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May 16, 1990

Mr. James H. O'Brien, P.E.
Senior Energy and Environmental Engineer
U.S. Steel Corporation
Fairless Hills, PA 19030

Subject: Submission of Report, "Roadway Emission Field Tests at U.S. Steel's Fairless Works," USX Purchase Order No. 146-0001191-0068, MRI Project No. 9459-L

Dear Mr. O'Brien:

Enclosed please find two (2) copies of the subject report. Please call if you have any questions.

Sincerely,

MIDWEST RESEARCH INSTITUTE

Gregory E. Muleski
Principal Environmental Engineer

GEM/jer

Enclosures

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May 16, 1990

Mr. Roy J. Weiskircher
Senior Environmental Engineer
U.S. Steel Corporation
One Tech Center Drive
Monroeville, PA 15146

Subject: Submission of Report, "Roadway Emission Field Tests at U.S. Steel's Fairless Works," USX Purchase Order No. 146-0001191-0068, MRI Project No. 9459-L

Dear Mr. Weiskircher:

Enclosed please find three (3) copies of the subject report. Please call if you have any questions.

Sincerely,

MIDWEST RESEARCH INSTITUTE

Gregory E. Muleski
Principal Environmental Engineer

GEM/jer

Enclosures

MRI REPORT

Roadway Emission Field Tests at U.S. Steel's Fairless Works

Final Report

For United States Steel Corporation
Fairless Hills, Pennsylvania 19030

Attn: Mr. James H. O'Brien, P.E.
215 736 4217

and

United States Steel Corporation
One Tech Center Drive
Monroeville, Pennsylvania 15146

Attn: Mr. R. J. Weiskircher
412 825-2824

USX Purchase Order No. 146-0001191-0068
MRI Project No. 9459-L

May 16, 1990

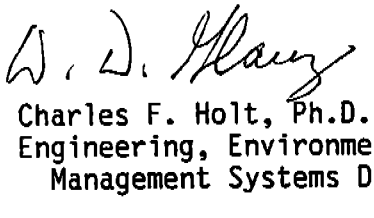
MIDWEST RESEARCH INSTITUTE 425 Volker Boulevard, Kansas City, MO 64110-2299 • (816) 753-7600

PREFACE

This report describes a field testing program conducted at U.S. Steel's Fairless Hills plant during the fall of 1989. The report was prepared under USX Purchase Order No. 146-0001191-0068. All work was performed in Midwest Research Institute's Air Quality Assessment Section (Dr. Gregory E. Muleski, Acting Head). This report was written by Dr. Muleski and Mr. Frank Pendleton.

Approved for:

MIDWEST RESEARCH INSTITUTE



for Charles F. Holt, Ph.D., Director
Engineering, Environmental, and
Management Systems Department

May 16, 1990

CONTENTS

SECTION 1

INTRODUCTION

This report describes the roadway emissions testing program conducted at U.S. Steel's (USS's) Fairless Hills plant during the period of October to December 1989. The purpose of these field characterizations of paved and unpaved road emissions was to support USS's pending alternative emission reduction[1] by providing site-specific data for roadway emissions. This report compares those data against values obtained from the emission estimation methods presented in the U.S. Environmental Protection Agency (EPA) document "Compilation of Air Pollutant Emission Factors (AP-42)."[2] This comparison forms a very important part of the report, in that it addresses the uncertainties (as described in the alternative emission reduction plan)[1] that results when the estimation methods are used outside their range of applicability.

SECTION 2

DESCRIPTION OF THE TEST SITES

The Fairless Works is located along the Delaware River, approximately 10 miles northeast of Philadelphia. Buildings and roads in the plant (Figure 1) are largely aligned parallel to plant north, which is approximately 18 degrees clockwise from true north. The bubble application[1] identified major paved and unpaved sources of particulate emissions, and the following test sites were selected during a September 7, 1989, site survey:

Site C-1 is on a four-lane paved road on the main access route to the plant. During a 1988 traffic survey, this (plant) north-south road was reported to experience over 4,000 vehicle passes per day.[1] Because it is on the main access route, the traffic mix at this site can be considered as reasonably representative of the "foreign" (i.e., other than Euclids and other plant equipment) traffic in the plant.

Site E-2 is on the main paved road leading to the southwest corner of the plant, where both the iron- and steel-making facilities as well as the sinter plant are located. As such, plant equipment can be expected to constitute a major fraction of the traffic at this site. Emissions from this road account for approximately 34% and 14% of the paved road and total emissions, respectively, in the proposed trade.[1] The road is oriented along plant north and south.

Site X is on an unpaved road located approximately in the center of the Fairless Works. The road is used primarily as a shortcut between different portions of the plant and light-duty vehicles constitute a considerable fraction of the traffic at this site.

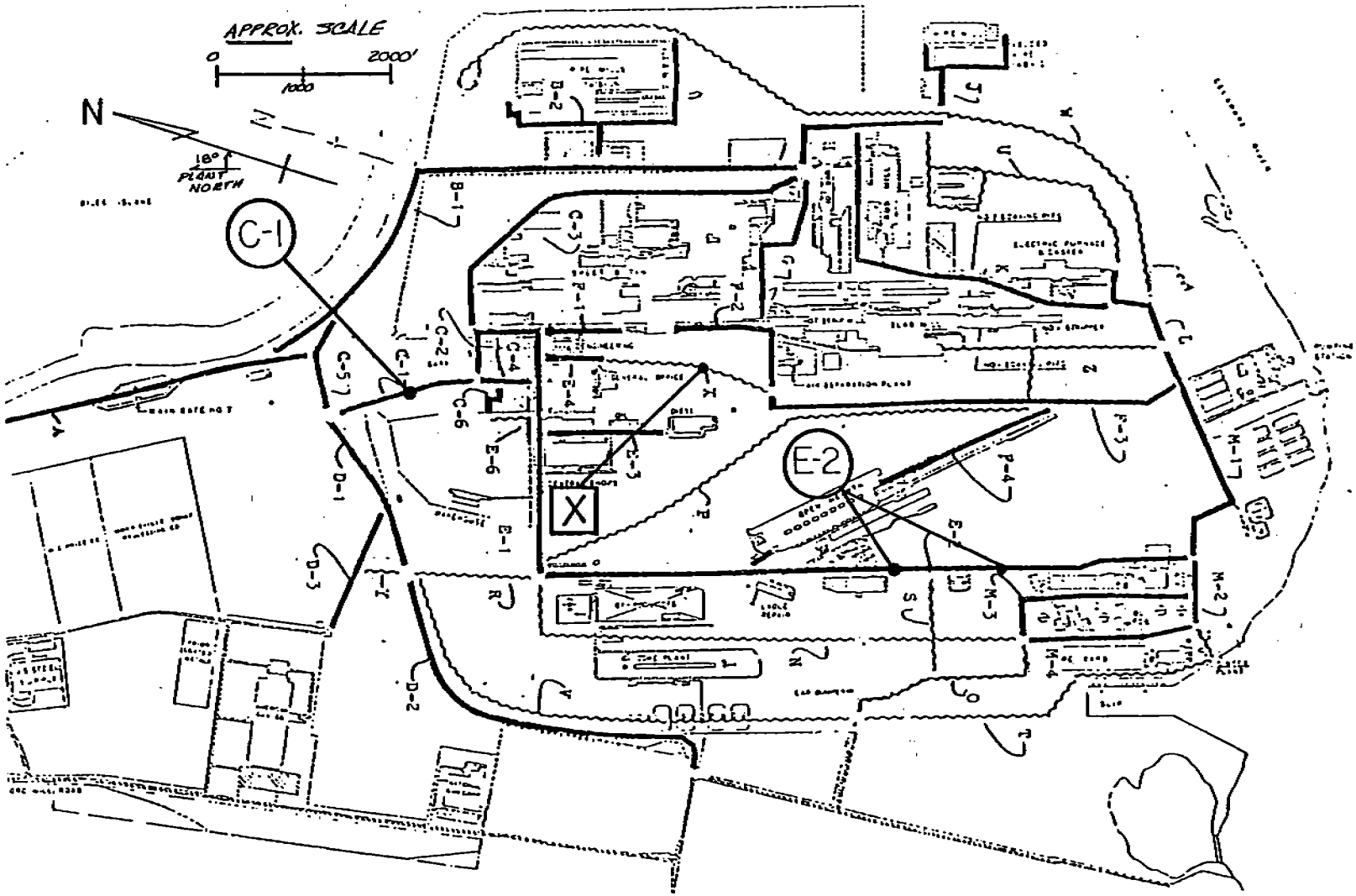


Figure 1. Test sites at Fairless Works.
Circles indicate paved roads; squares, unpaved roads.

SECTION 3

QUALITY ASSURANCE

The sampling and analysis procedures followed in this field testing program were subject to certain quality control (QC) guidelines. These guidelines are discussed in conjunction with the activities to which they apply. These procedures meet or exceed the requirements specified in the reports entitled "Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II--Ambient Air Specific Methods" (EPA 600/4-77-027a) and "Ambient Monitoring Guidelines for Prevention of Significant Deterioration" (EPA 450/2-78-019).

As part of the QC program for this study, routine audits of sampling and analysis procedures were performed. The purpose of the audits is to demonstrate that measurements are made within acceptable control conditions for particulate source sampling and to assess the source testing data for precision and accuracy. Examples of items to be audited include gravimetric analysis, flow rate calibration, data processing, and emission factor and control efficiency calculation. The mandatory use of specially designed reporting forms for sampling and analysis data obtained in the field and laboratory aids in the auditing procedure. Further details on specific sampling and analysis procedures are provided in the following section.

SECTION 4

SAMPLING AND ANALYSIS PROCEDURES

GENERAL AIR SAMPLING EQUIPMENT AND TECHNIQUE

Exposure profiling, which was the primary air sampling technique used in this study, is based on the isokinetic profiling concept used in conventional source testing. The passage of airborne pollutant immediately downwind of the source was measured directly by means of simultaneous multipoint sampling (Table 1) over the effective cross section of the open dust source plume. This technique uses a mass-balance calculation scheme similar to EPA Method 5 stack testing rather than requiring calculation through the application of a generalized atmospheric dispersion model.

The MRI exposure profiler (as shown in Figure 2) is a portable tower (4- to 7.5-m height) supporting an array of sampling heads. During testing each sampling head is operated as an isokinetic exposure sampler directing passage of the flow stream through a settling chamber and then upward through a standard 20.3- x 25.4-cm (8- x 10-in) glass fiber filter positioned horizontally. Sampling intakes are pointed into the wind, and sampling velocity of each intake adjusted to match the local mean wind speed, as determined by 5- to 15-min averages prior to and during the test.

A high-volume, parallel-slot cascade impactor (Sierra Instruments, Model No. 230) with 34-m^3/hr (20-ft^3/min) flow controllers measured the downwind particle size distribution alongside the exposure profiler. The height selected for the downwind samplers was based on an examination of previous MRI testing[3-5] to approximate the point in the dust plume at which half the mass emissions are above and half below. A standard hi-vol sampler (operating at 40 acfm) was deployed at the same height to determine the total suspended particulate (TSP) mass fraction.

The downwind impactor unit (as shown in Figure 3) was equipped with Sierra Model No. 230CP cyclone preseparators to remove coarse particles which otherwise would tend to bound off the glass fiber impaction substrates, causing fine particle measurement bias. To further reduce particle bounce problems, each substrate was sprayed with stopcock grease solution to provide a sticky impaction surface. The upwind particle size distribution was measured using a standard hi-vol/impactor combination. Experience has shown that the background size distribution is essential in determining control efficiencies for fine particulate emissions.

Table 1. AIR SAMPLING EQUIPMENT

Location	Sampler	Intake height (m)
Upwind	Standard hi-vol/ impactor	2.2
Downwind station	Profiling head	1.5 3.0 4.5 6.0 (7.5)[a]
	Standard hi-vol	2.2
	Cyclone/impactor 37-mm cassette	2.2

[a] Because of the high travel speeds and the width of the road at C-1, a 7.5-m tower was used in place of the standard 6 m. In addition, two lanes were blocked during periods of actual sampling (see Section 5).

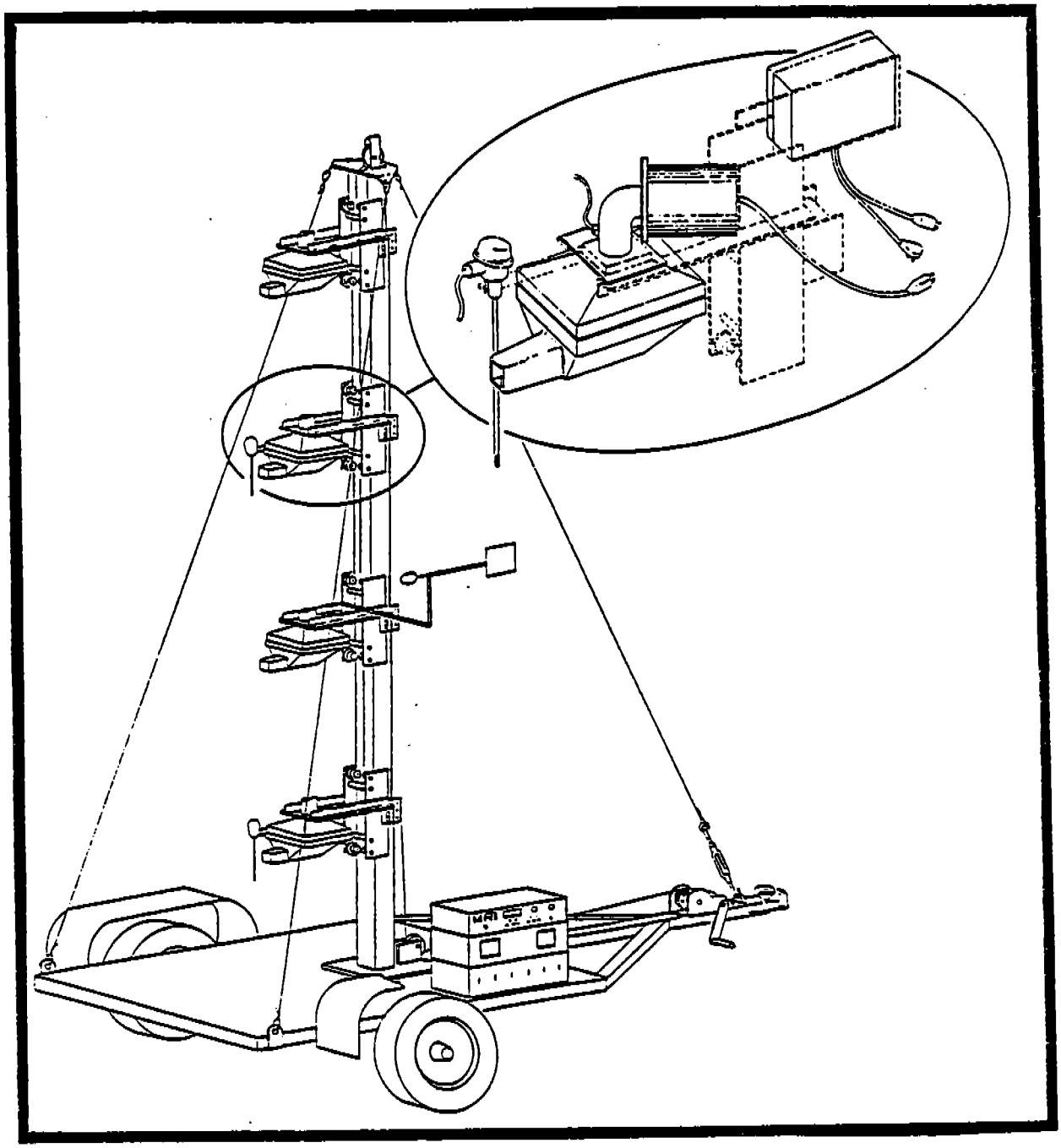


Figure 2. MRI exposure profiler.

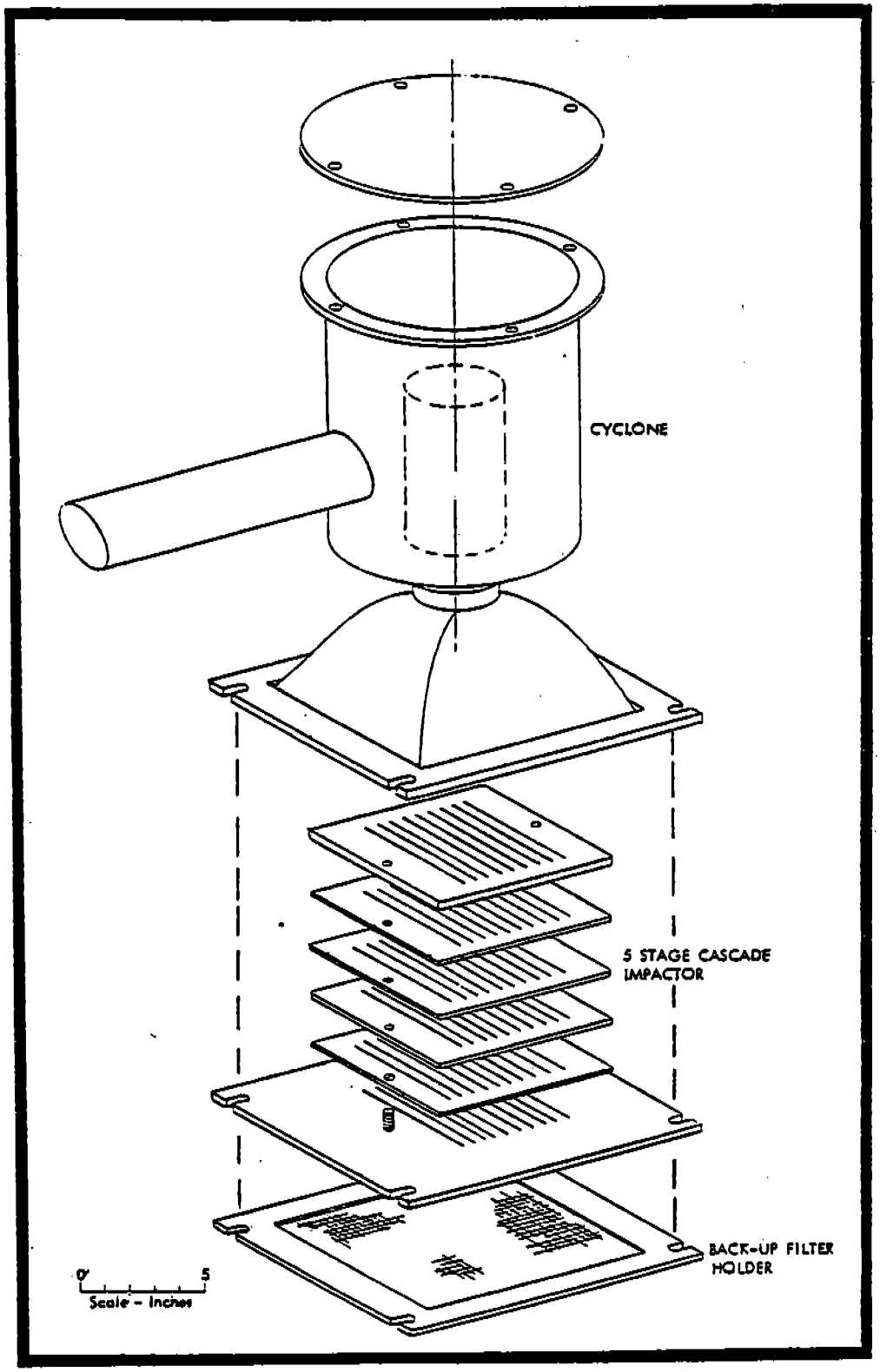


Figure 3. Cyclone preseparator/cascade impactor combination.

Each impactor consisted of five impaction stages. In order to determine the particle size distributions at the coarse particle end of the spectrum by microscopy, 37-mm cassette samplers were deployed at the same locations as the impactors.

Throughout each test, wind speed was monitored by warm-wire anemometers (Kurz Model 465) at two heights and the vertical wind speed profile determined by assuming a logarithmic distribution. (An integrating Biram's vane anemometer served as a backup system.) Horizontal wind direction was monitored by a wind vane at a single height, with 5- to 15-min averages determined electronically prior to and during the test. The sampling intakes were adjusted for proper directional orientation based on the average wind direction.

EMISSION TESTING PROCEDURE

Preparation of Sample Collection Media

Particulate samples were collected on Type A slotted glass fiber impactor substrates and on Type AE grade glass fiber filters. All glass fiber cascade impactor substrates were greased to reduce the problem of particle bounce. The grease solution was prepared by dissolving 140 g (4.9 oz) of stopcock grease in 1 L (0.26 gal) of reagent-grade toluene. No grease was applied to the borders or backs of the substrates. The substrates are handled, transported, and stored in frames which protect the greased surfaces.

Prior to the initial weighing, the filters and greased substrates were equilibrated for 24 hr at constant temperature and humidity in a special weighing room. During weighing, the balance is checked at frequent intervals with standard (Class S) weights to ensure accuracy. The filters and substrates remained in the same controlled environment for another 24 hr, after which a second analyst reweighed them as a precision check. If a substrate or filter cannot pass audit limits, the entire lot is reweighed. Ten percent of the substrates and filters taken to the field were used as blanks. The quality assurance guidelines pertaining to preparation of sample collection media are presented in Table 2.

Pretest Procedures/Evaluation of Sampling Conditions

Prior to equipment deployment, a number of decisions needed to be made as to the potential for acceptable source testing conditions. These decisions were based on forecast information obtained from the local U.S. Weather Service office. If conditions were considered acceptable, the sampling equipment deployment will be initiated. At this time the sampling flow rates were set for the various air sampling instruments. The quality control guidelines governing this activity are found in Table 3.

Table 2. QUALITY ASSURANCE PROCEDURES FOR SAMPLING MEDIA

Activity	QA check/requirement
Preparation	Inspect and imprint glass fiber media with identification numbers.
Conditioning	Equilibrate media for 24 hr in clean controlled room with relative humidity of less than 50% (variation of less than ±5%) and with temperature between 20° and 25°C (variation of less than ±3%).
Weighing	Weigh hi-vol filters and impactor substrates to nearest 0.1 mg.
Auditing of weights	Independently verify final weights of 10% of hi-vol filters and impactor substrates (at least four from each batch). Reweigh batch if weights of any hi-vol filters or impactor substrates deviate by more than ±2.0 and ±1.0 mg, respectively. For tare weights, conduct a 100% audit. Reweigh tare weight of any hi-vol filters or impactor substrates that deviate by more than ±1.0 and ±0.5 mg, respectively.
Correction for handling effects	Weigh and handle at least one blank for each 1 to 10 hi-vol filters or impactor substrates of each type for each test.
Calibration of balance	Balance to be calibrated once per year by certified manufacturer's representative. Check prior to each use with laboratory Class S weights.

Table 3. QUALITY ASSURANCE PROCEDURES FOR SAMPLING FLOW RATES

Activity	QA check/requirement
Calibration	
• Cyclone/impactors	Calibrate flows in operating ranges using calibration orifice upon arrival and every 2 weeks thereafter at each regional site prior to testing.
• Profiler heads	Calibrate flows in operating ranges using calibration orifice upon arrival and every 2 weeks thereafter at each regional site prior to testing.
• Orifice and electronic calibrator	Calibrate against displaced volume test meter annually.

Once the source testing equipment was set up and the filters inserted, air sampling commenced. Information was recorded on specially designed reporting forms and included:

a. Exposure profiler--Start/stop times, wind speed profiles, and sampler flow rates (5- to 15-min average), and wind direction relative to the roadway perpendicular (5- to 15-min average).

b. Other samplers--Start/stop times and flow rates.

c. Traffic count by vehicle type and speed.

d. General meteorology--Wind speed, wind direction, and temperature.

From the information in (a), adjustments could be made to ensure isokinetic sampling of both profiler heads (by changing the intake velocity and orientation) and cyclone preseparators (by changing intake nozzles and orientation). Table 4 outlines the pertinent QA procedures.

Sampling time was long enough to provide sufficient particulate mass and to average over several cycles of the fluctuation in the emission rate (i.e., vehicle passes on the road). Sampling generally required 1 to 3 hr, depending on source activity and control measure. Occasionally sampling may have been interrupted because of the occurrence of unacceptable meteorological conditions and then restarted when suitable conditions returned. Table 5 presents the criteria used for suspending or terminating a source test.

Table 4. QUALITY ASSURANCE PROCEDURES FOR SAMPLING EQUIPMENT

Activity	QA check/requirement[a]
Maintenance	
• All samplers	Check motors, gaskets, timers, and flow measuring devices at each plant prior to testing.
Operation	
• Timing	Start and stop all samplers during time span not exceeding 1 min.
• Isokinetic sampling (profilers only)	Adjust sampling intake orientation whenever mean wind direction changes by more than 30 degrees. Adjust intake velocity whenever mean wind speed approaching sampler changes by more than 20%.
• Isokinetic sampling (cyclone/impactors)	Adjust sampling intake orientation whenever adjustments are made to the exposure profiler intake orientation. Change the cyclone intake nozzle whenever the mean wind speed approaching the sampler falls outside of the suggested bounds for that nozzle. This technique allocates no nozzle for wind speeds ranging from 0 to 6 mph, and unique nozzles for each of the wind speed ranges 6-8, 8-11, 11-15, and 15-20 mph.
• Prevention of static mode deposition	Cap sampler inlets prior to and immediately after sampling.

[a] All means refer to 5- to 15-min averages.

Table 5. CRITERIA FOR SUSPENDING OR TERMINATING AN EXPOSURE PROFILING TEST

A test may be suspended or terminated if:[a]

1. Rainfall ensues during equipment setup or when sampling is in progress.
2. Mean wind speed during sampling moves outside the 1.3- to 8.9-m/sec (2- to 20-mph) acceptable range for more than 20% of the sampling time.
3. The angle between mean wind direction and the perpendicular to the path of the moving point source during sampling exceeds 45 degrees for two consecutive averaging periods.
4. Daylight is insufficient for safe equipment operation.
5. Source condition deviates from predetermined criteria (e.g., occurrence of truck spill or accidental water splashing prior to uncontrolled testing).

[a] "Mean" denotes a 5- to 15-min average.

Sample Handling and Analysis

To prevent particulate losses, the exposed media were carefully transferred at the end of each run to protective containers for transportation. In the field laboratory, exposed filters were placed in individual glassine envelopes and then into numbered file folders. Impactor substrates were replaced in the protective frames. Particulate that collects on the interior surfaces of profiler intakes and cyclone preseparators were rinsed with distilled water into separate sample jars which were then capped and taped shut.

When exposed substrates and filters (and the associated blanks) were returned to the MRI laboratory, they were equilibrated under the same conditions as the initial weighing. After reweighing, 10% were audited to check weighing accuracy.

To determine the sample weight of particulate collected on the interior surfaces of samplers, the entire wash solution was passed through a 47-mm (1.8-in) Buchner-type funnel holding a glass fiber filter under suction. This water was passed through the Buchner funnel ensuring collection of all suspended material on the 47-mm filter which was dried in an oven at 100°C for 24 hr. After drying, the filters were conditioned at constant temperature and humidity for 24 hr.

All wash filters were weighed with a 100% audit of tared and a 10% audit of exposed filters. Blank values are determined by washing "clean" (unexposed) profiler or cyclone intakes in the field and following the above procedures.

EMISSION FACTOR CALCULATION PROCEDURE

To calculate emission rates using the exposure profiling technique, a conservation of mass approach is used. The passage of airborne particulate (i.e., the quantity of emissions per unit of source activity) is obtained by spatial integration of distributed measurements of exposure (mass/area) over the effective cross section of the plume. Exposure is defined as the point value of the flux (mass/area-time) of airborne particulate integrated over the time of measurement (or equivalently, the net particulate mass passing through a unit area normal to the mean wind direction during the test). The steps in the calculation procedure are described below.

Particulate Concentrations

The concentration of particulate matter measured by a sampler is given by:

$$C = 10^3 \frac{m}{Qt}$$

where: C = particulate concentration ($\mu g/m^3$)

m = particulate sample weight (mg)

Q = sampler flow rate (m^3/min)

t = duration of sampling (min)

The specific particulate matter concentrations are determined from the various particulate catches as follows:

Size range	Particulate catches
TP	Profiler filter + intake or cyclone + impactor substrates + backup filter
TSP	Impactor substrates (if any) + backup filter
PM_{10}	Impactor substrates + backup filter

To be consistent with the National Ambient Air Quality Standard for total suspended particulate (TSP), all concentrations and flow rates are expressed in standard conditions (25°C and 101 kPa or 77°F and 29.92 inHg).

Isokinetic Flow Ratio and Particle Size Distributions

The isokinetic flow ratio (IFR) is the ratio of a directional sampler's intake air speed to the mean wind speed approaching the sampler. It is given by:

$$IFR = \frac{Q}{aU}$$

where: Q = sampler flow rate (m^3/min)

a = intake area of sampler (m^2)

U = mean wind speed at height of sampler (m/min)

This ratio is of interest in the sampling of TP, since isokinetic sampling ensures that particles of all sizes are sampled without bias. In this study, profilers and cyclone preseparators are the directional samplers that were used.

Occasionally it is necessary to sample at a superisokinetic flow rate (IFR > 1.0) to obtain sufficient sample under light wind conditions. Correction factors for superisokinetic TP concentrations are based on a relationship developed by Davies.[6]

A value for the average ratio ($\bar{R}$) of measured to true concentration can be found by integrating the product of the particle size distribution and Davies' relationship over all possible particle diameters. Note that because the particle size distribution and the isokinetic corrections are interrelated, isokinetic corrections are of an iterative nature.

Particle size distributions are determined by plotting ratios of the cumulative concentrations measured by each impactor stage to the total concentration against the 50% cutoff diameters presented earlier. These data are fitted to a log normal mass size distribution after correction for residual particle bounce.

The technique used in this study to correct for the effects of residual particle bounce has been discussed in earlier MRI studies.[3-5] Prior examination of particle bounce corrections has shown only negligible changes in size fractions for PM_{10} and above.[7]

Particulate Exposures and Profile Integration

For directional samplers operated isokinetically, total particulate exposures are calculated by:

$$E = 10^{-7} \times CUt$$

where: E = total particulate exposure (mg/cm^2)

C = net TP concentration ($\mu g/m^3$)

U = approaching wind speed (m/sec)

t = duration of sampling (sec)

The exposure values vary over the height of the plume. If exposure is integrated over the height of the plume, then the quantity obtained represents the total passage of airborne particulate matter due to the source per unit length of the line source. This quantity is called the Integrated Exposure A and is found by:

$$A = \int_0^H E \, dh$$

where: A = integrated exposure ($m\text{-}mg/cm_2$)

E = particulate exposure (mg/cm^2)

h = vertical distance coordinate (m)

H = effective extent of plume above ground (m)

The effective height of the plume is found by linear extrapolation of the uppermost net TP concentrations to a value of zero.

Because exposures are measured at discrete heights of the plume, a numerical integration is necessary to determine the quantity A. The exposure must equal zero at the vertical extremes of the profile (i.e., at the ground where the wind velocity equals zero and at the effective height of the plume where the net concentration equals zero). However, the maximum TP exposure usually occurs below a height of 1 m so that there is a sharp decay in TP exposure near the ground. To account for this sharp decay, the value of exposure at the ground level is set equal to the value at a height of 1 m. The integration is then performed using Simpson's rule.

Particulate Emission Factors

The emission factor for total airborne particulate generated by vehicular traffic on a straight road segment expressed in grams of emissions per vehicle-kilometer traveled (VKT) is given by:

$$e = 10^4 \frac{A}{N}$$

where: e = total particulate emission factor (g/VKT)

A = integrated exposure (m-mg/cm^2)

N = number of good vehicle passes (dimensionless)

Emission factors for the other particle size ranges will be obtained by multiplying the emission factors by net mass fractions. These mass fractions are found by dividing the net (i.e., downwind minus upwind) concentration for the size range of interest by the net TP concentration.

SURFACE MATERIAL SAMPLING AND ANALYSIS

Associated with paved and unpaved road source tests are samples of the roadway surface material. The collection and analysis of these samples are important because the available emission factor and control performance models make use of road surface parameters. Samples of the road surface material are analyzed for silt (those particles passing a 200-mesh screen) and moisture contents and to determine road surface loading values. Detailed steps for collection and analysis of samples for silt and moisture are given elsewhere. An abbreviated discussion is presented below.

Paved roadway surface dust samples were removed from the traveled portion of the road by vacuuming, preceded by broom sweeping if a heavy loading of aggregate is present. The samples were collected from the traveled portion of the road which was determined by observing the traffic and the road itself, noting that the portions of a roadway not traveled (e.g., curbs and center strips) usually exhibit a heavy loading of dust. The vacuum bags were equilibrated to the same constant temperature and humidity conditions as were the air sampling filters before both tare and final weighings.

Unpaved roadway dust samples were collected by sweeping the loose layer of soil or crushed rock from the hardpan road base with a broom and dust pan. Sweeping was performed so that the road base is not abraded by the broom, and so that only the naturally occurring loose dust was collected. The sweeping was performed slowly so that dust is not entrained into the atmosphere.

If necessary, field samples were split with a riffle to a sample size amenable to laboratory analysis. Laboratory analysis procedures to determine silt and moisture contents are identical for all samples regardless of origin.

The basic procedure for moisture analysis is determination of weight loss on oven drying. Collection and analysis of the road surface samples was the responsibility of USS air monitoring contractor (BCM) and followed the general procedures given in Reference 1.

SECTION 5

FIELD TEST RESULTS AND DISCUSSION

The following section describes the results of field tests conducted at the Fairless Works during the fall of 1989. In addition, the results are discussed and compared to values from available estimation methods and, finally, recommendations made.

RESULTS OF THE FIELD TESTING PROGRAM

Twelve tests of road dust emissions were conducted during the course of the field program:

- Seven tests of emissions from paved roads vacuum-swept twice per week.
- Three tests of emissions from a paved road vacuum-swept five times per week.
- Two tests of emissions from a controlled unpaved road.

Table 6 presents the site parameters associated with each of the exposure profiling tests. Included are general descriptions of (1) meteorological conditions during the testing period and (2) traffic conditions on the road during the test.

Each field test is referenced following these conventions:

1. Fairless has been designated as plant "AU," and all run numbers start with that plant ID.
2. The second part of the run number is a single letter code for the specific site identified in the September 27 test plan (C for paved road C-1, X for unpaved road X, and E for paved road E-2). See Figure 1.
3. The third and final portion of the run ID is a sequential number for tests at that road site.

Note that (1) Runs AU-C-1, AU-C-2, and AU-X-4 were aborted; and (2) Runs AU-X-3 and AU-X-5 were "blank" tests used to correct catches on the sampling media for handling.

Table 6. TEST SITE PARAMETERS

Run	Date	Meteorology Temp. (°F)	Meteorology Wind[a] (mph)	Test start	Duration (min)	Number of vehicle Passes	Mean vehicle weight[b] (ton)	Mean vehicle speed[c] (mph)
AU-X-1	11-1-89	62	8.7	12:42	168	110	3.9	25
AU-X-2	11-1-89	60	6.5	15:31	71	101	2.1	26
AU-C-3[d]	11-10-89	50	12	13:35	103	836	5.5	(27)
AU-C-4[d]	11-14-89	63	11	13:05	147	1,057	6.0	25
AU-C-5[d]	11-15-89	62	14	13:55	120	963	3.9	29
AU-C-6[d]	11-17-89	39	14	11:31	187	685	6.2	(27)
AU-C-7[d]	11-17-89	42	12	14:57	96	703	3.0	(27)
AU-C-8[d]	11-18-89	40	15	12:12	218	779	2.0	(27)
AU-E-1[e]	11-20-89	43	12	11:20	154	210	12	15
AU-E-2[e]	11-20-89	44	13	14:06	89	373	5.1	16
AU-E-3[e]	11-30-89	41	9.3	13:46	118	330	2.6	(15)
AU-E-4[e]	11-30-89	41	9.3	13:50	130	364	2.6	(15)

[a] Mean measured at 4.5-m height just prior to, during, and immediately after tests.

[b] Vehicle class weights (e.g., values for 18-wheelers, cars, etc.) based on information contained in Exhibit C of the bubble application.[1]

[c] Value given in parentheses for tests without mean vehicle speed measurements. Value in parentheses is average speed measured for that road during the field exercise.

[d] Only two of four lanes were open to traffic during Road C tests to ensure adequate plume characterization. Runs 3 through 5 were conducted on outbound lanes which were vacuum swept twice per week, and runs 6 to 8 on the inbound lanes which were swept five times per week.

[e] Because the surface loadings appeared to be visibly different on the inbound (west) and outbound lanes, traffic was restricted to the outbound lane on runs 1 and 2 and the inbound lane on runs 3 and 4.

Table 7 compares for each test the raw total particulate (TP) and total suspended particulate (TSP) concentrations measured at a 2.2-m height by the various sampling devices, including a TP value interpolated from the 1.5- and 3-m profiler intakes. In general, agreement between the various downwind concentrations is good.

Table 8 presents size-specific emission factors developed for the tests. Also shown in that table are surface aggregate material properties that appear in the emission factor models presented in the EPA document AP-42.[2]

Two points about the field testing should be noted prior to discussion of the results. First, the wind speeds measured during the tests (as shown in Table 6) were substantially greater than the mean values supplied during early stages of the project.[8] Higher wind speeds kept the dust plume closer to the ground, which in turn affects the particle size measurements. As a result, size-specific concentrations sampled at the 2.2-m height were lower than originally expected; and, for some of the paved road tests, it was not possible to identify net PM_{10} concentrations. In those cases (indicated by Footnote c in Table 8), the mean PM_{10}/TSP ratio measured downwind of the paved roads was applied to estimate the PM_{10} emission factor. Second, some background (upwind) concentrations were larger than MRI expected. In those instances, it is likely that the higher background concentration compounded particle sizing problems.

On the basis of the data presented for Road C in Table 8, it appears that (compared to twice per week sweeping) vacuum sweeping paved roads five times per week results in:

- An approximately 80% lower TSP emission factor, on average.
- An approximately 70% lower PM_{10} emission factor, on average.
- An approximately 50% lower silt loading values, on average.

Table 7. REPRESENTATIVE CONCENTRATIONS (μg/m³)

Run	Upwind[b]	Downwind[a]		
		TSP[c]	TP[d]	TP[e]
AU-X-1	43	227	157	246
AU-X-2	43	268	254	465
AU-C-3	46	140	198	154
AU-C-4	140	237[f]	202	620
AU-C-5	62	136	186	296
AU-C-6	60	52	52	79
AU-C-7	60	96	112	116
AU-C-8	61	72	161	102
AU-E-I	265	361	611	537
AU-E-2	265	361	611	629
AU-E-3	148	204	185	228
AU-E-4	148	170	119	185

a At a 2.2-m height.

b Measured with a standard hi-vol at 20 cfm.

c Measured with a standard hi-vol at 45 cfm.

d Measured with a cyclone/impactor at 20 cfm.

e Interpolated from 1.5- and 3.0-m profiler data.

f Problem noted in keeping sampler running throughout the test period.

Table 8. EMISSION FACTORS AND VEHICLE/SURFACE PROPERTIES

Run	Emission factor (g/VKT) TP	TSP	PM_{10}	Silt loading (g/m^2)	Silt content (%)	Total loading (kg/km)
AU-X-1	290	270	40	NA[a]	3.3	NA
AU-X-2	200	110	51	NA	4.1	NA
AU-C-3	24	19	1.4	0.42	10	28.7
AU-C-4	48	34[b]	10	0.52	12	30.2
AU-C-5	40	13	9.5	0.23	9.7	16.2
AU-C-6	6.7	4.6[c]	2.3[c]	0.23[d]	8.6	18.8
AU-C-7	4.6	3.4	0.25	0.26[d]	7.7	24.0
AU-C-8	19	4.6	4.9	0.15[d]	9.9	10.6
AU-E-1	240	84	2.0	4.0	17	85.7
AU-E-2	97	14	6.6	4.0	17	85.7
AU-E-3	30	21	10[c]	2.2	18	65.8
AU-E-4	16	9.3	5.6[c]	1.3	15	31.2

[a] NA = not applicable.

[b] Mean TSP/TP ratio for paved roads used to estimate TSP emission factor because of difficulty in keeping sample running (see Footnote f in Table 7).

[c] Mean TSP/TP or PM_{10}/TP ratio applied. See discussion in text.

[d] Test conducted on a paved road surface vacuum-swept five times per week.

In general, the paved road emission factors and silt loading values obtained during this field program more closely resemble those for "urban" rather than "industrial" roads. That is, the emissions generally show closer agreement with factors estimated by the methods in AP-42 Section 11.2.5 than by methods in Section 11.2.6:

Runs	Emission factor (g/VKT)	
	TSP[a]	PM_{10}[a]
AU-C-3 to -5	20/3.3/4.7	5.1/79/1.9
AU-C-6 to -8	4.2/1.4/2.7	1.4/65/1.1
AU-E-1 to -4	22/25/25	5.2/140/8.3

[a] Values represent (1) mean of the measured emission factors, (2) emission estimate using AP-42, Section 11.2.6 (Industrial Paved Roads), and (3) emission estimate using AP-42, Section 11.2.5 (Urban Paved Roads). Both (2) and (3) use the mean value of the correction parameters over the runs for input.

While both the TSP and PM_{10} urban models show a slight tendency to underestimate emissions from the paved roads tested, the industrial PM_{10} model overestimates each set of paved road emissions by at least an order of magnitude. The performance of industrial road TSP model, on the other hand, is only slightly worse than that for the corresponding urban model.

Because the unpaved road (X) was treated with chemical suppressants throughout the 1989 dust control season, direct comparisons between emissions factors and estimates from AP-42 Section 11.2.1 are not possible. However, the AP-42 unpaved road emission factor model together with the road's mean uncontrolled silt content (measured as 7.6% in April 1988)[1] may be used to estimate the degree of dust control. On this basis, then, at the time the tests were conducted, PM_{10} emissions from Road X are estimated to have been approximately 80% to 90% controlled, while the corresponding estimate for TSP emissions control is 70% to 80%. The higher level of control for a finer size range is in keeping with the tests of chemically controlled unpaved roads.[3,4,9]

RECOMMENDATIONS FOR FURTHER STUDY

This section presents several items for USS's consideration; each has been presented to expand upon available information and thus better characterize the roadway emissions involved in the alternative reduction plan for Fairless.

It is recommended that USS provide this report to Energy and Environment Management, Inc. (EEM) to consider what effect the field test results may have on the bubble application. As before, MRI will cooperate fully with USS and its contractors to jointly develop a strategy for revision of the application. This strategy may, for example, include (a) a limited field testing program to characterize emissions during the warmer periods of the year; (b) a reexamination of the historical data base underlying the paved road emission factor models to determine if the quality of controlled emission estimates could be improved; and (c) collection of additional surface material samples from roads at Fairless which provide an indirect method of tracking control efficiency.

A final recommendation (and one which could be quickly implemented) involves a near-source monitoring program at Fairless. This program would make use of the Wedding samplers stored in BCM's laboratory area as well as two standard hi-vol samplers, to provide data to refine the PM_{10} emission factors given in Table 8. Upon approval and receipt of additional meteorological data from USS and EEM, MRI could prepare a sampling plan that BCM would conduct. In general terms, the sampling would entail upwind and downwind monitoring of both PM_{10} and TSP to determine the net PM_{10}/TSP ratio. The sampling plan would describe deployment, sampling frequency, handling requirements and data analysis to provide the information necessary to refine the PM_{10} emission factors.

SECTION 6

REFERENCES

1. Energy and Environmental Management Inc., "Fairless Works Sinter Plant Alternative Emission Reduction Plan," November 1988 (revised August 1989).

2. U.S. Environmental Protection Agency, "Compilation of Air Pollutant Emission Factors (AP-42)," Research Triangle Park, North Carolina, (September 1989).

3. Muleski, G. E., T. Cuscino, Jr., and C. Cowherd, Jr., "Extended Evaluation of Unpaved Road Dust Suppressants in the Iron and Steel Industry," EPA-600/2-84-027, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (February 1984).

4. Cuscino, T., Jr., G. E. Muleski, and C. Cowherd, Jr., "Iron and Steel Plant Open Source Fugitive Emission Control Evaluation," EPA-600/2-83-110, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (October 1983).

5. Cowherd, C., Jr., R. Bohn, and T. Cuscino, Jr., "Iron and Steel Plant Open Source Fugitive Emission Evaluation," EPA-600/2-79-103, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (May 1979).

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7. Muleski, G. E. Critical Review of Open Source Particulate Emissions Measurements: Field Comparison. MRI Final Report Prepared for Southern Research Institute, MRI Project No. 7993-L(2) (August 1984).

8. Letter from L. Simmons of Energy and Environmental Management Inc. to G. Muleski of MRI dated July 3, 1989.

9. Muleski, G. E., C. Cowherd, Jr., "Evaluation of the Effectiveness of Chemical Dust Suppressants on Unpaved Roads," EPA-600/2-87-102, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (November 1987).