	1.99	2.11

TABLE E-12

SAMPLING LOCATION #11—PAVED HAUL ROAD

Distance from Edge of Road Bearing Traffic 7 Feet
Richmond, Virginia

Date	Height Above Ground (ft)	Concentration (µg/m³)	Avg. Flow Rate (CFM)	Avg. Wind Speed (MPH)	Avg. Wind Direction	Construction Activities Roadway Traffic and	General Meteorology (% Cloud Cover; Rainfall; Avg. Temp. °F)
7/2	3.5	461	43	4.8	SW	Hauling, Watering & Sweeping	90%; 0; 77°F
7/3	3.5	577	47.75	7.5	SW	Hauling, Watering & Sweeping	30%; 0; 82°F
7/4	3.5	135	46	9.2	SW	No others	10%; 0; 84°F

No. of Samples - 3
Arith. Mean - 391
Std. Deviation - 229
Geo. Mean - 328
Geo. Std. Dev. - 1.01

TABLE E-9

SAMPLING LOCATION #8

Distance from Edge of Road Bearing Traffic 86&42 Feet
Distance from Edge of Construction 112&68 Feet

Date	Height Above Ground (ft)	Concentration (µg/m³)	Avg. Flow Rate (CFM)	Avg. Wind Speed (MPH)	Avg. Wind Direction	Construction Activities Roadway Traffic and	General Meteorology (% Cloud Cover; Rainfall; Avg. Temp. °F)
6/21	10.1 BK*	87	70.0	5.3	NE	No others	60%; 0; 81°F
6/22	3.5 BK	85	66.0	5.8	WNW	No others	40%; 0; 82°F
	3.5 FR**	89	58.3				
6/23	10.1 BK	102	72.0	11.5	WSW	No others	70%; + ; 83°F
	10.1 FR	96	66.0				
6/24	3.5 FR	40	58.5	11.3	SSW	No others	100%; .95; 76°F
	3.5 BK	34	65.0				
6/26	3.5 FR	43	59.5	10.9	S	No others	100%;3.47; 77°F
	3.5 BK	28	69.0				
6/28	3.5 BK	136	70.0	6.1		No others	100%;3.36; 79°F
	10.1 FR	97	66.0				

* Back Location - 86 Feet from Edge of Road Bearing Traffic

** Front Location - 42 Feet from Edge of Road Bearing Traffic

	3.5 ft.		10.1 ft.		Combined
	FR	BK	FR	BK	
No. of samples	3	4	2	2	11
Arith. Mean	57	71	95	97	76
Std. Deviation	28	53	11	1	35
Geo. Mean	52	58	94	97	69
Geo. Std. Dev.	1.57	1.89	1.11	1.1	1.54

TABLE E-11

SAMPLING LOCATION #10

Sampler Height above Ground 3.5 ft.

Date	Location	Concentration (µg/m³)	Avg. Flow Rate (CFM)	Avg. Wind Speed (MPH)	Avg. Wind Direction	Construction Activities Roadway Traffic and	General Meteorology (% Cloud Cover; Rainfall; Avg. Temp. °F)
7/19	West	169	54.5	6.2	E	Hauling	40%; .06; 83°F
7/21	West	121	58	7.3	W	No Others	80%; +; 82°F
	East	101	61				
7/23	West	289	55.5	5.0	SW	Hauling	40%; .42; 81°F
	East	234	66				

Combined East and West

No. of Samples	5
Arithmetic Mean	183
Std. Deviation	78
Geo. Mean	169
Geo. Std. Dev.	1.19

TABLE E-13

SAMPLING LOCATION #12—FRENCH STREET

Distance from Edge of Construction (top of slope) 2 Feet
Distance from Roadway Traffic along slope 85 Feet
Richmond, Virginia

Date	Height Above Ground (ft)	Concen- tration (μg/m³)	Avg. Flow Rate (CFM)	Avg. Wind Speed (MPH)	Avg. Wind Direction	Construction Activities Roadway Traffic and	General Meteorology (% Cloud Cover; Rainfall; Avg. Temp. °F)
7/8/74	3.5	468	45.75	4.5	W	Grading, Compacting & Dressing Side Slope	50%; 0; 81°F
7/9/74	3.5	388	38.5	4.2	SW	Excavation for water pipe	10%; 0; 82°F
7/10/74	3.5	930	46	5.4	W	Hauling and Excavation	50%; 0; 82°F
7/11/74	3.5	574	42	8.4	N	Hauling	40%; 0; 76°F
7/12/74	3.5	198	50	6.9	N	Hauling moved about 50 feet Northwest of Samples and 20 feet lower	50%; 0; 71°F

No. of Samples - 5
Arith. Mean - 512
Std. Deviation - 271.3
Geo. Mean - 453.5
Geo. Std. Dev. - 1.00

TABLE E-16

U.S. WEATHER SERVICE METEOROLOGICAL DATA—ORLANDO AREA, McCOY JETPORT

Date	% Sky *SR→SS	% Cover **MN→MN	Rain (in.)	Pressure (in.) From	To	Avg. Temp. (°F)	Max/Min Temp. (°F)	Max Wind Speed (Knts)	Avg. Speed (Knts)
April 10	0	1	0	30.000	30.100	64	76/51	12	6.9
11	8	6	0	30.140	30.110	69	79/59	21	8.7
12	8	8	0	30.070	29.980	75	83/66	16	8.6
13	2	4	0	30.010	29.930	80	91/69	17	8.6
14	7	8	0	30.000	29.960	81	91/70	14	6.7
15	7	7	0	29.930	29.860	80	90/69	15	5.9
16	9	8	.25	29.890	29.920	75	85/65	9	3.1
17	9	9	+	29.960	29.970	70	79/61	9	4.6
18	0	2	0	29.960	29.960	68	80/55	14	4.7
19	1	1	0	29.980	29.980	67	81/53	12	3.1
20	5	4	0	30.030	30.100	70	82/58	16	6.4
21	5	3	0	30.120	30.110	70	82/58	17	7.6
22	6	6	+	30.080	29.950	73	84/61	14	6.5
23	8	5	+	29.950	29.840	73	84/62	14	5.6
24	1	1	0	29.370	29.810	73	85/60	15	6.1
25	1	1	0	29.920	30.010	67	79/55	15	7.8
May 14	10	10	.11	29.880	29.870	78	88/67	16	9.3
15	7	7	.46	29.880	29.940	79	89/68	21	8.4
16	10	9	.07	29.960	29.980	78	88/67	20	6.2
17	8	7	.23	29.980	29.985	79	87/70	13	7.2
18	6	5	0	29.990	29.940	77	88/66	16	8.4
19	8	5	0	29.960	29.920	80	89/70	17	8.8
20	7	5	0	29.945	29.900	79	89/69	18	9.2
21	9	5	0	29.930	29.870	78	89/67	14	8.7
22	9	8	0	29.890	29.810	78	89/66	15	8.5
23	10	9	.35	29.825	29.820	81	87/74	23	10.3
24	9	6	+	29.860	29.860	81	88/73	15	8.3
25	4	4	0	29.860	29.780	83	92/73	14	8.8
26	9	9	0	29.810	29.755	82	92/71	18	9.9
27	10	9	.06	29.775	29.850	80	86/74	17	10.9
28	7	6	0	29.925	29.960	79	88/70	14	7.1
29	7	7	+	29.970	29.850	80	90/70	15	6.4
30	6	5	0	29.850	29.785	81	92/70	15	7.8
31	3	3	0	29.840	29.860	85	95/74	15	7.5
June 1	3	4	1.19	29.900	29.900	83	95/71	15	8.1
2	7	7	.07	29.930	29.905	82	92/71	16	8.7
3	9	9	.05	29.910	29.890	80	89/71	17	7.2
4	8	6	0	29.880	29.910	80	90/69	20	6.7
5	5	5	.01	29.910	29.860	80	89/70	17	5.8
6	3	4	0	29.880	29.810	82	92/71	12	6.7
7	3	4	+	29.830	29.790	83	94/72	16	9.4
8	5	5	0	29.845	29.865	84	94/74	15	8.3
9	7	6	+	29.900	29.890	82	92/72	14	6.3
10	8	7	2.19	29.910	29.920	82	93/71	36	8.0
11	6	7	.18	29.900	29.840	81	91/71	18	8.0

TABLE E-14

SAMPLING LOCATION #13—JACKHAMMER OPERATION

Distance from Operation 5 Feet North, and 1½ Feet South
Newark, New Jersey

Date	Distance from Operation (ft)	Concentration (μg/m^3)	Avg. Flow Rate (CFM)	Avg. Wind Speed (MPH)	Avg. Wind Direction	Construction Activities Roadway Traffic and	General Meteorology (% Cloud Cover; Rainfall; Avg. Temp. ^oF)
7/23	5.0	16,670	25	7.3	S	Jack Hammer Operations	70%; 0; 71 F
7/23**	1.5	7,497	28	7.3	S	Jack Hammer Operation	70%; 0; 71 F
7/24	5.0	336	38	8.9	S	No others	100%;.45; 66 F
7/24**	1.5	159	34.5	8.9	S	No others	100%;.45; 66 F

* Because of the high concentrations and the sampling technique, a considerable amount of fugitive dust was lost

**This sampler was located South of construction and therefore had relatively less concentration than the North Sampler.

TABLE E-15

SAMPLING LOCATION #14—GENERAL MAINTENANCE LOCATION ON ASPHALT PAVEMENT

General Maintenance Location on Asphalt Pavement
Jersey City, New Jersey

Date	Height Above Ground (ft)	Concentration (μg/m^3)	Avg. Flow Rate (CFM)	Avg. Wind Speed (MPH)	Avg. Wind Direction	Construction Activities Roadway Traffic and	General Meteorology (% Cloud Cover; Rainfall; Avg. Temp. ^oF)
7/25	3.5	360	41	7.8	NE	Maintenance and Storage Yard	90%; 0; 69^{o}F
7/25	3.5	186	32.5	7.8	NE	Lumber Storage (no pavement-grass area)	90%; 0; 69^{o}F

Date		% Sky *SR+SS	% Cover **MN+MN	Rain (in)	Pressure (in) From	To	Avg. Temp. (^{o}F)	Max/Min Temp. (^{o}F)	Max Wind Speed (Knts)	Avg. Speed (Knts)
	12	5	5	0	29.860	29.810	81	91/71	14	8.3
	13	8	6	0	29.850	29.840	81	92/70	12	5.7
	14	9	8	.05	29.890	29.845	81	90/72	14	5.8
	15	10	10	.54	29.835	29.760	77	84/69	16	7.9
	16	6	6	0	29.730	29.685	79	88/70	13	6.9
	17	4	4	.09	29.725	29.720	81	91/71	17	7.7
	18	7	7	+	29.800	29.870	82	92/72	21	5.3
June	19	7	7	+	29.920	29.920	83	92/73	23	7.0
	20	7	6	0	29.950	29.850	81	91/71	14	6.3
	21	7	6	0	29.840	29.790	81	92/70	14	5.3
	22	5	4	0	29.760	29.730	82	95/70	17	5.8
	23	7	7	+	29.780	29.735	83	91/74	23	11.5
	24	10	10	.95	29.740	29.430	76	79/73	18	11.3
	25	10	10	1.07	29.590	29.700	80	85/74	33	12.9
	26	10	10	3.47	29.735	29.750	77	83/71	23	10.9
	27	10	10	1.89	29.715	27.820	75	78/72	16	7.5
	28	10	10	3.36	29.835	29.910	76	82/70	12	6.1
	29	10	9	+	29.975	31.000	79	85/72	15	6.2
	30	10	10	.17	30.010	29.980	79	88/70	21	7.2
July	1	10	9	.12	29.950	29.985	79	87/70	14	5.5
	2	10	10	.88	30.000	30.045	74	77/71	13	6.9
	3	9	9	.20	30.065	30.045	77	84/70	23	7.6
	4	10	9	.53	30.025	30.960	77	84/70	25	4.7
	5	8	8	.10	29.940	29.920	79	86/71	23	5.2
	6	6	6	.17	29.940	29.996	78	85/71	12	4.9
	7	8	7	.05	30.005	29.980	82	90/73	21	6.6
	8	6	5	.01	30.000	29.990	81	89/72	21	5.5
	9	8	6	.16	29.960	29.930	81	85/72	15	5.2
	10	6	7	.0	29.940	29.890	83	92/74	13	6.5
	11	5	4	0	29.910	29.840	85	94/75	17	9.4
	12	9	7	.05	29.865	29.910	82	91/73	18	9.2
	13	4	4	.0	29.940	29.980	80	88/72	17	9.8
	14	2	2	0	29.990	29.920	80	88/71	14	8.4
	15	2	1	0	29.910	29.845	80	90/69	10	6.7
	16	3	3	0	29.890	29.910	81	91/71	13	5.7
	17	7	6	+	29.990	30.030	81	91/71	13	5.3
	18	9	6	.30	30.090	30.170	80	89/71	23	3.5
	19	5	4	.06	30.100	30.000	83	93/73	12	5.1
	20	5	5	.0	30.025	29.890	84	94/74	14	7.9
	21	10	8	+	29.905	29.820	82	89/74	13	7.3
	22	10	8	+	29.830	29.260	83	91/75	21	7.6
	23	6	4	.42	29.880	29.880	81	90/72	12	5.4
	24	6	6	.04	29.920	29.940	83	92/74	15	4.9
	25	9	8	.03	29.950	29.980	82	91/73	23	6.5
	26	6	7	.85	29.950	29.940	83	93/73	21	7.8
	27	9	9	.60	29.910	29.940	80	88/71	12	6.4
	28	9	8	.60	29.930	29.840	82	89/74	25	7.8

TABLE E-17

U.S. WEATHER SERVICE METEOROLOGICAL DATA—RICHMOND, VA., BYRD AIRPORT

Date	% Sky *SR→SS	% Cover **MN→MN	Rain (in)	Pressure (in) From	To	Av. Temp. (°F)	Max/Min Temp. (°F)	Max Wind Speed (Knts)	Av. Speed (Knts)
July 1	9	9	0	29.87	30.03	78	89/66	15	7.6
2	2	3	0	30.02	30.14	77	92/61	13	4.8
3	2	1	0	30.08	30.16	82	95/68	13	7.5
4	1	1	0	30.02	30.14	84	73/84	17	9.2
5	10	9	Trace	30.02	30.08	80	88/71	17	9.2
6	10	10	Trace	30.06	30.15	76	85/66	12	6.9
7	9	8	0	30.08	30.16	79	88/69	7	4.3
8	5	5	0	30.01	30.11	81	94/68	7	4.5
9	2	1	0	29.91	30.03	82	97/67	14	4.2
10	3	5	0	29.77	29.92	82	96/68	20	5.4
11	5	4	0	29.81	30.03	76	87/64	18	8.4
12	7	5	0	30.04	30.16	71	79/59	16	6.9

TABLE E-18

U.S. WEATHER SERVICE METEOROLOGICAL DATA—NEWARK AIRPORT

Date	% Sky *SR→SS	% Cover **MN→MN	Rain (in)	Pressure (in) From	To	Av. Temp. (°F)	Max/Min Temp. (°F)	Max Wind Speed (Knts)	Av. Speed (Knts)
22	5	3	0	30.02	30.09	74	84/64	14	6.0
23	9	7	0	30.08	30.12	71	78/63	14	7.3
24	10	10	.45	30.05	30.09	66	70/61	14	8.9
25	10	9	0	30.05	30.12	69	76/61	13	7.8

TABLE E-19

PARTICLE SIZE DATA

Test Date	Stage	Mass on Stage (mg)	Cumulative Mass (mg)	D_p Microns	% Less Than Size
4-10-74	1	0.8270	1.2556	5.80	29.7
	2	0.2786	0.3729	2.84	7.5
	3	0.0887	0.0943	1.57	0.45
	4	0.0056	0.0056	0.75	
4-13-74	1	0.5579	0.8625	5.60	35.3
	2	0.2380	0.3046	2.70	7.7
	3	0.0635	0.0666	1.50	0.36
	4	0.0031	0.0031	0.72	
4-17-74	1	0.0762	0.1377	5.30	44.7
	2	0.0412	0.0615	2.50	14.7
	3	0.0187	0.0203	1.38	1.16
	4	0.0016	0.0016	0.65	
5-1-74	1	0.0630	0.1196	5.30	47.3
	2	0.0381	0.0566	2.60	15.5
	3	0.0177	0.0185	1.40	0.7
	4	0.0008	0.0008	0.66	
5-31-74	1	0.1253	0.2451	5.30	48.9
	2	0.0722	0.1198	2.60	19.4
	3	0.0277	0.0476	1.40	8.12
	4	0.0199	0.0199	0.66	
6-20-74	1	0.0459	0.1030	5.30	55.4
	2	0.0318	0.0571	2.55	24.6
	3	0.0142	0.0253	1.38	10.8
	4	0.0111	0.0111	0.65	
6-30-74	1	0.0256	0.0802	5.30	68.1
	2	0.0295	0.0546	2.55	31.3
	3	0.0163	0.0251	1.38	11.0
	4	0.0088	0.0088	0.65	
7-10-74	1	0.0350	0.0831	5.20	57.9
	2	0.0237	0.0481	2.50	29.4
	3	0.0109	0.0244	1.35	16.3
	4	0.0135	0.0135	0.62	
7-18-74	1	0.0738	0.1583	5.00	53.4
	2	0.0495	0.0845	2.40	22.1
	3	0.0165	0.0350	1.29	11.7
	4	0.0185	0.0185	0.60	

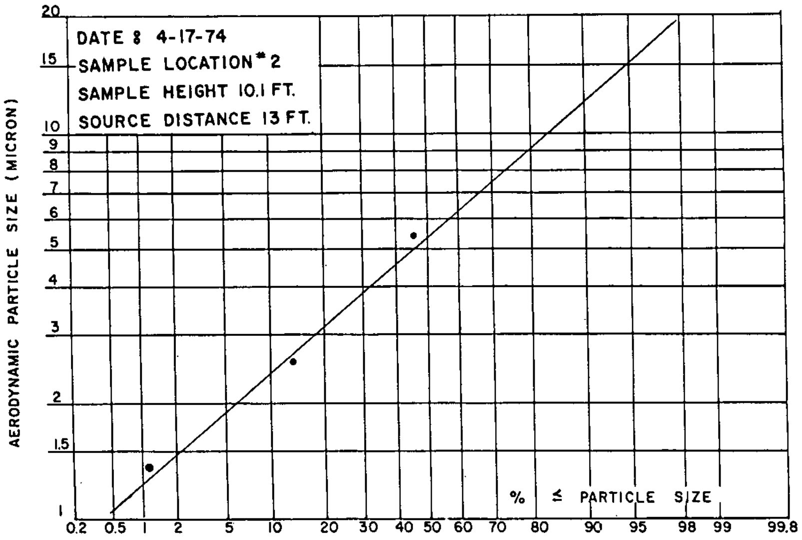


Figure E-34. Particle sizing.

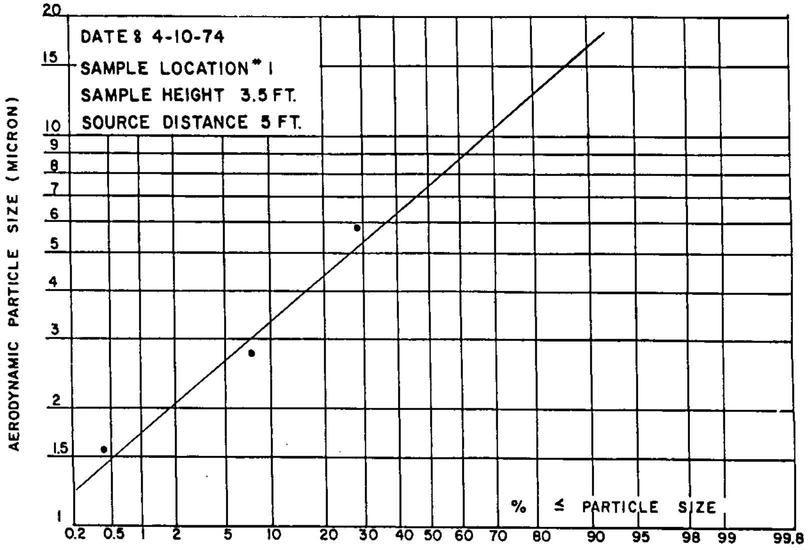


Figure E-32. Particle sizing.

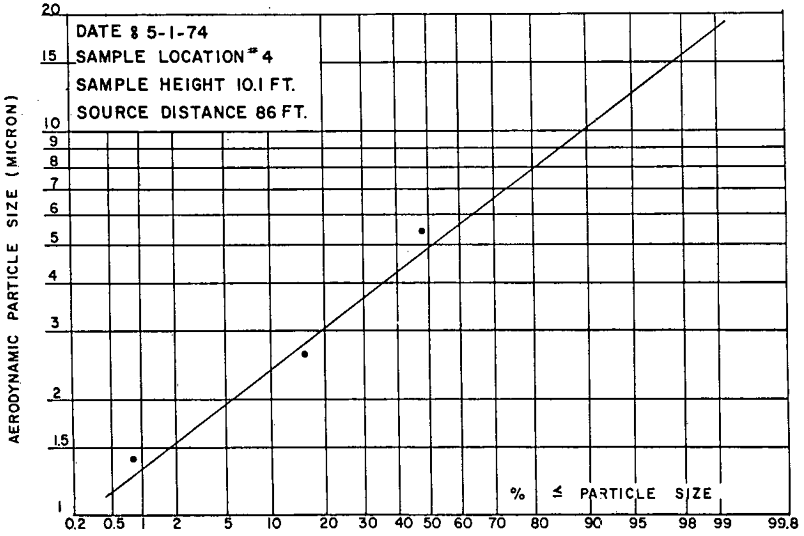


Figure E-35. Particle sizing.

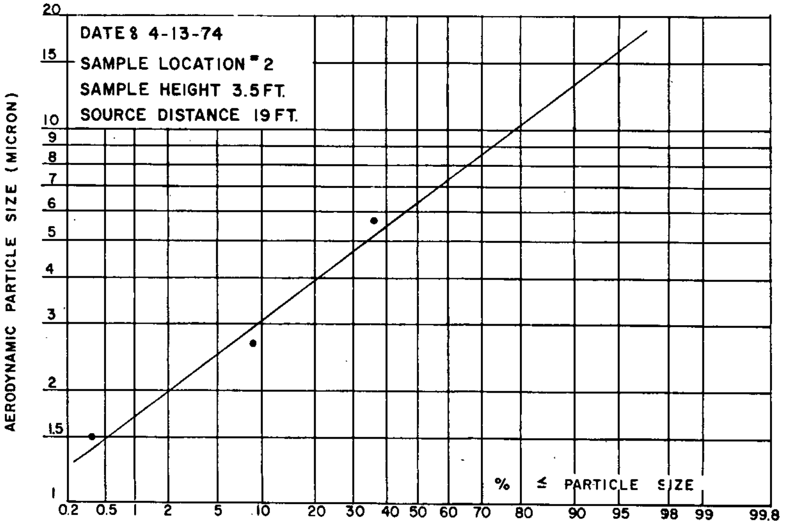
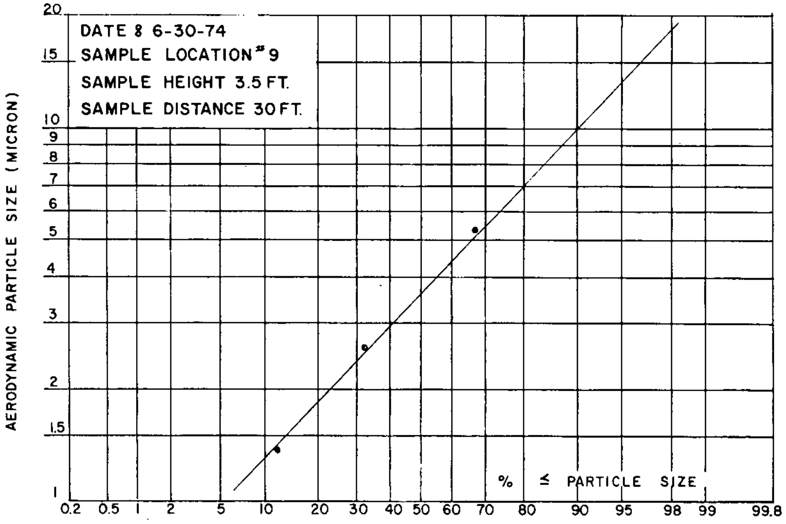


Figure E-33. Particle sizing.



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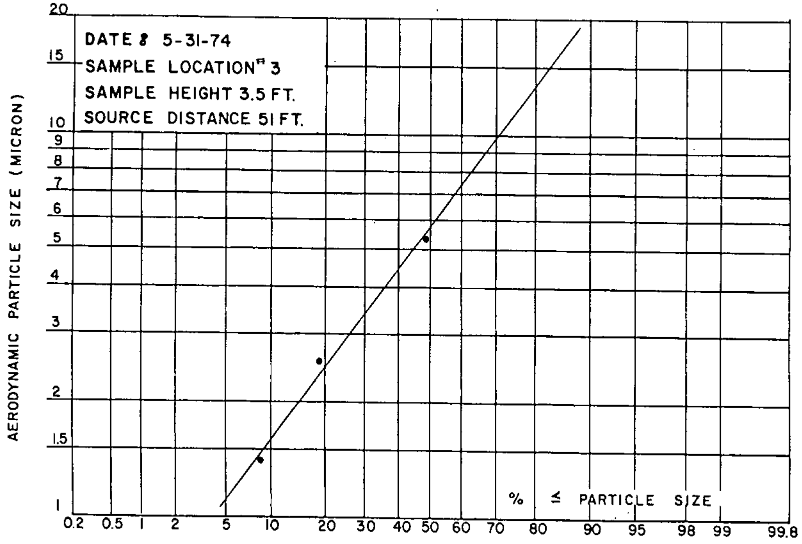


Figure E-36. Particle sizing.

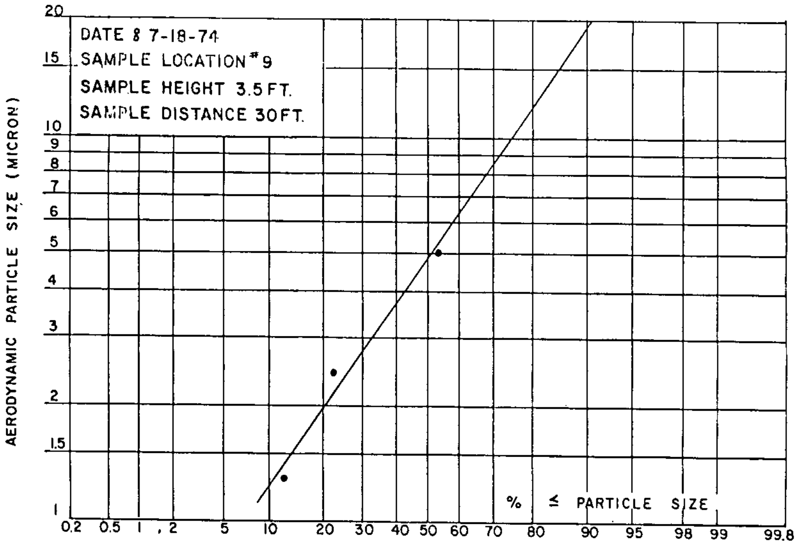


Figure E-39. Particle sizing.

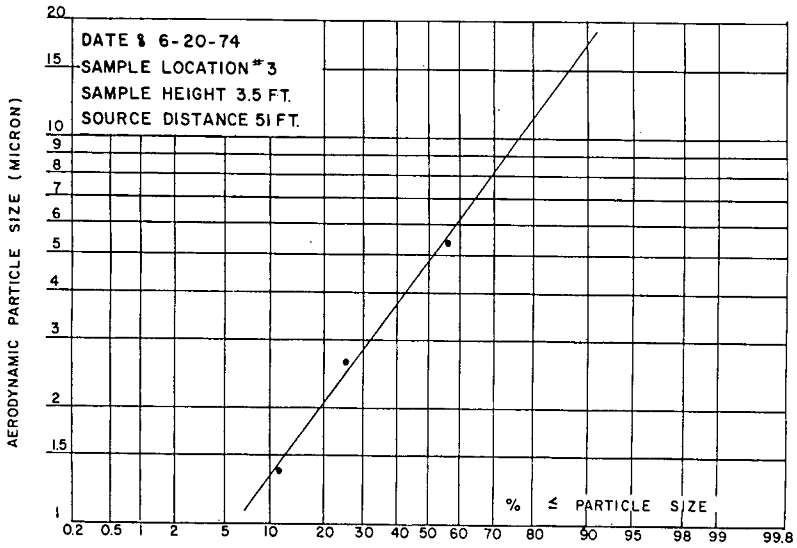


Figure E-37. Particle sizing.

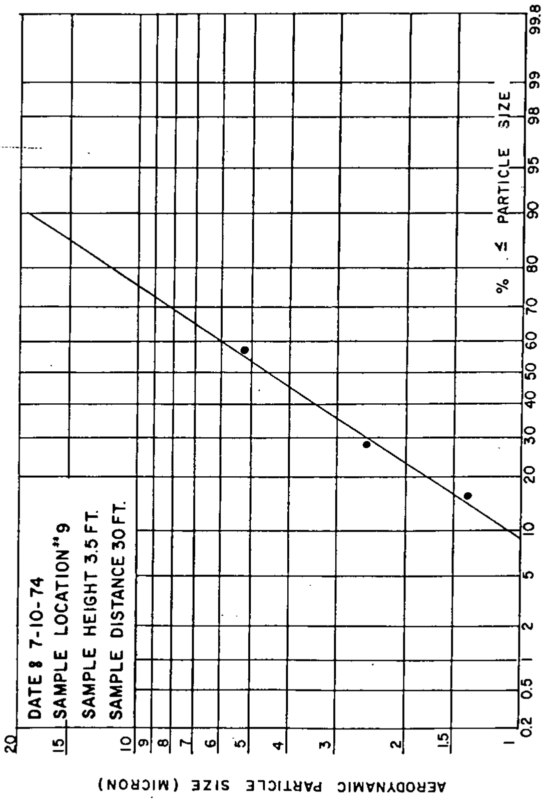
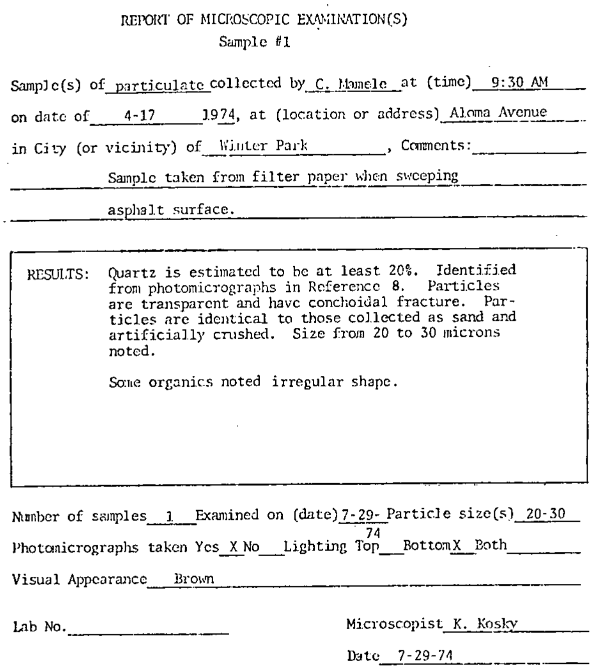


Figure E-40. Particle sizing.



REPORT OF MICROSCOPIC EXAMINATION(S)
Sample #1

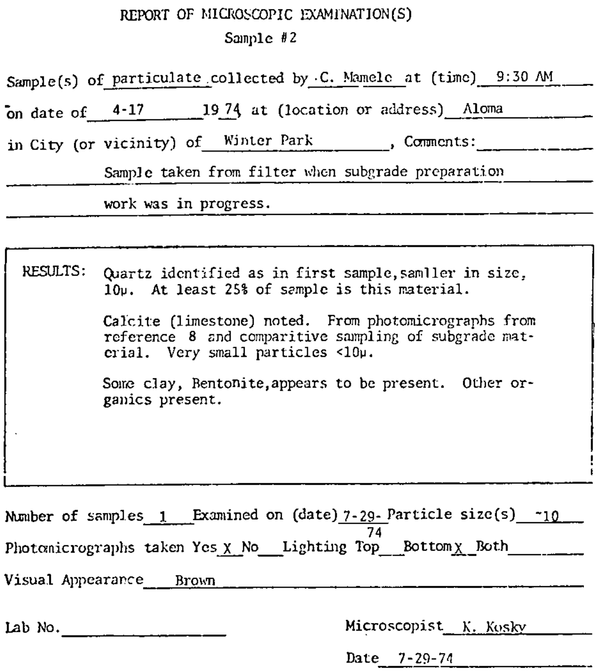
Sample(s) of particulate collected by C. Mamele at (time) 9:30 AM
on date of 4-17 1974, at (location or address) Aloma Avenue
in City (or vicinity) of Winter Park, Comments:
Sample taken from filter paper when sweeping
asphalt surface.

RESULTS: Quartz is estimated to be at least 20%. Identified from photomicrographs in Reference 8. Particles are transparent and have conchoidal fracture. Particles are identical to those collected as sand and artificially crushed. Size from 20 to 30 microns noted.

Some organics noted irregular shape.

Number of samples 1 Examined on (date) 7-29-74 Particle size(s) 20-30
Photomicrographs taken Yes X No Lighting Top Bottom X Both
Visual Appearance Brown
Lab No.
Microscopist K. Kosky
Date 7-29-74

Figure E-41. Report of microscopic examinations(s) sample #1.



REPORT OF MICROSCOPIC EXAMINATION(S)
Sample #2

Sample(s) of particulate collected by C. Mamele at (time) 9:30 AM
on date of 4-17 1974 at (location or address) Aloma
in City (or vicinity) of Winter Park, Comments:
Sample taken from filter when subgrade preparation
work was in progress.

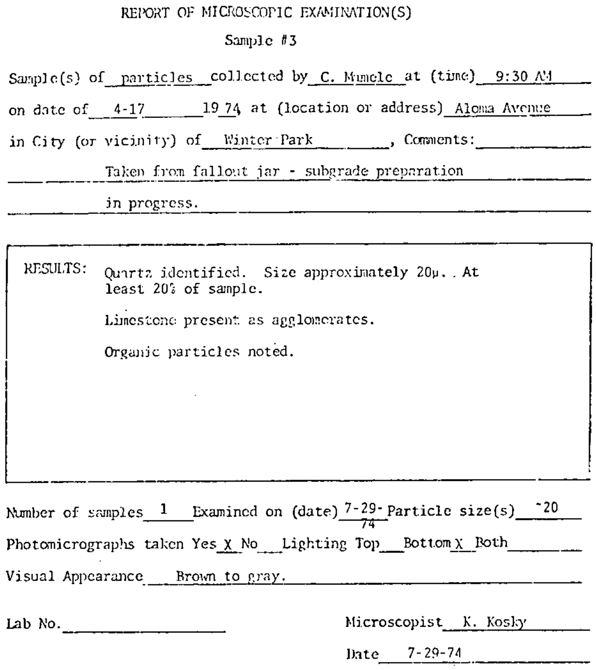
RESULTS: Quartz identified as in first sample, samller in size, 10µ. At least 25% of sample is this material.

Calcite (limestone) noted. From photomicrographs from reference 8 and comparitive sampling of subgrade material. Very small particles <10µ.

Some clay, Bentonite, appears to be present. Other organics present.

Number of samples 1 Examined on (date) 7-29-74 Particle size(s) ~10
Photomicrographs taken Yes X No Lighting Top Bottom X Both
Visual Appearance Brown
Lab No.
Microscopist K. Kosky
Date 7-29-74

Figure E-42. Report of microscopic examination(s) sample #2.



REPORT OF MICROSCOPIC EXAMINATION(S)
Sample #3

Sample(s) of particles collected by C. Mamele at (time) 9:30 AM
on date of 4-17 1974 at (location or address) Aloma Avenue
in City (or vicinity) of Winter Park, Comments:
Taken from fallout jar - subgrade preparation
in progress.

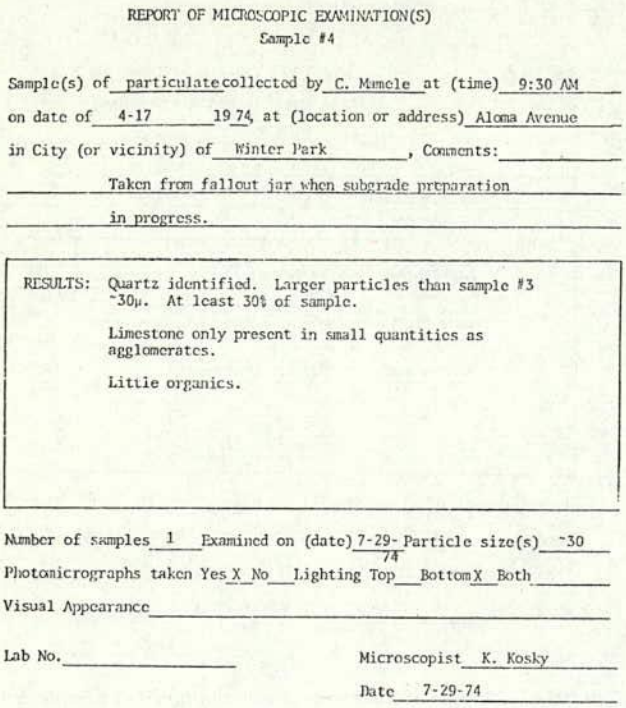
RESULTS: Quartz identified. Size approximately 20µ. . At least 20% of sample.

Limestone present as agglomerates.

Organic particles noted.

Number of samples 1 Examined on (date) 7-29-74 Particle size(s) ~20
Photomicrographs taken Yes X No Lighting Top Bottom X Both
Visual Appearance Brown to gray.
Lab No.
Microscopist K. Kosky
Date 7-29-74

Figure E-43. Report of microscopic examination(s) sample #3.



REPORT OF MICROSCOPIC EXAMINATION(S)
Sample #4

Sample(s) of particulate collected by C. Mmele at (time) 9:30 AM
on date of 4-17 19 74, at (location or address) Aloma Avenue
in City (or vicinity) of Winter Park, Comments:
Taken from fallout jar when subgrade preparation
in progress.

RESULTS: Quartz identified. Larger particles than sample #3 ~30μ. At least 30% of sample.

Limestone only present in small quantities as agglomerates.

Little organics.

Number of samples 1 Examined on (date) 7-29-74 Particle size(s) ~30
Photomicrographs taken Yes X No __ Lighting Top __ Bottom X Both __
Visual Appearance __
Lab No. __
Microscopist K. Kosky
Date 7-29-74

Figure E-44. Report of microscopic examination(s) sample #4.

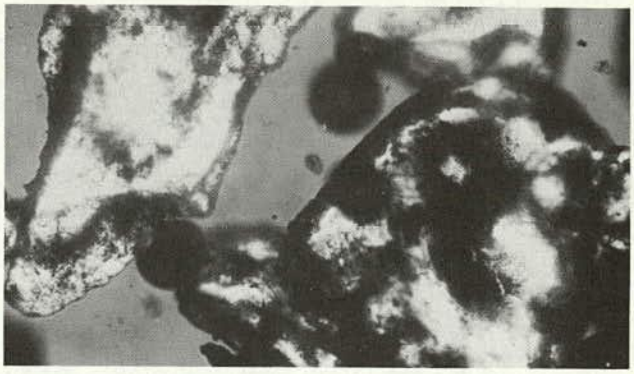


Figure E-45. Sand—undisturbed.

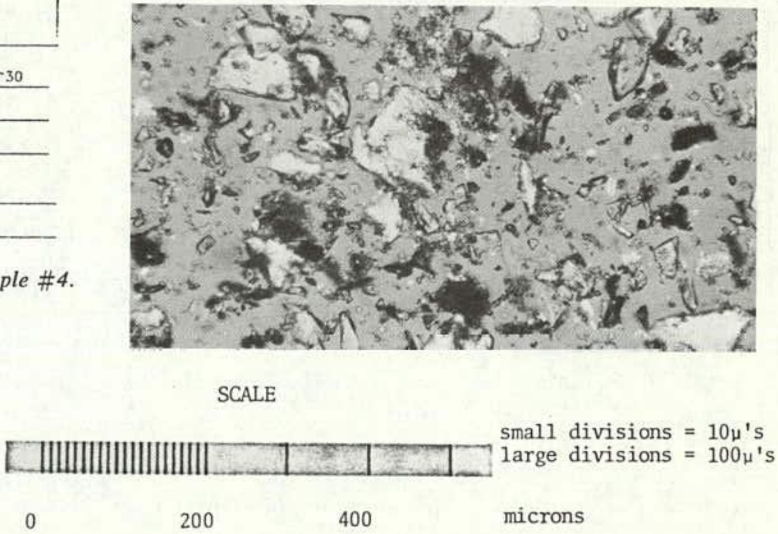


Figure E-46. Sand—crushed.

Figure E-47. Limestone—undisturbed.

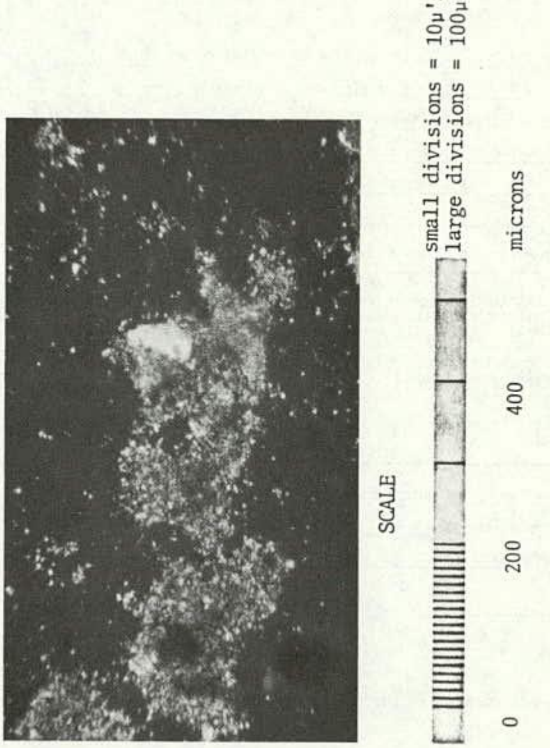


Figure E-48. Limestone—crushed.

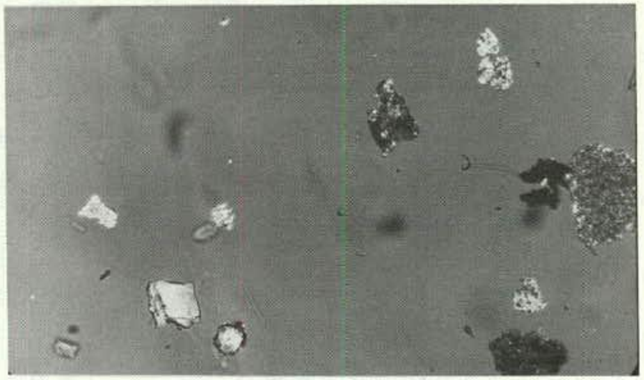


Figure E-49. Filter paper—sweeping, asphalt surface.

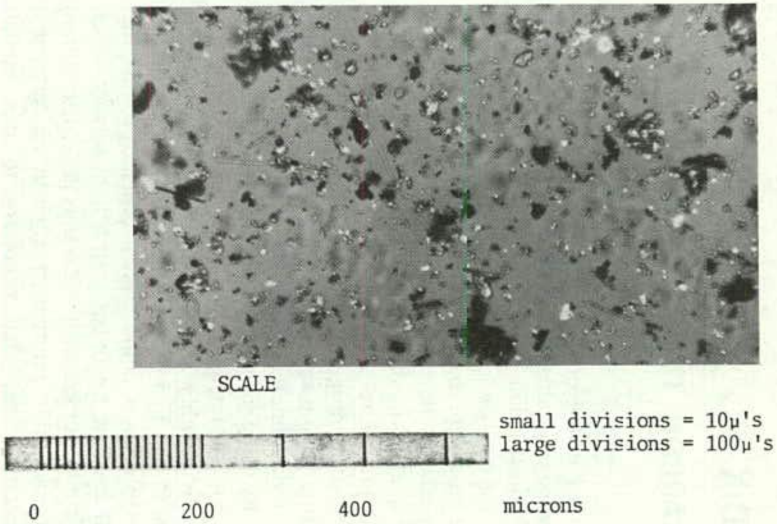


Figure E-50. Filter paper—subgrade preparation.

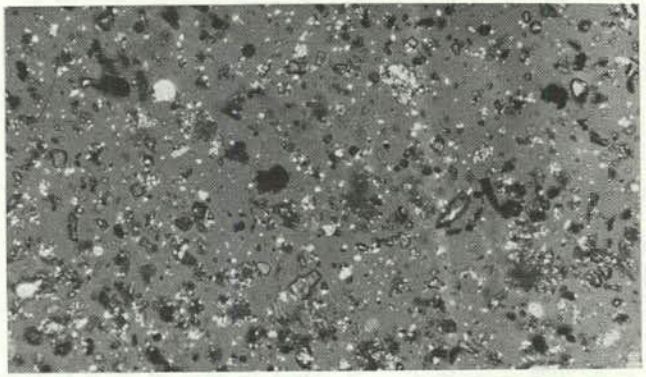


Figure E-51. Fallout jar—subgrade preparation.

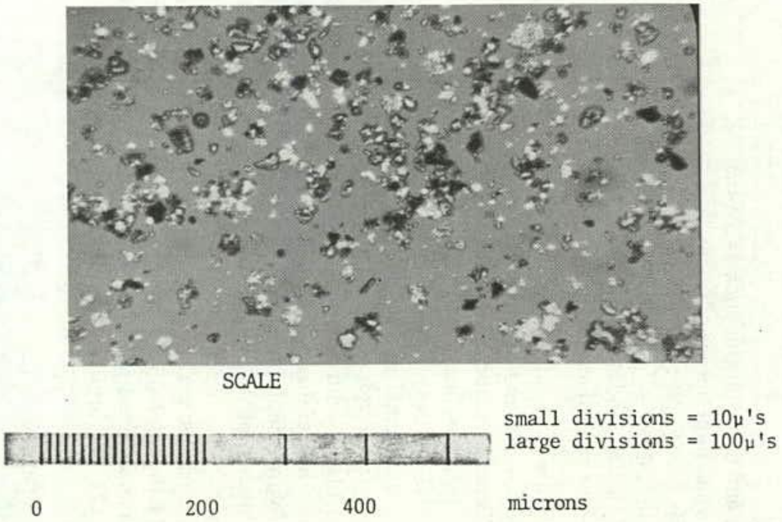


Figure E-52. Fallout jar—subgrade preparation with watering.

APPENDIX F

HYDROCARBON TESTING PROGRAM

As described in the body of this report, series of tests were performed on grab samples of air taken in the vicinity of highway construction operations involving both asphalt paving and the application of cutback asphalt as a prime coat. These tests were made to evaluate the contribution of the highway construction industry to the attainment of the ambient air quality standard for hydrocarbons. The background, test procedures, and results associated with the hydrocarbon testing program are discussed in this appendix.

An asphaltic paving mixture is obtained at the plant by mixing and drying different screenings and types of mineral aggregates. By using specified proportions of crushed stone, gravel, and sand aggregates mixed with approximately 5 to 10 percent (by weight) asphalt cement in the form of a liquid at 300 to 350 F, a paving asphalt material is formed.

Cutback asphalt is a liquid asphalt cement product that has been fluidized by treatment with a light solvent—such as gasoline, naptha, or kerosene. It is thus possible to obtain a penetrating asphaltic solution of a given viscosity at a lower temperature than that necessary to mix asphalt cement with aggregates. The evaporation of the "oil" or solvating agent after application leaves the asphalt cement residue in an unsegregated form to adhere to the aggregates and thus stabilize a low volume road base or parking lot base.

The order of volatility of petroleum distillates is given in the following listing, with each of those distillates being composed of many organic compounds having approximately the same boiling point:

Gaseous hydrocarbons with boiling points above 60 C. (hexane);
Gasoline and light solvents such as naptha;
Kerosene and light burner oils;
Diesel oil;
Lubricating oil;
Residual fuel oil; and
Asphalt—air refined and steam refined.

Road oils are normally designated as "slow cure" (SC grades) and are a blend of air-refined asphalt and an oily distillate. Kerosene cutback asphalts normally use kerosene (and sometimes gasoline) solvents to form medium cure asphalts (MC grades). Naptha and gasoline cutback asphalts are designated as "rapid cure" (RC grades) because of the greater volatility of these solvents. Emulsified asphalts are blends with water and have RS, MS, and SS designations. RC cutback products provide the greatest amount of hydrocarbon fumes for a given temperature level relative to other asphaltic products, thus their selection for field testing.

All hydrocarbons are divided into two main structural classes: (1) the aliphatic compounds whose molecules are normally open chained to have cyclic analogs of the open chain and (2) the aromatic compounds that are various forms and derivatives of benzene and other hydrocarbon compounds resembling benzene in chemical behavior. From an environmental viewpoint, aliphatic hydrocarbon fumes are not harmful to the health per se and become harmful only when, by combining with oxidants in the air (with energy from the photosynthesis process), they are formed into photochemical smog and PAN (peroxyacetylnitrate). Benzene is considered toxic at concentrations above 25 ppm and can have other physiological effects. (During sampling of one of the RC storage tanks, one of the researchers obtained a strong wiff of the vapors that seared his throat and resulted in a very husky voice for a period of two days thereafter.)

Today "solvent naptha" generally is used for cutback purposes because of the high demand for gasoline. Although both gasoline and naptha may have similar volatility and solvating capabilities, gasoline will normally have a large percentage of aliphatic hydrocarbons whereas naptha's principal chemicals are xylenes, coumarone, and phenols that are aromatic compounds (*28*).

Experimental data resulting from the exposure of animals and humans to various hydrocarbon compounds indicate that: aliphatic and alicyclic hydrocarbons are generally biochemically inert, with no effects reported at levels below 500 ppm; systemic injury can result from inhalation of vapors of aromatic compounds if concentrations in excess of 25 ppm are experienced (*29*). However, eye irritation and pulmonary effects are experienced by animals and humans when exposed to smog concentrations, which can be the photochemical product resulting from reactive hydrocarbon concentrations in the atmosphere. Formaldehyde, one of these products, has been estimated to cause eye irritation when the concentration is between 0.01 and 1.0 ppm; acrolein has a similar effect at concentrations between 0.25 and 0.75 ppm. It was concluded by the reference reviewed (*29*) that: "Our present state of knowledge does not demonstrate any direct health effects of the gaseous hydrocarbons in the ambient air on populations. . . . Injury to sensitive plants has been reported in association with ethylene concentrations of from 0.001 to 0.5 ppm over a time period of 8 to 24 hours."

SAMPLING STRATEGY AND DATA COLLECTION

The testing of hydrocarbons was performed on two basic highway construction operations. The first phase of sampling involved those hydrocarbons emitted during an asphalt paving operation, and the second phase was concerned with those more volatile fumes from the placing of a cutback asphalt during a prime coat operation.

The initial strategy for sampling was to obtain air samples both adjacent to the paving machine on its downwind side and at various locations downwind to determine the dilution and mixing effects of wind and temperature. This overly simplified approach was soon found to be inadequate because of the variability of the ambient conditions and the low RH-C concentrations generated by the paving operation. Later, the strategy was modified to ascertain the reliability of measuring the fumes given off from new paving, their contribution to atmospheric concentrations, and their decay factors. On each field trip, samplers were reserved for so-called "targets of opportunity" such as an idling, nonloaded paving machine during its morning warm-up; the THC contribution from the auto traffic flow during paving operations and nonpaving times; etc. The last two sampling days were directed to sampling other related THC sources to provide comparative data on the production of THC by other activities. Sampling strategies in the future should be directed to more definitive objectives and statistical verification of this investigation.

Two general areas were used during the first phase of testing for the field sampling operations. During the period July 31 to August 7, 1974, paving operations were conducted on US 50 on the east side of Orlando (see Fig. F-1). Paving operations involving the widening of a previous four-lane concrete highway with a median strip to a six-lane, asphalt-paved highway with appropriate middle turning lanes at intersections were being completed during this period. The paving project was bounded on the east by Semoran Blvd (SR 436) and on the west by Bennett Rd., a distance of approximately 1⅜ mi. The western 1 mi of this stretch was bounded on the south by the city's Herndon Airport (not used by large commercial jets, but having moderate light plane traffic), and on the north by various commercial stores and activities. The eastern ⅜ mi is completely commercial on both sides of the highway with Lake Barton behind the southern line of stores and a residential area behind the northern line of stores.

The second area used for field sampling during the period August 21 to August 26, 1974 was a section of State Road 436 (now running east and west in this area) extending westward from Interstate 4 to State Road 434, a distance of approximately 1¾ mi. This Forest City area is approximately 5 mi north of the Orlando city limits. Except for the afternoon of August 26, 1974, all sampling was done in the vicinity of the State Road 436 overpass of Interstate 4, an area of heavy traffic flow and new commercial and apartment activity to the west of Altamonte Springs. Sampling on the afternoon of August 26 and on the morning of August 28 was the only occasion of sampling performed in nonurban areas (see Fig. F-2).

The second phase of testing involved the evaluation of RC fumes given off during paving operations. These fumes would give the highest concentrations because RC-70 has the lowest viscosity and the highest dilution with a volatile solvent of the commercially available asphalt products. RC-70 is used in the Orlando area primarily for the prime coat of compacted limestone base.

The sampling plan involved obtaining ambient readings throughout the sampling period. Sampling began with the hand spray of curbing and of irregular areas and was followed by samples obtained downwind during tank truck application. Samples from a point ½ in. above the surface (to minimize wind mixing effects) were obtained immediately after application at 15, 30, and approximately 60 min. Normally, at least two samples were obtained for the same condition but at different locations. When noticeable fumes were observed, a sample was taken at nose height for comparison purposes.

Figure F-1. Paving operations with traffic US 50.

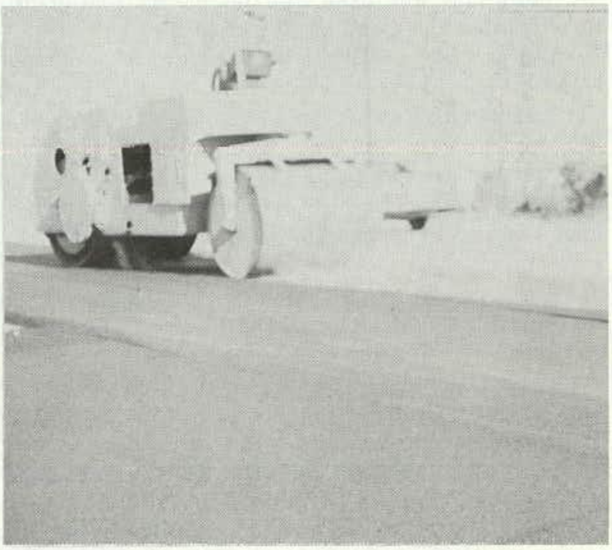


Figure F-2. Wetted steel roller showing vapor generated.

On October 10, 1974, two samples of fumes were obtained from a tank, at the Orlando Paving Company's mixing plant, containing RC-250 at 150 F.

On October 16, 1974. a single lane of about 1,000 ft of limerock base on Aloma Avenue in Winter Park, Fla., was primed with an application of RC-70 (see Fig. F-3). Twenty-one air samples were obtained in approximately a 1-hr period.

On October 21, 1974, a limerock-based parking lot (140 ft × 700 ft) was primed by 12 to 14 truck passes after an initial hand curb spray, (see Figs. F-4 and F-5).

Truck spraying was completed in about 20 min after an initial 20 min of hand spraying at various points on the lot. Twenty-four samples were collected over a 2-hr period at this site.

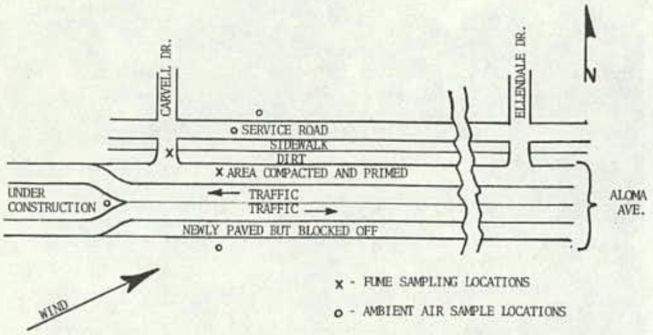


Figure F-3. Aloma Ave. RC-70 priming area—Winter Park, Fla.

On October 22, 1974, fume samples were taken from two RC-70 storage tanks of 4,000-gal capacity each. Both tanks were at a temperature of approximately 76 F (25 C). The north tank was about half full and the south tank was three-quarters full (see Figs. F-6 and F-7).

All hydrocarbon analyses were performed on a modified Hewlett-Packard gas chromatograph (see Fig. 4). Samples were taken with a small "propane tank" (available at most hardware stores). The tanks were modified by evacuating the propane gas, removing the central "backflow" spring valve, and attaching a hose extension to the manual valve line. Figure 5 in Chapter Two shows a recording of a tank sample.

Prior to a field trip for samples, the tank was evacuated by means of a laboratory vacuum source. The tank valve was then opened in the field with the hose inlet located at the desired sampling position. Only grab samples were obtained because there was no method of measuring the amount of sample collected when the valve was opened. After the air sample was collected, the valve was closed to prevent dilution during transport to the lab. At the laboratory, each tank was pressurized to 15 psi gage with helium, thus reducing the RH-C and methane concentrations to half of their field value. It was found necessary to "up-end" these bottles several times just prior to injecting their samples into the sampling line of the GC in order to minimize stratification of gases within the tank. However, when stratification did occur, this was quite evident on the chart record in that the proportional heights of the helium and air signatures were changed.

DATA ANALYSIS

In the following analysis, the instances showing unexpected characteristic reactions or results can be related to statistically insufficient data. The fact that the collected grab samples do not accurately represent the general or average concentration of a nonhomogeneous mixture requires a statistical approach. An ambient value that was not representative of the general ambient conditions tends to conceal the reaction existing when a downwind or later measurement is made. In a few instances during the first phase of testing, unexpected decreases in ambient concen-

Figure F-4. Shopping center parking lot, looking NE—Altamonte Springs, Fla.

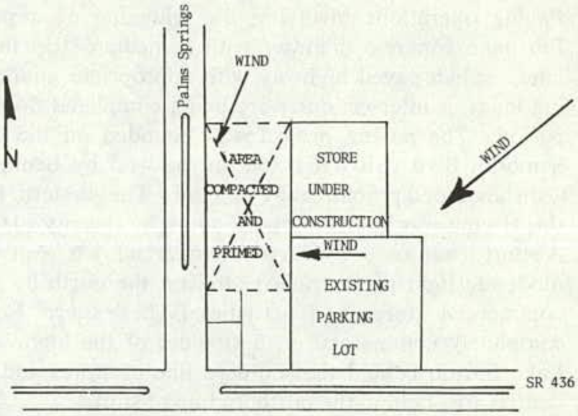


Figure F-5. Parking lot RC-70 priming area—Altamonte Springs, Fla.

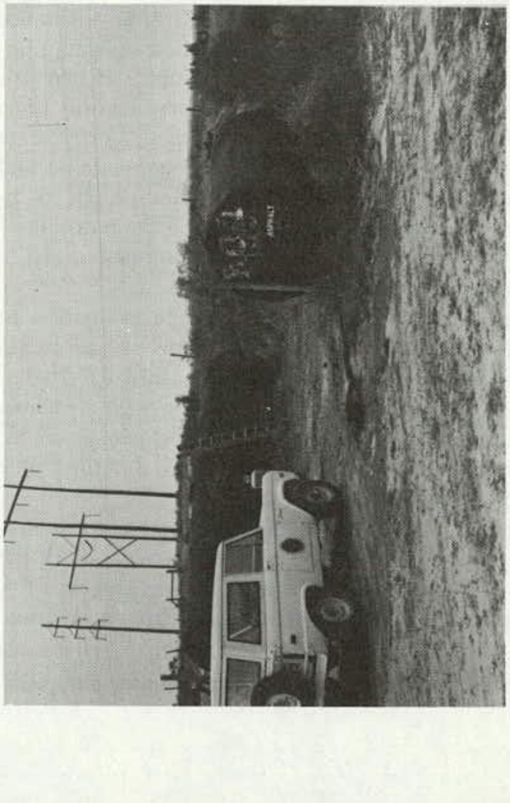


Figure F-6. Hubbard Construction Co. RC-70 storage site—Orlando, Fla.

trations of H-C were measured. In such cases, the investigator has presented the data, as obtained, with a comment on the lack of sufficient data to draw firm conclusions on the unexpected results. However, in the second phase of testing, the confidence level in the data obtained was greatly increased because of a gain in operator experience and the availability of some 20 sampling tanks during a single field sampling expedition. In all runs where measurable RH-C concentrations were found in this portion of the investigation, the characteristic "tail-off," designated as "heavy" RH-C during the initial testing, was experienced when measuring RC-70 and RC-250 fumes. Figure F-8 shows typical examples.

Evaluation of Ambient Air Measurements

During the first phase of testing, 20 individual ambient air samples were collected and analyzed; 6 samples were taken in the afternoon and the remaining 14 samples were collected on 12 different days. Table F-1 lists the reactive hydrocarbon and methane concentrations found—along with the weather, date/time, and site location. The following is a summary of the average morning and afternoon concentrations of RH-C and methane for the samples collected during July and August 1974:

	RH-C		METHANE	
	Avg. Value	Std. Dev.	Avg. Value	Std. Dev.
Average a.m. values	0.85	0.94	3.6	2.51
Average p.m. values	0.42	0.52	1.8	0.47
Over-all average	0.72	0.86	3.0	2.24

It is apparent from Table F-1 that (1) there is a high degree of variability in the data, and (2) the average values exceed the ambient standard established by the Environmental Protection Agency.

The data variability demonstrates that single grab samples inadequately describe what is probably a nonhomogeneous mix of hydrocarbons from many sources. Composite and statistical sampling is necessary if valid data are to be obtained at a high confidence level. This is expensive and time consuming and needs to be weighed against the worth of the improved validity. A correlation of the ambient recorded data was made based on whether the sample was collected in the morning or early afternoon. The morning values of both the reactive hydrocarbons and the methane concentrations were twice their afternoon average value. Although many of the high concentrations of RH-C possibly can be explained by local heavy traffic, some of the samples were collected at times and places that no apparent H-C production source was evident.

On 8 of the 11 mornings that samples were collected, a reactive hydrocarbon content considerably in excess of the 0.24 ppm EPA standard was determined. Only 2 of the 6 afternoon measurements showed excessive reactive hydrocarbons, and on the 21st a "haze" was noted in the weather observation.

The 5 or 6 independent ambient air measurements during the cutback asphalt sampling operations decreased the probability that some unknown contaminant from the sur-

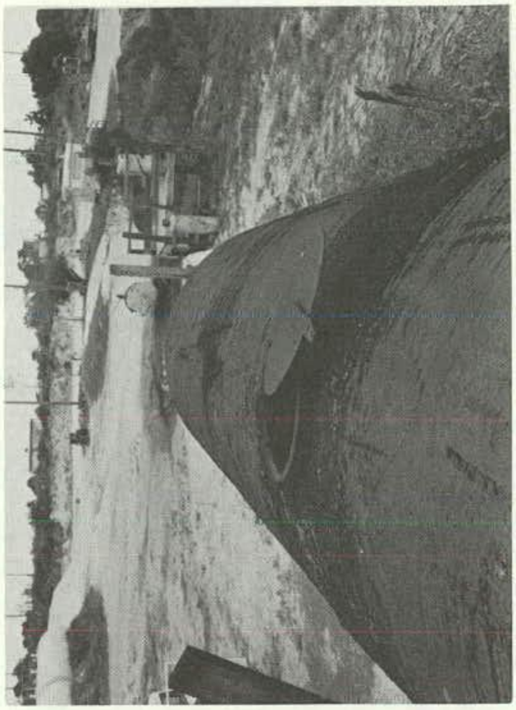


Figure F-7. Hubbard Construction Co. RC-70 storage tank hatch open for sampling.

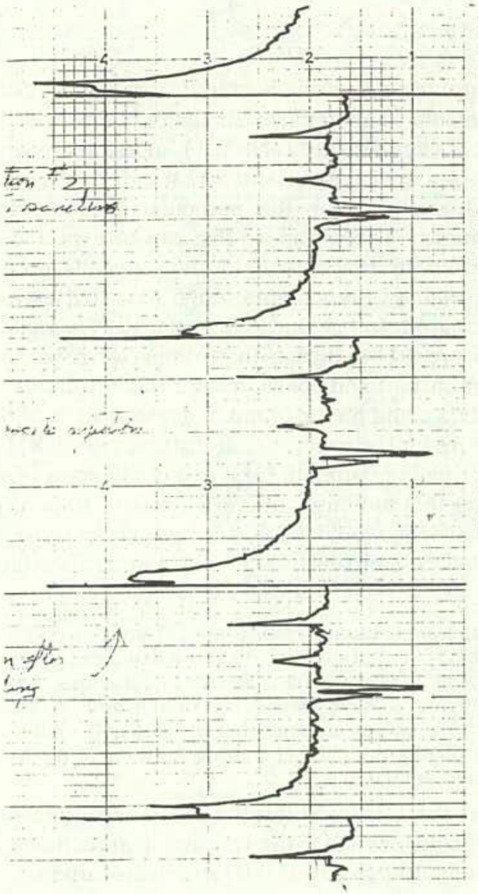


Figure F-8. GC data runs on 10/17/74—samples collected 10/16/74.

TABLE F-1

AMBIENT AIR HYDROCARBON MEASUREMENTS, PPM$_v$ AS METHANE

Date	Time	Air T. °F	Clouds Type	Wind Dir. MPH	React. H-C	Methane	Location and Remarks
7/31/74	0915	82	95 Lo Cum.	SE 7	1.16	11.4	SW corner intersection SR 436 & US 50 on site of demolished gas station.
					0.75	3.8	NW corner, gas station parking lot
8/01/74	0900	80	10 Hi Strat.	SE 4	0.58	1.9	SW corner intersection SR 436 & US 50
	1415	95	100 Thdrstrm.	W 10	0.23	1.7	0.5 mi. west of intersection on US 50
8/02/74	0915	82	0 Clear	SE 3	0.00	1.7	0.7 mi. W. of intsct. air off of lake
	1330	91	100 Thdrstrm.	NW10-20	0.00	1.6	0.9 mi. W. of intsct., showering
8/05/74	0930	85	0 Clear	S10-12	0.00	3.3	0.9 mi. W. of intsct., air off airport
8/06/74	0735	78	90 Hi Strat.	SW 0-2	3.01	3.6	0.7 mi. W. of intsct., Earth-mover ops 150 ft. away
	1230	87	90 Hi Strat.	SE 8	1.47	2.3	0.9 mi. W. of intsct., air off airport
8/07/74	0800	79	10 Cirrus	SE 5	2.86	2.5	1.5 mi W. of intsct., air off airport
8/21/74	1230	90	50 Cum.-Haze	NE 0-5	0.65	2.8	SR 436 & Wymore near I-4 overpass
8/22/74	0800	86	100 Fog	NE 0-3	0.66	2.5	SR 436/I-4 overpass, syringe sampler used
					1.35	2.6	Same location, tank sampler used
	1200	95	20 Cum.	N 3-6	0.00	1.6	E. end of overpass, SR436/I-4
8/23/74	0800	81	40 Hi Strat.	N 0-3	0.58	4.7	SR 436 & Douglas, gas station entrance
8/26/74	0800	84	0 Clear	N 2	0.48	6.5	SR 436/I-4 overpass, E. end
	1330	102	60 Cum.	SE 3-7	0.17	1.8	SR 436 & 434,1/2 mi. to built up area
8/27/74	0930	85	70 Cum.	NNE 3	0.51	1.8	Aggregate yard of asphalt mixing plant
8/28/74	0830	79	10 Hi Strat.	Calm	0.00	1.9	FTU campus btwn. Engr. & Nat. Sc. Bldgs.
	1045	85	30 Cum.	SE 3	0.00	1.5	FTU Engr. Bldg. parking lot.
10/16/74	1145	85	60 Cumulus	WSW 8-10	0.9	1.6	North side Aloma, dwnwd traffic
	1230	88			0.0	1.6	Same location, Carvelle & Aloma
	1230				0.0	1.5	S. side Aloma, upwind traffic
	1450	92	60 Thdrstms N & S Aloma	SW 10	1.1	1.6	Middle Aloma, 100' upwind of priming operations
	1510	90			1.0	1.4	Same as above location
10/21/74	1200	74	80 Cumulus	E 15-20	0.0	0.9	Palm Sprgs Rd. & SR 436 NE Cor.
	1215	77		no wind	0.0	0.8	Same, to leeward of new store
	1254			E 6	0.0	0.9	Same, wind lull before ops
	1318			NE 15 gusty	0.0	1.7	Same
	1352			E 8	0.0	0.9	Same
	1500	81	40 Cumulus	E 10	0.0	1.0	Same
10/22/74	1030	71	100 Cumulus	N 3-5	0.0	1.0	Hubbard Constr. Co., Pine Hills Rd., Orlando

rounding environment was inadvertently measured during H-C measurements. The ambient air data obtained on the 16th and 21st of October (set Table F-1) appear reasonable and provide a range of the variations that can be expected in RH-C and methane for the particular location and weather conditions. The variations that can be expected in RH-C concentrations found along Aloma Avenue apparently are the result of the variable traffic flow that existed immediately adjacent to the lane being primed. The opportunity to measure RH-C during the priming of a parking lot with a zero background concentration was fortuitous.

Definitive data could not be found in a brief search of the current literature on the proportional distribution of RH-C to methane normally existing in rural and urban areas. One source indicates that in nonurban areas less than 10 percent of the hydrocarbons would be RH-C, primarily terpenes and other biological emissions (*29*). This source also states that:

> Yearly averages of monthly maximum 1-hour average hydrocarbon concentration including methane, recorded continuously in various stations of the Continuous Air Monitoring Projects, have reached maximum hourly values of 8 to 17 ppm (as carbon), but at least half of this amount is probably the photochemically unreactive methane component in all cases.

It is noted that the average ambient air H-C measurements obtained in this project show the reactive hydrocarbons to be approximately 20 percent of the total hydrocarbons.

TABLE F-2

AIR SAMPLES ADJACENT PAVING MACHINE, PPM$_v$ AS METHANE

Date	Time	Air T. °F	React. H-C	Methane	Remarks
7/31/74	0915	82	[1.16]	[11.4]	Measured ambient condition
			0.00	1.8	Sample possibly diluted during transport to lab.
8/01/74	0900	80	[0.58]	[1.9]	Measured ambient conditon
			0.58	2.2	1 ft. from Paver, nose height sample
			3.46	2.0	Same Conditions, in fumes from paver
			12.00		Based on Tail-off area, heavy hydrocarbons
	1415	95	[0.23]	[1.7]	Measured ambient condition
			1.04	1.7	1 ft. from Paver, nose height sample
			4.92		Based on tail-off area, heavy hydrocarbons
			15.40	2.7	Same conditions, different sampler
			81.1		Based on tail-off area, heavy hydrocarbon
8/02/74	0915	82	[0.00]	[1.7]	Measured ambient condition
			0.41	1.7	1 ft. from Paver, nose height
8/06/74	0730	78	[3.01]	[3.6]	Measured ambient (in vicinity of Earthmovers)
			1.22	3.0	1 ft. from Paver, nose height
	1230	87	[1.47]	[2.3]	Measured ambient condition
			2.95	3.7	1 ft. from Paver, nose height
8/07/74	0800	79	[2.86]	[2.5]	Measured ambient condition
			5.30	5.7	1 ft. from Paver, nose height
8/21/74	1230	90	[0.65]	[2.8]	Measured ambient condition
			1.23	1.8	1 ft. from burner off
			8.31	2.0	Sampled at screed vent with vent blower on
			31.00		Based on tail-off area, heavy hydrocarbons
8/22/74	0800	86	[1.35]	[2.6]	Measured ambient condition
			2.62	2.1	6 inches above screed
			2.02	2.8	Fumes from asphalt hopper, same paver
			4.76		Based on tail-off area, heavy hydrocarbons
	1200	95	[0.00]	[1.6]	Measured ambient condition
			1.60	1.8	6 inches from screed exhaust Paver

Evaluation of Air Samples Adjacent to Paver

Thirteen of the 14 samples collected in the immediate vicinity of the operating paving machines were considered valid. These results are given in Table F-2. In 5 samples, an unknown H-C component (designated as "heavy" H-C) was measured and is indicated by asterisks; these values are discussed later in this appendix. The data show that there is an increase in the reactive hydrocarbon concentrations in the immediate vicinity of asphaltic paving machines in 11 of the 13 measurements. The average incremental increase in RH-C adjacent to the paving machine is 2.64 ppm with a standard deviation of 4.08 ppm.

The variability in concentrations indicated by the large standard deviation value again demonstrates the difficulty in obtaining meaningful and valid quantitative measurements when wind, temperature, location, and paving machine types were varied. Qualitatively, fumes emanating from the screed vent, the asphalt hopper, the engine exhaust, and the burners, when undiluted with ambient air, show higher than normal concentrations. The concentrations of H-C in samples adjacent to the paving machine will be dependent on the proximity of the sampling inlet to such point sources and the dilution occurring prior to the sampling point.

Evaluation of Air Samples Adjacent to Tank Truck Sprayer

Hand spraying RC prime coat over irregular areas and along curbs and gutters is performed in one application, as shown in Figure F-9.

The Aloma Avenue application was performed with a tanker spray truck at an estimated speed of about 5 to 6 mph, thus necessitating the "sample taker" to trot adjacent to the truck in order to sample during the truck application. In the parking lot application, an instrumented truck equipped with a special speedometer and a flowmeter for the RC-70 was used; the application rate was 140 gal/min at a speed of about 340 ft/min (about 3.9 mph) (see Figs. F-10 and F-11). The spray applications at both sites were performed during a period of above-average winds (about 10 mph plus), thus resulting in sampling being performed at a greater distance from the sprayer than was done with the asphalt paving machine. Additionally, in the case of the parking lot application, the truck passes were made in a N-S direction with the east and west edges being primed first and the later passes working toward the centerline of the lot. Thus, after the fourth pass, samples could only be taken from the west side of the lot. In spite of these precautions and limitations to sampling adjacent to the sprayer, one white shirt worn by the sample taker was found to have 20 to 30 small asphaltic particles per square inch on its front after the sampling was completed.

The results in Table F-3 indicate that the reactive hydrocarbons given off to the atmosphere by RC-70 sprayer operations (with measurements made at 5- to 30-ft downwind) are considerably greater than those emitted from the asphalt pavers, with measurements made within 1 ft of the machine, downwind. Wind and distance tend to attenuate the concentrations through dilution with larger volumes of air; although, in the case of RC-70, winds may have a greater (faster) drying effect resulting in a more rapid vaporization of the solvent. On the basis of these samples, the concentrations of RH-C of 5 to 6 ppm can be expected at distances of 5 ft from a sprayer operating in light-to-moderate wind when making a single pass. In the case of parking lots, where the fumes from previous passes are additive, concentrations of 4 to 5 ppm of RH-C may be found 30-ft downwind from the sprayer with light-to-moderate winds.

The application of RC-70 at the Aloma Avenue site had little, if any, effect on the ambient methane concentrations;

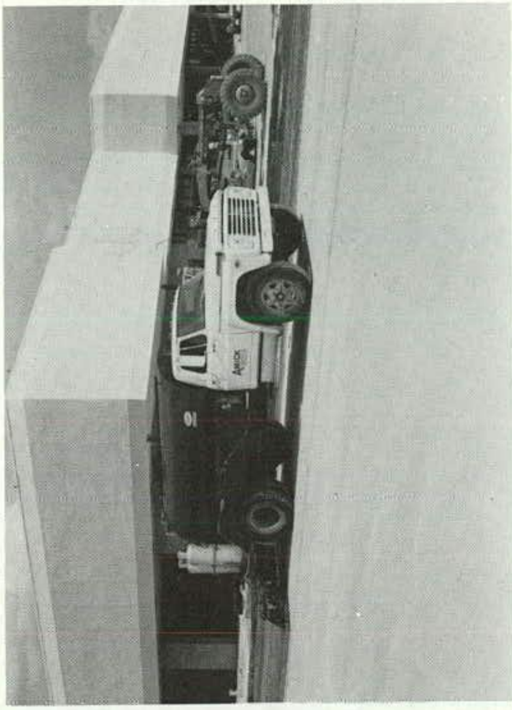


Figure F-10. Second pass east side (upwind) of parking lot—tanker moving south.

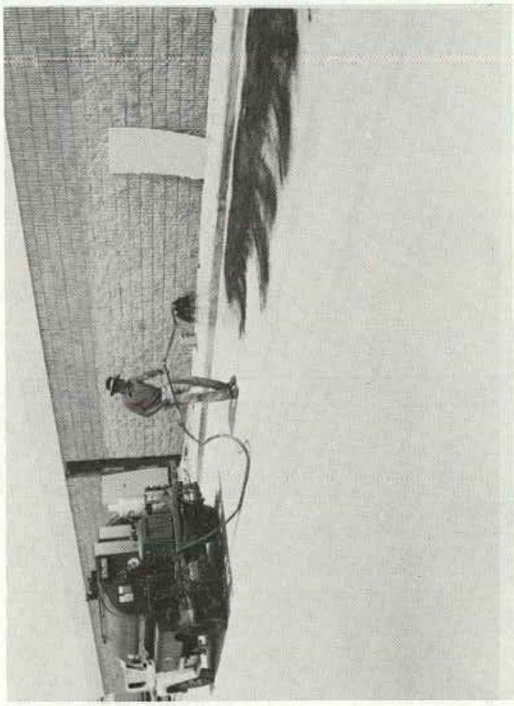


Figure F-9. Hand spraying RC-70 along gutter adjacent to store in shopping center.

TABLE F-3

AIR SAMPLES DURING PRIMING OPERATIONS, PPM$_v$ AS METHANE

Date	Time	Air T. °F	React. H-C	Methane	Remarks
10/16/74	1230	88	(0.0)	(1.6)	Measured ambient conditions
	1425	91	4.7	1.4	8' downwind of intersection handspray
	1427		0.5	1.5	10' downwind intersection handspray, very gusty wind during sampling
	1432	91	5.1	1.7	5' dw, tanker making 2' curb spray
	1437		5.6	1.5	5' dw of 8' width spray at a trot speed, 1 pass only
	1450	92	(1.1)	(1.6)	Measured ambient condition
10/21/74	1254	77	(0.0)	(0.9)	Measured ambient condition
	1320		Trace	1.5	10' dw, hand spray, brisk wind
	1335		2.9	1.7	12' dw, hand spray, light wind (to lee of bldg.)
	1340		3.5	1.6	15' dw, 1st pass spray truck, moderate wind
	1345		3.2	1.5	15' dw, 4th pass, light wind
	1355		4.3	1.6	30' dw, last pass, moderate wind

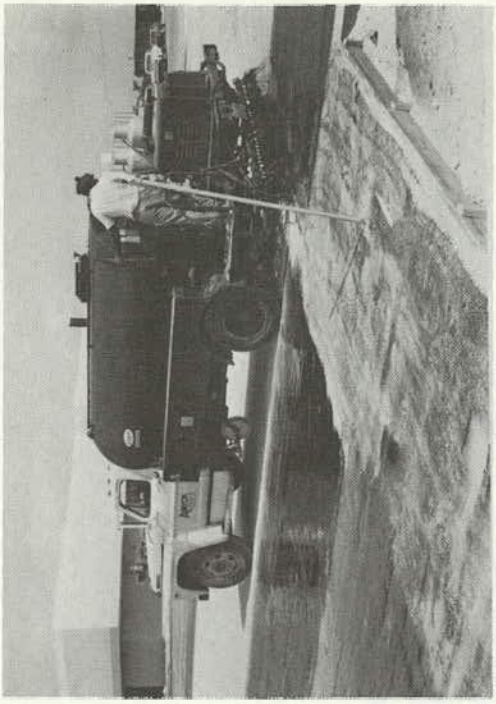


Figure F-11. Third pass on west side (downwind) of parking lot—tanker moving north.

however, in the parking lot application there appeared to be a small increase, about 0.5 to 0.7 ppm, in the measured methane because of the spraying operations.

Evaluation of Downwind Fumes from Paving Operations

The concentration increase over ambient, approximately 25-ft downwind from paving operations, averages 2.12 ppm for 12 samples with a standard deviation of 1.47 (see Table F-4). Downwind measurements of paving operations include increases in H-C concentrations because of the traffic flow on the highway being paved. The ambient dilution of H-C generating sources is illustrated by the reduced magnitude of the standard deviation.

Evaluation of Downwind Fumes from Spray Operations

Only 3 samples of downwind conditions at varying times after application were obtained, because the previous series of samples had shown little consistency and correlation with measured parameters. In the instant series, these samples were considered as "samples of opportunity" and were taken only when a strong fume odor was noted (see Table F-5). When the samples were analyzed in the laboratory, little, if any, RH-C concentrations above ambient conditions could be found. It appears that the RC-70 will normally evaporate a large proportion of its solvent within an hour after its application and, combined with mixing wind action, will provide almost no measurable RH-C concentration at the end of this period at nominal distances from the application site.

Special Investigations

1. *Traffic Generated H-C Concentrations*—During the first phase of testing, downwind curbside samples were taken on three occasions in an attempt to determine the automobile traffic contribution to the THC measurements. This attempt was unsuccessful because, in each instance, the ambient concentrations were relatively high and exceeded the RH-C concentrations measured. The incremental differences between the ambient reading and the downwind curbside readings were, in ppm$_v$ as methane, as follows:

DATE/TIME	RH-C	CH$_4$
8/6/74/0730	−2.16	+2.2
8/6/74/1230	−0.96	+1.3
8/7/74/0800	−2.25	+1.0

The apparent similarity in readings was considered noteworthy; however, because of the small sampling and the high ambient concentrations, it was not considered appropriate to draw any conclusions from these data.

2. *H-C Emissions from Asphalt Paving vs. Time*—Listed in Table F-6 (data abstracted from Table F-9) are the incremental differences from ambient measured concentrations against time intervals after paving. In the last two sample sets, air and asphalt temperatures at the point of sampling were also taken and are included.

TABLE F-4

AIR SAMPLES DOWNWIND FROM PAVING OPERATIONS, PPM$_v$ AS METHANE

Date	Time	Air T. °F	React. H-C	Methane	Remarks
7/31/74	0915	82	[1.16]	[11.4]	Measured ambient condition
			0.30	1.7	12 ft. downwind from operating **Paver**
			0.00	1.9	50 ft. downwind from operating **Paver**
8/01/74	0900	80	[0.58]	[1.9]	Measured ambient condition
			0.39	6.5	25 ft. downwind from operating **Paver** sampler #2
			2.85	1.8	Same position, sampler #3, volatile H-C
			6.56		Based on tail-off area, heavy H-C, sampler #3
	1415	93	[0.23]	[1.7]	Measured ambient condition
			0.84	1.4	25 ft. downwind from paving ops plus inbetween traffic
			4.64	1.7	Same position and conditions, dif. sampler, volatile H-C
			22.20		Based on tail-off area, heavy H-C, sampler same as above
8/02/74	0915	82	[0.00]	[1.7]	Measured ambient condition
			0.67	4.2	25 ft. downwind paving ops, fumes noticable, sampler #2
			0.00	1.6	Same position, no odor due light wind and rising fumes
8/05/74	0930	85	[0.00]	[3.3]	Measured ambient condition
			1.54	1.7	25 ft. downwind paving ops, tank sampler #1
			0.00	1.8	Same position, sampler #3
8/06/74	0730	78	[3.01]	[3.6]	Measured ambient (in vicinity of Earthmovers)
			16.15	2.6	25 ft. downwind paving ops plus inbetween traffic
	1230	87	[1.47]	[2.3]	Measured ambient condition
			2.47	3.0	25 ft. downwind paving ops - **Paver**
8/22/74	1200	95	[0.00]	[1.6]	Measured ambient condition
			0.00	1.8	10 ft. downwind in traffic line, visible vapors
			1.88	2.3	20 ft. downwind plus inbetween traffic, noticable odor, no visible fumes.

TABLE F-5

AIR SAMPLES DOWNWIND FROM SPRAY OPERATIONS, PPM$_v$ AS METHANE

Date	Time	Air T. °F	React. H-C	Methane	Remarks
10/16/74	1510	90	(1.0)	(1.4)	Measured ambient condition
	1515	90	0.7	1.5	75' downwind, 45 minutes after application
10/21/74	1500	81	(0.0)	(1.0)	Measured ambient condition
	1420		0.0	1.4	Downwind edge of pk. lot, gusty wind, nose height sample, 30 min. after application.
	1458		Trace	1.5	dw heavy applied area at SW corner, nose ht. one hour after application

It would seem that the high RH-C reading on August 2, 1974 is not representative of normal emissions obtainable from recent paving operations. However, the wind direction on this occasion was from an area not previously or subsequently measured and could have a high H-C production source located therein. During the collection of samples on August 7, the gusty wind conditions were particularly noted, and it is likely that considerable mixing of ambient air with the fumes in the 2-in. surface layer was occurring. The factors of wind and temperature appear to have a strong influence in obtaining valid measurements of paving emissions with time. The two sets of data obtained on August 26 provide a qualitative indication that the emission rate of RH-C from new paving is halved in about the first 20 min and apparently completed at the end of 45 min. It is considered unlikely that the fresh paving can act as a sink for methane concentrations and that the negative values are the result of obtaining either nonrepresentative ambient values or the measurement of differences that are approaching the measuring precision of the equipment, or a temperature effect.

3. *H-C Emissions from RC-70 Prime vs. Time*—The decay of RH-C emission with time was tested to provide a data comparison with the paving information previously obtained. The results are given in Table F-7.

The Aloma Avenue application was sanded 10 to 14 min after application. Although this did not appear to have any immediate effect on emission, approximately 20 min later the measurement of an unsanded spot of the RC-70 that had not penetrated the aggregate thoroughly exhibited a stronger emission concentration than the surrounding sanded portions.

TABLE F-6

H-C PAVING EMISSIONS VS. TIME

	PPM$_v$ as CH$_4$ Increase above Ambient				
Time after paving	RH-C	CH$_4$	Inlet ht.	Air temp. °F	Asphalt temp. °F
8/2/74 1330	Amb. Air Temp.		= 91 °F	Wind NW 10 MPH	
15 min.	11.23	0.0	1/2 in.	---	----
8/7/74 1330	Amb. Air Temp.		= 90 °F	Wind E gusty to 15 MPH	
0 min.	0.75	-0.1	2 in.	---	----
10 min.	0.75	-0.1	2 in.	---	----
20 min.	1.33	0.3	2 in.	---	----
8/26/74 0800	Amb. Air Temp.		= 84 °F	Wind N 2 MPH	
0 min.	1.91	-3.9	1/2 in.	126	273
10 min.	0.59	-4.2	1/2 in.	120	259
20 min.	0.82	-4.3	1/2 in.	118	244
45 min.	-0.11	-4.3	1/2 in.	113	241
8/26/74 1330	Amb. Air Temp.		= 102 °F	Wind SE 3-7 MPH	
0 min.	1.02	-0.1	1/2 in.	151	266
(Paving rolled at 8 min.)					
10 min.	-0.17	-0.2	1/2 in.	131	230
20 min.	0.82	0.1	1/2 in.	120	208
45 min.	-0.17	-0.2	1/2 in.	115	172

The parking lot application was not sanded, and the sampling was performed at two locations: one area had the desired application dosage that penetrated well and was relatively dry in about 30 min; the other area had a greater quantity of RC-70 applied per square foot and had not completely penetrated at the end of 70 min. In general, higher emissions were obtained from the latter location, although the exact same spot was not measured each time.

Apparently sanding tends to slow down the evaporation process of the solvent, although this cannot be concluded from the available data because of the lack of control of other variables (especially the wind conditions).

TABLE F-7

CUTBACK H-C EMISSIONS VS. TIME

	PPM$_v$ as CH$_4$ Increase above Ambient				
Time after application	RH-C	Ch$_4$	Inlet ht.	Air temp. °F	Asphalt temp. °F
1C/16/74 1430 Ambient Air Temp. = 90°F Wind WSW 10 MPH Average Ambient RH-C = 0.6 ppm CH$_4$ = 1.5 ppm					
0 min.	51.4-55.4	0.1-0.1	1/2 in.	--	150(-)
12 min.	5.4	0.2	1/2 in.	--	
15 min.	5.2-7.0	0.1-0.0	1/2 in.	(sanded)	
30 min.	5.9	0.3	1/2 in.	(well sanded by shovel)	
34 min.	7.4	0.1	1/2 in.	(unsanded spot)	
50 min.	0.5	0.1	1/2 in.	(sanded)	
1C/21/74 1330 Ambient Air Temp. = 80°F Wind E 10-20 gusy Average Ambient RH-C - 0.0 ppm CH$_4$ = 1.0 ppm					
0 min.	76.2-60.5	0.6-0.7	1/2 in.	--	160(-)
15 min.	3.1-7.0	0.8-0.4	1/2 in.	--	--
30 min.	3.3-0.1	0.9-0.4	1/2 in.	--	--
70 min.	3.2-0.0	0.6-0.4	1/2 in.	--	--

TABLE F-8

H-C PAVING EMISSIONS VS. HEIGHT

	PPM$_v$ as CH$_4$ Increase above Ambient			
Ht. above Surface	RH-C	CH$_4$	Air temp. °F	Asphalt temp. °F
8/7/74	1330 Amb. Air Temp.		= 90°F	Wind E gusty to 15 MPH
2 in.	0.75	-0.1	----	----
8/21/74	1230 Amb. Air Temp.		= 90°F	Wind NE 0-5 MPH
6 in.	-0.65	-1.2	----	290
3 ft.	-0.05	-1.1	----	290
8/22/74	0800 Amb. Air Temp.		= 86°F	Wind NE 0-3 MPH
1 ft.	-1.35	0.1	----	239
	1200 Amb. Air Temp		= 95°F	Wind N 3-6 MPH
1 ft	0.37	0.0	----	257
8/23/74	0800 Amb. Air Temp.		= 81°F	Wind N 0-3 MPH
surface	1.06	-2.0	100	266
6 in.	0.51	-1.7	93	266
1 ft.	0.37	-1.2	90	266
(freshly layed and rolled immediately				
6 in.	0.22	0.4	90	----

It does appear that a 90-percent reduction in emission concentrations of RH-C occurs within the first 15 min of application and thereafter the reduction depends on wind, temperature, and the amount of RC applied.

4. *H-C Measurements vs. Height Above New Paving*—Sample sets were made obtaining data at varying heights above freshly paved surfaces to ascertain if a "layering" effect, or the effect of diffusion with height above the surface, could be noted. Selected data appropriate to this search, from Table F-9, have been combined in Table F-8.

On the basis of the limited data for analysis in Table F-8, it is difficult to arrive at conclusive results. A case can be made, however, that a characteristic RH-C concentration pattern with height might be:

HEIGHT	PPM$_v$ OVER AMBIENT
surface	1.06
2 in.	0.75
6 in.	0.51
1 ft	0.37
3 ft	0.00

This would be based on the assumption that some of the samples measured on August 21 and 22 were not representative. It is probable from these data that some form of layering or stratification of the methane does exist. It is possibly temperature related, wherein the ambient methane concentrations (normally taken at chest height) are reduced in layers close to the surface. Considerably more data would be necessary to substantiate this hypothesis.

5. *Paving Equipment Emissions When Parked*—On two occasions, air sample measurements in the close vicinity of the parked paving machine were taken in an effort to isolate various machine-related H-C emissions from those directly associated with its paving function. At 0730 on August 6, a sample was taken immediately adjacent and downwind of the paver that was parked with its engine and burners on, its asphalt hopper empty, and the asphalt delivery trucks not present. This sample indicated an emission of 1.99 ppm$_v$ of RH-C above ambient and a reduction of the ambient methane concentration of 3.6 ppm$_v$ to a concentration of 0.3. These readings can be supported on the basis of the emissions from both the internal combustion engine powering the paver and the warm-up burners, which would provide this increase in RH-C while the screed warm-up burners were either consuming (oxidizing) the ambient methane concentration or (more probably) were creating a layering or stratification (as discussed in the previous section).

On August 6 the paver was parked with the engine on, burners off, but with the hopper about half full of asphalt. A point having the strongest asphalt odor was found to be about 25-ft downwind from the parked machine and a sample was taken at this point. On analysis, the sample exhibited a volatile RH-C concentration of 7.93 ppm$_v$ above ambient.

The sample obtained on August 7 was designed to duplicate the sample of the previous morning with the paver parked during warm-up, the engines and burner operating, and the hopper empty. The sample analysis showed a 2.44 ppm$_v$ decrease in RH-C concentration and a 1.2 ppm$_v$ increase in methane (over ambient)—just the opposite from the previous morning. It is considered probable that the sampler used to take the ambient conditions had residue contamination from the previous day's operations.

6. *Spray Equipment Emissions When Parked*—Two samples were obtained from the vicinity of the spray trucks when parked and prior to their spraying operations. At the Aloma Avenue location, very little odor from the truck could be detected (engine and burners off) and a sample 6 in. from the spray nozzles provided a measureable concentration of RH-C above the average ambient conditions in the vicinity of about 2.0 ppm. At the parking lot site, the tanker truck arrived with the RC at a temperature of 95 F. It was thus parked for about 20 min with its engine and propane burners on while bringing the RC up to a temperature of 160 F. During this period, a sample was taken approximately 12-ft downwind where the odor from the burner appeared greatest. An RH-C measurement of

TABLE F-9

AIR SAMPLES FROM TARGETS OF OPPORTUNITY AND SPECIAL INVESTIGATIONS, PPM$_v$ AS METHANE

Date	Time	Air T. °F	React. H-C	Methane	Remarks
8/02/74	1330	91	[0.00]	[1.6]	Measured ambient condition
			11.23	1.6	½ in. above paved surface, 15 min after paving
8/06/74	0730	78	[3.01]	[3.6]	Measured ambient, Earthmover ops in vicinity
			0.85	5.8	No paving ops, curbside downwind of traffic
			5.00	0.3	Fumes adjacent Cedarapid paver, burners on, engine idling, no asphalt in hopper
	1250	87	[1.47]	[2.3]	Measured ambient condition
			0.51	3.6	No paving ops, curbside downwind of traffic
			9.40	1.4	Strong fumes from asphalt hopper during idle, volatile H-C
			30.8		Based on tail-off area, heavy hydrocarbon
8/07/74	0800	79	[2.86]	[2.5]	Measured ambient condition
			0.42	3.3	Paver parked, no asphalt in hopper, burners & engine on
			0.61	4.4	No paving ops, curbside, downwind two traffic lines
	1330	90	1.17	1.7	Sample inlet 2 in. above fresh paving
			1.17	1.7	Same position 10 minutes later
			1.75	4.1	Same position 20 minutes after paving
8/21/74	1230	90	[0.65]	[2.8]	Measured ambient condition
			0.00	1.6	Sample inlet 6 in. above fresh paving, asphalt temp. = 290°F
			0.60	1.7	Inlet 3 ft. above fresh paving, asphalt temp.=290°F
8/22/74	0800	86	[1.35]	[2.6]	Measured ambient condition
			0.00	2.7	Inlet 1 ft. above fresh paving, asphalt temp. = 239°F
	1200	95	[0.00]	[1.6]	Measured ambient condition
			0.37	1.6	Inlet 1 ft. above fresh paving, asphalt temp. = 257°F.
8/23/74	0800	81	[0.58]	[4.7]	Measured ambient condition
			1.64	2.7	Inlet at surface fresh paving, Air ≈ 100°F, Asphalt = 266°F
			1.09	3.0	Inlet 6 in above fresh paving, Air = 93°F, Asphalt = 266°F
			0.95	3.5	Inlet 1 ft. above fresh paving, Air = 90°F, Asphalt = 266°F
			0.80	5.1	Inlet 6 in. above freshly layed and rolled asphalt (in surface vapors) visible condensate in syringe, Air = 90°F
8/26/74	0800	84	[0.48]	[6.5]	Measured ambient condition Sample inlet ½ inch above surface of paving Time after paving Air°F Asphalt °F
			2.39	2.6	0 min. 126 273
			1.07	2.2	10 min. 120 259
			1.30	2.2	20 min. 118 244
			0.37	2.2	45 min. 113 241
	1330	102	[0.17]	[1.8]	Measured ambient condition
			1.19	1.7	0 min 151 266 (Rolled at 8 min.)
			0.00	1.6	10 min. 131 230
			0.99	1.9	20 min. 120 208
			0.00	1.6	45 min. 115 172
8/27/74	0930	85	[0.51]	[1.8]	Measured ambient condition at asphalt mixing plant
			1.33	4.0	Two in. above freshly loaded asphalt delivery truck
			0.60	3.7	Gas heater exhaust asphalt (AC) storage tank
			17.51	3.1	Fumes inside asphalt delivery truck from Tampa, AC temp. = 320°F
			845.	50.0	#6 fuel oil tank fumes, FTU utility building
			1,071.	23.8	Diesel fuel tank fumes, FTU maintenance building
			24,100.	97.6	Gasoline fumes in filler neck Ford Bronco gas tank.
8/28/74	1045	85	[0.00]	[1.5]	Ambient FTU Engr. Bldg. parking lot
			0.94	2.1	In auto exhaust stream, 8 ft. from exhaust
			39.7	36.5	In auto exhaust stream, 4 ft. from exhaust
			307.	299.	In auto exhaust stream, 2 ft. from exhaust
			768.	695.	In auto exhaust stream, 1 ft. from exhaust
TANK FUME MEASUREMENTS (Note: Ambient air mixing is uncontrolled after opening hatch to obtain sample)					
** 8/27/74	0930	85	17.5	3.1	AC delivery tanker, asphalt cement temp 320°F
**			845.	50.0	#6 fuel oil tank, temp. 85°F
**			1071.	24.	Diesel fuel tank, temp. 85°F
10/10/74	0830	75	4250.	124.	RC-250 storage tank, temp. 150°F - H-C samples ranged from 4960. to 3440.
10/16/74	1240	88	2310	84.	RC-70 Spray Tank, temp. 150°F
10/21/74	1220	76	1250	23.	RC-70 Spray Tank, temp. 95°F
10/22/74	1030	71	244	11.5	RC-70 Storage Tank, temp. 76°F, H-C samples ranged from 208. to 280.
FUMES FROM PARKED PAVING/SPRAYING VEHICLES					
** 8/06/74	0730	78	5.0	0.3	AC paving machine, burners on, engine on
** 8/06/74	1230	87	9.4	1.4	AC paving machine with asphalt in hopper
** 8/07/74	0800	79	0.4	3.3	AC paving machine, burners & engine on
10/16/74	1250	88	2.6	1.4	Sampler inlet 6" from coated nozzles on parked tanker, engine and burner off
10/21/74	1240	88	7.2	1.7	Parked tanker, engine & burner on (heating RC-70 from 95 to 160°F) 12' downwind

**Indicates data from basic report, listed here for comparison purposes.

TABLE F-9 (Continued)

Date	Time	Air T. °F	React. H-C Loc. 1	React. H-C Loc. 2	Methane Loc. 1	Methane Loc. 2	Remarks
FUMES MEASURED 1/2 " ABOVE PAVED OR SPRAYED SURFACE							
** 8/02/74	1330	91	11.2		1.6		15 min. after AC paving
** 8/23/74	0800	81	1.6		2.7		0 min. after AC paving
** 8/26/74	0800	84	2.4		2.6		0 min. after AC paving
**			1.1		2.2		10 min. after AC paving
**			1.3		2.2		20 min. after AC paving
**			0.4		2.2		45 min. after AC paving
10/16/74	1430	90	52.0	56.0	1.6	1.6	0 min. after spray RC-70
				6.0		1.7	12 min. after spray RC-70
			5.8	7.6	1.6	1.5	15 min. after spray RC-70-sanded
			6.5		1.8		30 min. after - well sanded
				8.0		1.6	34 min. after - unsanded spot
			1.1		1.6		50 min. after - sanded
10/21/74	1330	80	76.2	60.5	1.6	1.7	0 min. after RC-70 spray
			3.1	7.0	1.8	1.4	15 min. after RC-70 spray
			3.3	trace	1.9	1.4	30 min. after RC-70 spray
			0.0	3.2	1.4	1.6	70 min. after RC-70 spray

** Indicates data from basic report, listed here for comparison purposes

7.2 ppm was obtained, but it is considered to consist almost entirely of gas emissions from the burners and the truck's exhaust; RC odors were not noticeable (see Fig. F-12).

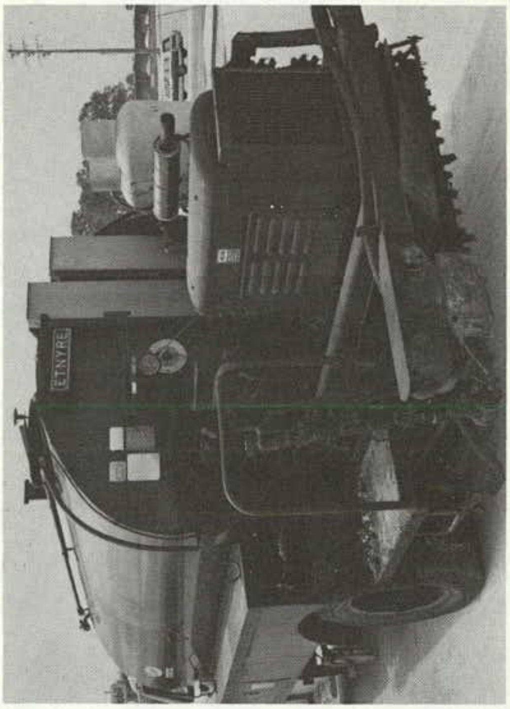


Figure F-12. Tanker spray truck.

7. *"Heavy" RH-C Measurements*—Eight of the more than 80 samples used in the first phase of testing exhibited a different RH-C signature on the gas chromatograph record than was obtained on the majority of runs and calibrations (see Fig. F-13). In these particular signatures the normal RH-C peak was followed by a "tail-off" that would last for approximately 3 min before the baseline datum was reached, an indication that the substance in column 1 of the GC was not eluting rapidly from the column during the backwash of the hydrocarbons from the column and into the detector. For samples exhibiting this characteristic, the analysis procedure was to measure the normal RH-C peak that occurs at the 1.9-min point in the run and to estimate the area under the tail-off by counting the 0.01-in.^{2} squares. The volatile RH-C and CH_4 concentrations were computed and recorded, as normally, by comparison with the calibration peak value for a known concentration. The area under the methane calibration peak was also measured in a similar manner to that used under the tail-off, and the ratio of the areas times the methane calibration concentration is quoted as the "total reactive hydrocarbons" (i.e. volatile plus heavy RH-C). These total RH-C concentrations are given in Table F-10 (see also Tables F-3, F-4, and F-9).

Every GC run in the second phase of measurements that obtained a measurable RH-C concentration from the RC-70 and RC-250 fumes exhibited a signature tail-off that in the first phase of testing was unexplained and tentatively designated as "heavy hydrocarbon" (see Fig. F-8). On the basis of this series of runs and the signature characteristic apparently provided by the solvating agent, it can be hypothesized that the tail-off is caused by solvent vapors condensing on the column material and eluting more slowly from the column than the reactive hydrocarbon gases having a lower boiling point. A clarification, or redesignation, of the term "heavy hydrocarbons" appears to be in order in view of this additional evidence of the source and/or cause of the tail-off type signatures. The sharp peak with no tail-off signature should be interpreted as a gaseous hydrocarbon concentration having a boiling point temperature below the GC oven temperature. Where the tail-off signature is found, the sample is contaminated with aerosol particles of hydrocarbon compounds that have a boiling point above the GC oven temperature and, condensing on the column material, are gradually eluted from the column during the backflush of column A. As liquid aerosol particles, they represent RH-C concentrations in the atmosphere and may be subject to chemical reactions forming smog. However, if these particles are aromatic compounds, their toxic effects need also be considered in determining allowable emission concentrations. The actual heavy compound molecules that make up asphaltic cements ($C_{35}+$) are nonvolatile and are therefore nonpolluting to the atmosphere either as smog-forming or toxic agents. It would therefore appear that with respect to pollution emissions to the atmosphere one's concern and attention should be directed to solvating agents and temperatures required in order to utilize asphaltic cements in their many applications, and not with the asphalt cement itself.

8. *Other H-C Producing Sources*—To provide comparative data on the seriousness and magnitude of the H-C concentration contribution to air pollution resulting from asphaltic paving and cutback asphalt operations, a visit to the asphalt mixing plant revealed that H-C emissions from various plant activities were considerably less than the paving operations themselves. Referring to Table F-9, the data taken on August 27 indicates that the fumes from a freshly loaded asphalt delivery truck had a 0.82 ppm$_v$ concentration above ambient. The heaters used for maintaining the asphalt in its liquid state and for the aggregate drying kiln were gas fired and provided a very small RH-C contribution.

On August 27, 1974, fume samples were obtained from the asphalt tanker truck delivering asphalt at a temperature of 320 F to the mixing plant. The RH-C and methane concentrations of these fumes were then compared with fumes from a #6 fuel oil storage tank, from a diesel oil storage tank, and from the filler neck of the Ford Bronco gasoline tank. Fume sampling from all of these tanks was accomplished by climbing on top of the tank, opening the hatch, and inserting the sampling tube as far as the tube length or liquid level would permit. The amount of mixing of ambient air through the opened hatch was therefore not controllable, and the measurement values obtained should therefore be used for qualitative comparisons only.

During this second phase of testing, measurements brought out very strongly the effect of temperature on H-C concentrations in storage tank fumes. The results of these tests are summarized in Table F-11 and provide a relative comparison of the volatility of these petroleum products.

During the initial modification checkout, a syringe sample of the investigator's personal auto exhaust was obtained and used to develop a technique for handling very high H-C concentrations on the gas chromatograph. A sampling plan was formed, on the basis of the experience gained from this early run, to measure in the exhaust gas stream the decay of RH-C concentrations with distance from the exhaust. The auto used for these runs, a 1971 Plymouth Cricket, was equipped with a crankcase vapor feedback to the carburetor; its mileage was approximately 31,000 mi (50,000 km). The results are, as follows, in ppm$_v$ above ambient:

RH-C	CH_4	DISTANCE FROM EXHAUST
0.94	0.6	8 ft
39.7	35.0	4 ft
307.	298.	2 ft
768.	695.	1 ft

The test was conducted in a wind-protected area, and demonstrates the high diffusion rate that occurs because of the exhaust gas velocity only (the choke had been set for a fast idle and a rich mixture). These data (auto exhaust and fuel tank fumes) are presented as an indication of the magnitude of the concentrations of RH-C that exist in a normal environment.

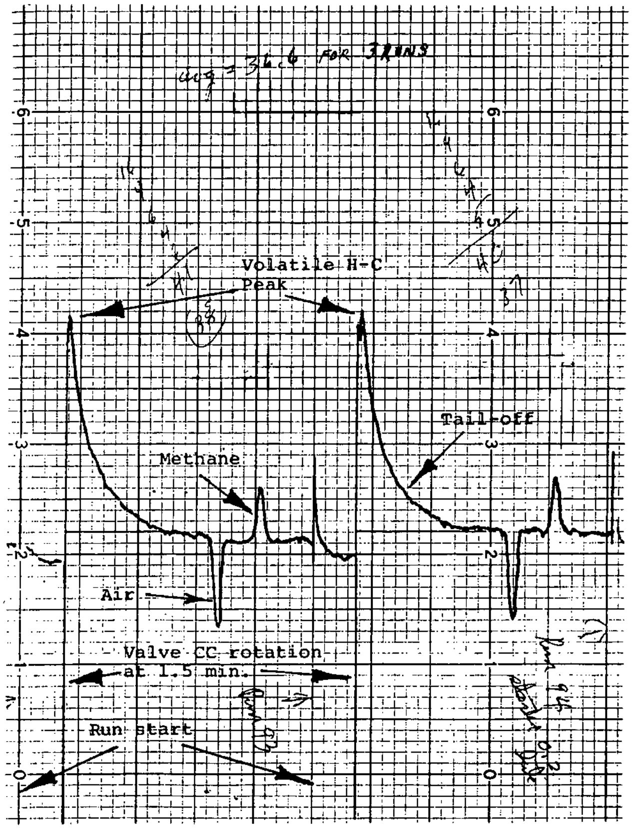


Figure F-13. "Heavy hydrocarbon" tail-off recording example.

TABLE F-10

"HEAVY" RH-C INSTANCES, PPM$_v$ AS CH_4

	Total RH-C	Volatile RH-C	
8/1/74 0900	12.0	3.46	Adjacent to machine
	6.56	2.85	25 ft. downwind from paving ops
1415	81.1	15.40	Adjacent to machine, gas syringe
	4.92	1.04	Adjacent to machine, medical syringe
	22.2	4.64	25 ft. downwind ops
8/6/74	30.8	9.40	25 ft. downwind parked paver with asphalt in hopper.
8/21/74 1230	31.0	8.31	PF-120 screed exhaust, burner off
8/22/74 0800	4.76	2.02	Fumes from asphalt hopper

TABLE F-11

COMPARISON OF VOLATILITY OF PETROLEUM PRODUCTS

RH-C (PPM$_v$)	CH_4 (PPM$_v$)	Source
17.51	3.1	Asphalt Tanker Truck (AC temp 320°F)
208-280	11.5	RC-70 @ 76°F
845	50.0	#6 fuel oil @ 85°F
1071	23.8	Diesel fuel tank
1250	23	RC-70 @ 95°F
2310	84	RC-70 @ 150°F
4250	124	RC-250 @ 150°F
24,100	97.6	Auto gasoline tank

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