Emission Tests of Paved Road Traffic at Cargill Sweeteners North America Blair, Nebraska Facility

Test Report

For
McVehil-Monnett Associates

MRI Project No. 310395.1.001

November 27, 2002

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Preface

This report presents the results from a field testing program conducted to evaluate emissions from paved roads at Cargill Sweeteners North America plant in Blair, Nebraska. The report has been prepared under a contract with McVehil-Monnett Associates (MMA). Dr. George McVehil is MMA's program manager. Dr. Gregory E. Muleski served as MRI's project leader and authored this report.

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Section 1. Introduction

The U. S. Environmental Protection Agency's (EPA's) *Compilation of Air Pollutant Emission Factors* (commonly referred to as "AP-42") [1] contains factors used to estimate particulate matter (PM) emissions at industrial operations. EPA guidance [2] notes that AP-42 emission factors are best viewed as representative of long-term conditions for all facilities within a source category (i.e., a population average). Furthermore, the EPA guidance [2] also notes that test data supporting AP-42 factors are usually insufficient to fully indicate the effect of various source parameters on emission levels.

These points are particularly relevant to the paved road emission factor predictive equation presented in Section 13.2.1 of AP-42:

$$e = k\ (sL/2)^{0.65}\ (W/3)^{1.5} \tag{1-1}$$

where:

- e = particulate emission factor in pounds emitted per vehicle mile traveled (lb/vmt)
- k = base emission factor
  - = 0.016 lb/vmt for particulate matter no greater than 10 microns in aerodynamic diameter (PM-10)
  - = 0.082 lb/vmt for total suspended particulate (TSP)
- sL = surface "silt loading" which consists of mass of dried sub-200 mesh material per unit area of road surface (g/m^2)
- W = average weight (ton) of vehicles traveling the road

This emission factor model has been used to estimate PM-10 emissions at the Cargill Sweeteners North America facility in Blair, Nebraska. However, in this case, the AP-42 model has been applied to situations outside what constitutes "typical conditions" in the supporting database. The Blair facility enforces a 15 mph speed limit at the plant. Furthermore, road sweeping at the plant results in a low "sL" value compared to what is contained in the AP-42 database.

As noted in the AP-42 background document [3], silt loading (sL) and mean vehicle speed are highly correlated. Figure 1-1 plots the combinations of sL and mean travel speeds from emission tests underlying Equation 1-1. Note that for travel speeds between approximately 10 and 20 mph, the average sL values is approximately 100 g/m^2. By contrast, sL values at Blair are modeled at 0.4 and 1.25 g/m^2 depending on the road. In other words, for travel at 15 mph, use of Equation 1-1 at Blair requires that the emission factor model be applied far outside typical conditions in the underlying data base.

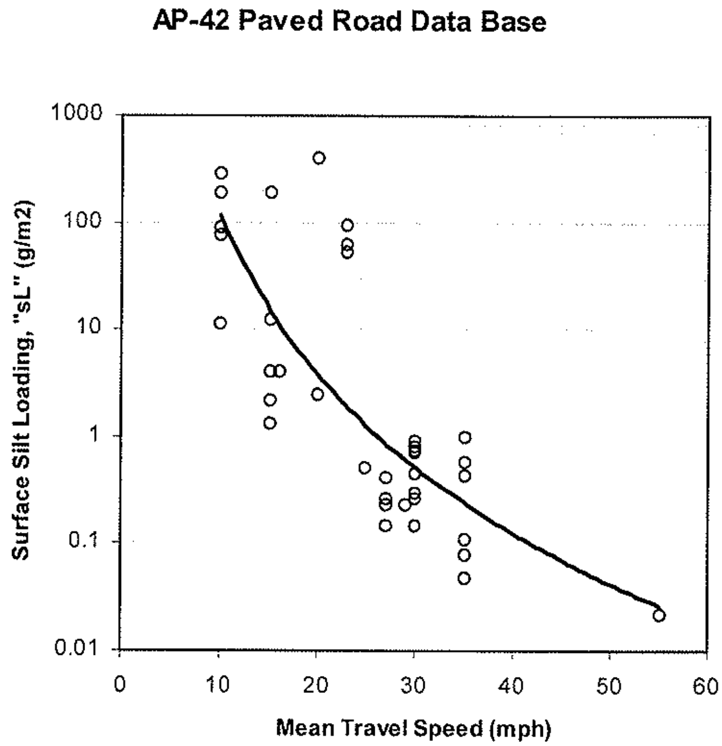

Figure 1-1. Silt Loading and Mean Vehicle Speed Combinations in AP-42 PM-10 Database

This report presents results from a field testing program of particulate emissions from paved roads at the Blair, Nebraska plant. It is important to note that the field program described in this plan applies the exposure profiling method, which is **the same fundamental emission measurement methodology** used to develop the AP-42 database. In other words, data generated from the field program described in this plan are directly comparable to the test data supporting AP-42.

The remainder of this report is structured as follows. Section 2 presents a brief description of the overall test program, including the test site as well as general test objectives and procedures. Section 3 provides detailed information on the test methodology. Section 4 presents and discusses the test results obtained. Section 5 lists the references cited. Appendix A presents quality assurance and quality control guidelines for the testing, while Appendix B presents detailed test results.

Section 2.
General Description of the Test Program

This section describes the test location site and lists the general objectives and procedures to be followed in the test program.

2.1 Description of the Blair Facility

Figure 2-1 presents a plan view of the Blair facility. Emission inventory materials supplied by the facility showed that corn receipts account for a substantial portion of both truck traffic and paved road PM-10 emissions (as estimated using the AP-42 factor, Equation 1-1). For this reason, attention in the field program focused on corn truck traffic.

Corn trucks enter and leave the plant at the location shown in Figure 2-1. The exposure profiling method relies on nearly perpendicular (to the road centerline) winds to carry the emissions to the sampling array. Because prevailing winds are from south to southeast, this means that a test section with an east-west orientation was preferred over one with a north-south orientation.

2.2 Test Objectives

The overall objective of the test program was to develop site-specific emission factors for paved roads at the Blair facility. Specifically, the objective was to develop emission factors that explicitly reference conditions at the Blair facility. Testing relied on the same exposure profiling test method used to develop the AP-42 data set. Road surface material samples were collected by the facility's contractor in connection with each test so that test results could be compared to the emission factor predicted from the AP-42 model (Equation 1-1).

The paved road sources of interest in this study, for testing purposes, can be represented as "line sources." Used in this context, a "line source" is an elongated source whose length is much greater than the distance from the source to the sampling array. All tests in the AP-42 paved road data are based on a line source representation of moving traffic.

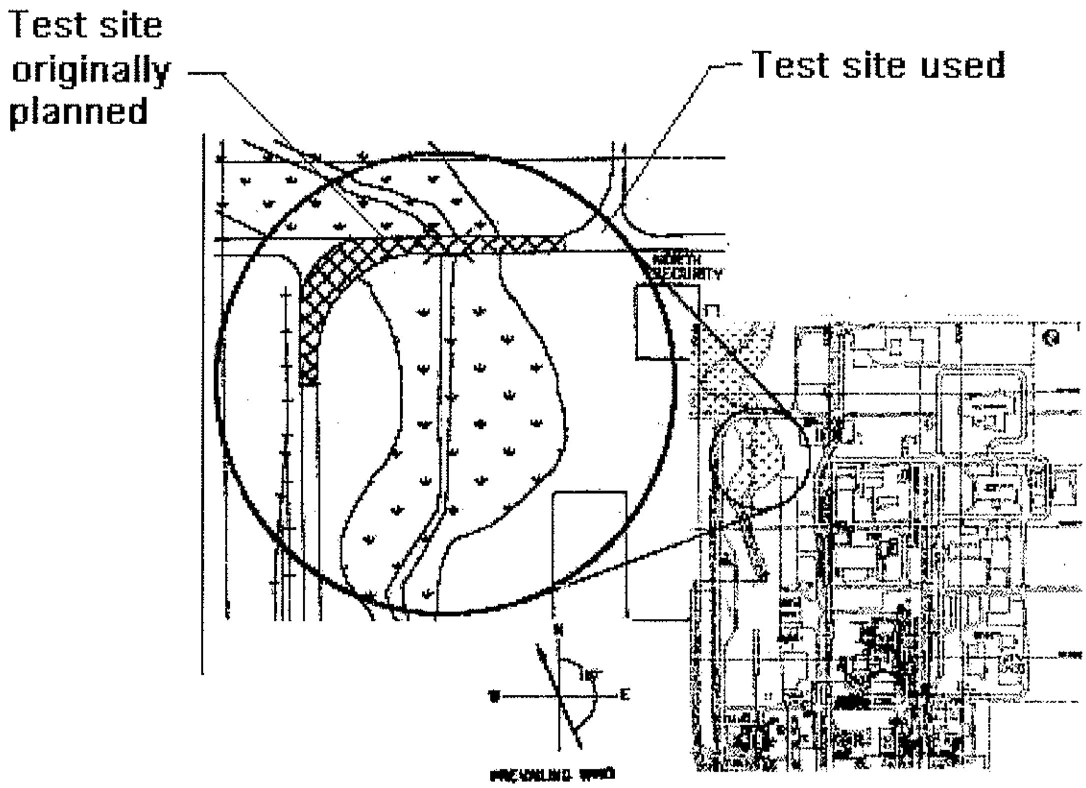

Figure 2-1. Overview of Blair Facility

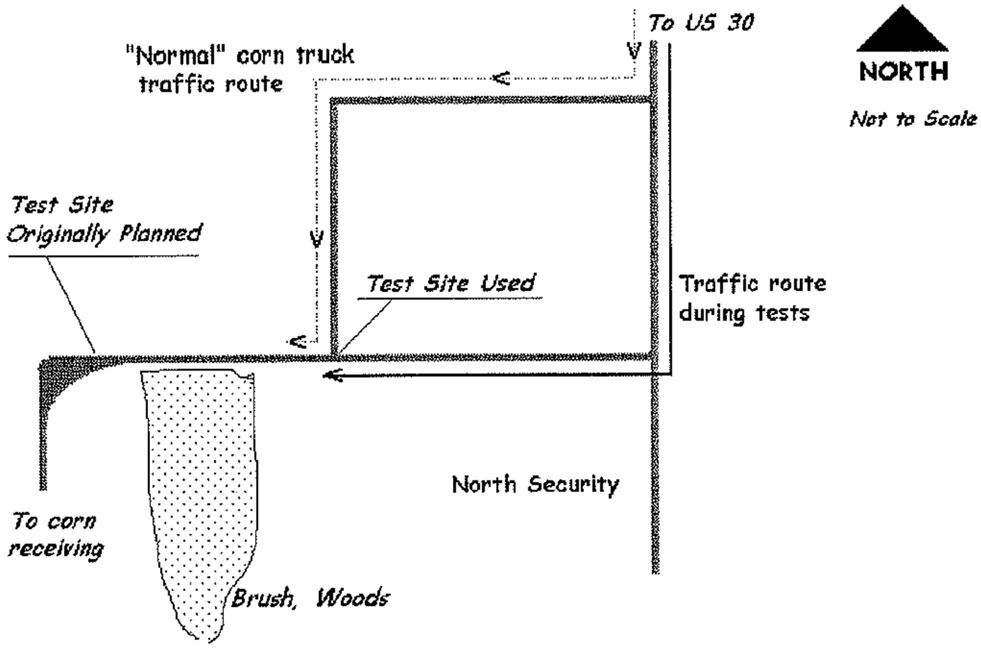

Figure 2-2. Paved Road Test Sites

2.3 Test Matrix

In setting goals for the number of tests to be conducted, it was important to note the following points:

- First, EPA guidance [2] recognizes that site-specific emission tests provide a far more reliable characterization of actual emission levels at a plant than do AP-42 emission factors. Thus, the tests conducted at Blair provide a much more accurate representation of the actual emission levels present at the facility.
- There are 65 emission tests in the AP-42 paved road emission factor database. Beyond the fact that none of these tests were conducted at a corn processing plant, tests in the underlying database do not reference the combination of speed/sL values found at the Blair facility.
- At least three (3) tests of a source are traditionally viewed as the minimum requirement for reliable quantification.

The test site was located in the northwest portion of the plant, as shown in Figure 2-2. The site selected accommodated winds from southeast to south-southwest and was wide enough to permit trucks traveling in opposite directions to pass. Note that the test site selected is not on the "typical" route used by corn trucks. The reasons for selecting this site are described below.

Testing was originally planned for the site shown in Figure 2-2. The original site could accommodate winds from southeast to south and was wide enough along the curved section to permit slight reorientation (using traffic cones) of the road centerline to better match the wind direction. This site was selected on the basis of prevailing wind direction of south-southeast. To maintain steady travel speeds, the test plan recommended traffic control to permit only one truck at a time to pass over the section.

However, in commenting on the test plan, the Nebraska Department of Environmental Quality (DEQ) questioned whether (a) trucks could maintain a speed of 15 mph over the test section and (b) two trucks would be able to pass one another. To address these concerns of the DEQ, the final test site was selected.

Section 3. Test Methodology

This section discusses the exposure profiling sampling methodology employed in the program. MRI developed exposure profiling during the early 1970s and has applied the concept to a wide variety of open fugitive emission sources. AP-42 emission factors based on exposure profiling test results first appeared in 1976. Exposure profiling is EPA's preferred method to characterize emissions from fugitive dust sources. Open source emission factors based on the profiling method typically have the highest quality ratings in AP-42.

3.1 Description of Exposure Profiling Test Method

The exposure profiling test method has been recognized by EPA as the technique most appropriate to characterize the broad class of open anthropogenic PM sources, such as material transfer and moving point sources. Because the method isolates a single emission source while not artificially shielding the source from ambient conditions (e.g., wind), the open source emission factors with the highest quality ratings in EPA's emission factor handbook AP-42[1] are typically based on this approach.

The exposure profiling technique for source testing of open particulate matter sources is based on the same isokinetic profiling concept that is used in stack testing. The passage of airborne pollutant immediately downwind of the source is measured directly by means of simultaneous multipoint sampling over the cross section of the open dust source plume. This technique uses a mass flux measurement scheme similar to EPA Method 5 stack testing rather than requiring indirect emission rate calculation through the application of a generalized atmospheric dispersion model.

The exposure profiling technique relies on simultaneous multipoint measurement of both concentration and air flow (advection) over the effective area of the emission plume. The technique uses a mass flux measurement scheme. Unlike traditional stack sources, both the emission rate and the air flow (i.e., ambient wind) are nonsteady. This requires simultaneous multipoint sampling of mass concentration and air flow over the effective area of the emission plume. When applied to line sources, the exposure profiling test method requires a vertically oriented array of sampling points.

The sampling deployment described below is fundamentally identical to that used to develop the test data base for the AP-42 emission factor equation.

Two vertical networks of samplers (Figure 3-1) were positioned just downwind and upwind from the edge of the source. (See the discussion about placement of the upwind sampler in Section 4.) The primary air sampling device in the exposure profiling portion of the field program was a standard high-volume air sampler fitted with a cyclone preseparator (Figure 3-2). The cyclone exhibits an effective 50 percent cutoff diameter

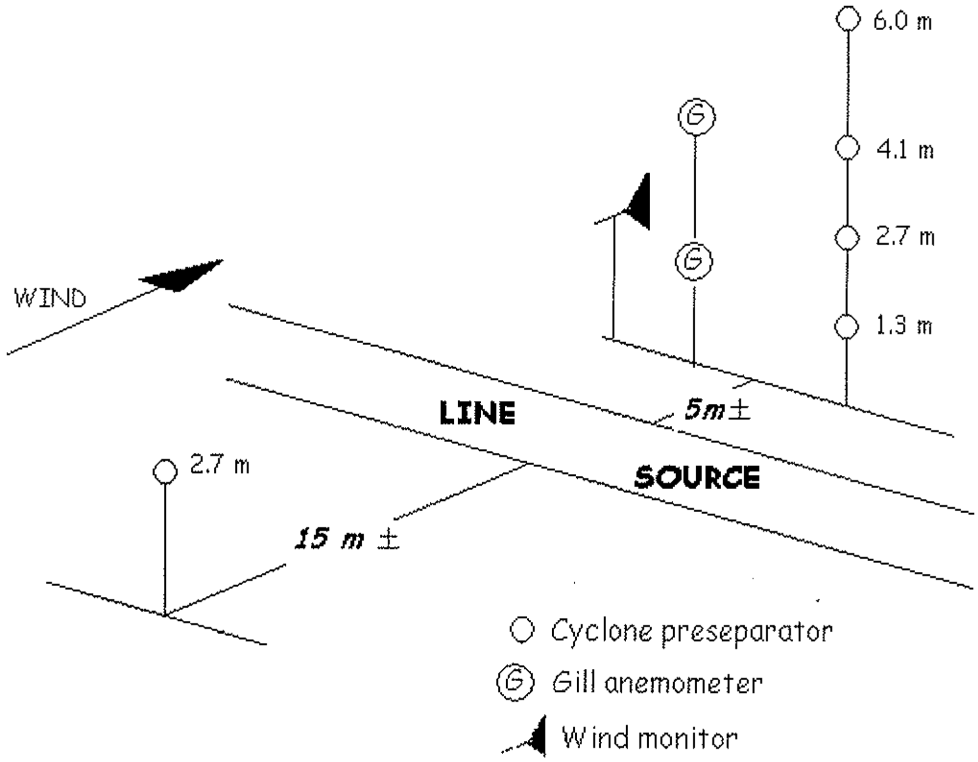

Figure 3-1. Sampler Deployment for Line Sources

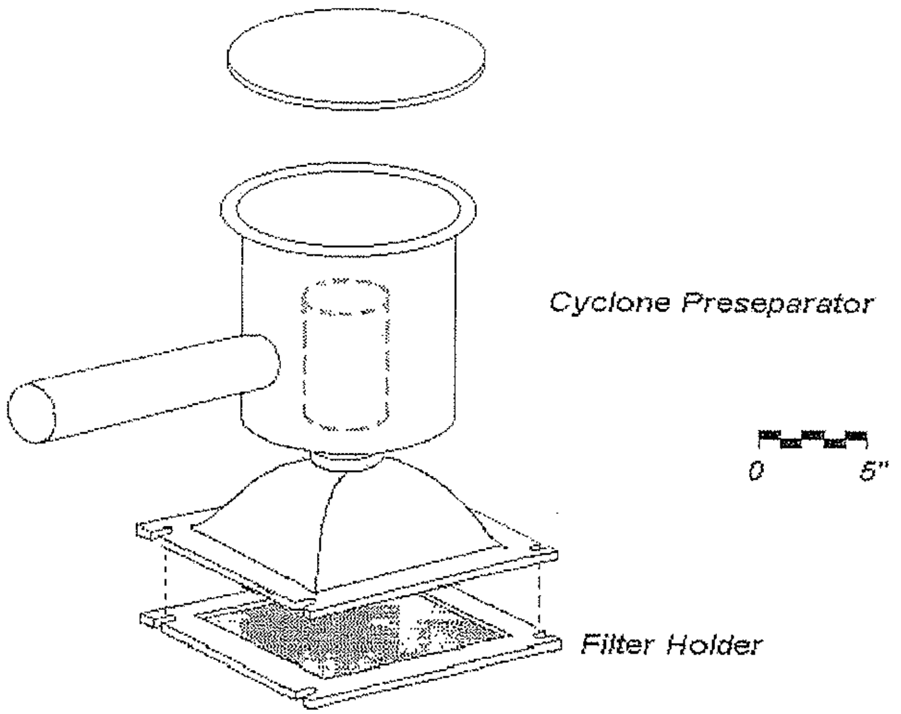

Figure 3-2. Cyclone Preseparator

(D_{50}) of approximately 10 μmA when operated at a flow rate of 40 cfm (68 m^3/h).[3] Thus, mass collected on the 8- by 10-inch backup filter represents a PM-10 sample.

Besides the air sampling equipment, Figure 3-1 also shows that, throughout each test, wind speed was monitored at two heights using R. M. Young Gill-type (model 27106) anemometers. Furthermore, an R. M. Young portable wind station (model 05305) was used to record wind speed and direction at the 3.0 m height. All wind data were accumulated into 5-min averages logged with a 26700 series R. M. Young "programmable translator."

Vehicle speeds were obtained by accumulating (with a stopwatch) the total time required for a series of trucks to traverse a 150 ft section centered on the test site. Separate records were kept for inbound (full) and outbound (empty) trucks.

Sampling activities were subject to the quality assurance/quality control (QA/QC) guidelines discussed in detail in Appendix A. Note that these are the same QA/QC guidelines used to conduct the tests contained in the AP-42 paved road data base.

3.2 Data Analysis

To calculate measurement-based emission rates and emission factors in 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 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 concentration of particulate matter measured by a sampler is given by:

$$C = m/QT \tag{3-1}$$

where:
- C = particulate concentration (mass/volume)
- M = net mass collected on the filter or substrate (mass)
- Q = volumetric flow rate of the sampler (volume/time)
- T = duration of sampling (time)

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:

$$IFR = Q/aU \tag{3-2}$$

where
- Q = volumetric flow rate of the sampler (volume/time)
- a = sampler intake area (area)
- U = approach wind speed (length/time)

This ratio is of interest in the sampling of total particulate, since isokinetic sampling ensures that particles of all sizes are sampled without bias. Because the primary interest is directed to PM-10, sampling under moderately nonisokinetic conditions poses little difficulty. It is readily recognized that 10 μm (aerodynamic diameter) and smaller particles have weak inertial characteristics at normal wind speeds and therefore are relatively unaffected by anisokinesis [4].

Exposure represents the net passage of mass through a unit area normal to the direction of plume transport (wind direction) and is calculated by:

$$E = (C - C_b)\ U\ T \qquad (3\text{-}3)$$

where
- E = net particulate exposure (mass/area)
- C = downwind particulate concentration (mass/volume)
- C_b = background particulate concentration (mass/volume)
- U = approach wind speed (length/time)
- T = duration of sampling (time)

Exposure values vary over the spatial extent of the plume. If exposure is integrated over the plume effective cross section, then the quantity obtained represents the total passage of airborne particulate matter due to the source. For a line source, a one-dimensional integration is used:

$$A_l = \int_0^H E\ dh \qquad (3\text{-}4)$$

where
- A_l = integrated exposure for a line source (mass/length)
- E = net particulate exposure (mass/area)
- h = height above ground (length)
- H = vertical extent of the plume (length)

The vertical extent H is determined by extrapolating the uppermost net concentration values to a value of zero. In no case was the plume height H set greater than 9 m (i.e., 3 m above the height of the top sampler).

Because exposures are measured at discrete points within the plume, a numerical integration is necessary to determine the integrated exposure. For line sources, 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 exposure usually occurs below a height of 1 m, so that there is a sharp decay in 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 the lowest sampling height. The integration is performed using the trapezoidal rule.

The measured emission factor for particulate matter is determined from the integrated exposure by normalizing the emissions against some measure of source activity. In this case, the integrated exposure is divided by the number of vehicle passes during the emission test to express emissions in terms of mass emitted per vehicle distance traveled:

$$e = A_l / N \qquad \textbf{(3-5)}$$

where e = measured emission factor (mass/vehicle-length)
A_l = integrated exposure for a line source (mass/length)
N = number of vehicle passes during the test

Section 4.
Test Results and Discussion

This section presents and discusses the results from the field test program carried out at the Blair facility during August 2002.

4.1 Paved Road Emission Test Results

Eight PM-10 emission tests were conducted between August 12 through 16, 2002. Table 4-1 lists the test site parameters associated with each run, and Table 4-2 presents traffic data. The plant provided a limited number of "drone" passes by an empty corn semi-trailer to supplement traffic during Runs CI-3 and -4.

Tests generally lasted 2 to 4 hr in order to collect adequate mass on both the upwind and downwind sampling media. A minimally detectable (with a confidence level of 95%) PM-10 concentration of approximately 14 $\mu g/m^3$ was derived, based on the following:

- The average (absolute) blank value (0.51 mg) plus two times the standard deviation (0.73 mg) of the blanks. (See Appendix B for a list of blank filters.) This produces a value of 0.51 + 2 (0.73) = 1.97 mg.
- A nominal 40 cfm sampling rate
- A nominal minimum sampling duration of 2 hr

Table 4-3 lists measured concentrations and exposure values for the different sampling locations. All measured concentrations were at least as large as the minimally detectable concentration value. Furthermore, the blank-corrected net catch for each exposed filter (as listed in Appendix B) was at least 5 times greater than the standard deviation of the blank values. This demonstrates that mass collected on the filters was due to airborne particulate and was not the result of filter handling.

Based on the above discussion, one can be highly confident of concentrations measured during the field program. Nevertheless, Table 4-3 shows that, in many instances, the measured downwind PM-10 concentrations were lower than the value measured upwind of the test section. That is to say, emissions from paved road contributed little to the PM-10 concentrations measured immediately downwind of the road, and no "net" mass (i.e., due to the paved road; see Equation 3-3) was detected in many cases.

The difficulty in isolating net PM-10 mass due to the paved road is believed to be an undesired result from moving the test location. The originally selected site would have permitted the background (upwind) monitor to be located in the immediate vicinity (15 m) of the emission source being tested. However, when the test section was moved to the position shown in Figure 2-1, the ditch on the upwind (i.e., south) side of the road, together with plant safety requirements, prevented similar placement of the background sampler. Instead, the sampler was deployed farther upwind at the fenceline near the north security building.

Table 4-1. Test Site Parameters[a]

Run No.	Date	Start time	Duration (min)	Mean wind speed[a] (mph)	Ambient temp. (°F)	Barometric pressure (in. Hg)
CI-1	08/14/02	6:46	269	6.99	70	29.2
CI-2	08/14/02	6:46	269	6.99	70	29.2
CI-3	08/14/02	11:58	240	8.84	85	29.2
CI-4	08/14/02	11:58	240	8.84	85	29.2
CI-7[b]	8/15/2002	6:40,7:31[c]	179	6.22	70	29.0
CI-8	8/15/2002	6:40,7:31[c]	179	6.22	70	29.0
CI-11[d]	8/16/2002	8:56,10:13,11:02[c]	125	5.70	72	29.4
CI-12	8/16/2002	8:56,10:13,11:02[c]	125	5.70	72	29.4

[a] All tests were conducted at the site shown in Figure 4-1. The nominal wind direction during each test was southerly (i.e., from the south). Mean wind speed refers to the speed measured at 5.4 m (17"9") height during test period.
[b] Runs CI-5 and -6 were blank runs.
[c] Test suspended on account of wind direction and then restarted upon return of favorable wind conditions.
[d] Runs CI-9 and -10 were abandoned because of unfavorable wind conditions.

Table 4-2. Traffic During Tests

Run No.	Date	Observation period[a]	Corn receipts[a] (lb) during test	No. of trucks[a] unloaded	Avg. vehicle speed[b] (mph) In/Outbound	Number of truck passes during test
CI-1,2	8/14/02	6:46 – 11:15	4,585,640	88	13.4 / 16.8	203
					12.8 / 16.9	
CI-3,4	8/14/02	11:48 – 15:58	2,831,940	57	13.6 / 14.7	238[c]
					13.5 / 15.5	
CI-7,8	8/15/02	6:40 – 10:10	3,769,400	72	15.2 / 16.2	133[d]
					13.6 / 16.1	
CI-11,12	8/16/02	8:56 – 11:14	2,297,000	47	13.5 / 14.7	116

[a] Data provided by the Blair facility.
[b] Developed by accumulating the time required for trucks to travel a measured 150-ft section centered on the sampling array.
[c] Includes 20 "drone" traffic provided by the plant.
[d] Excludes eight passes between 6:40 and 7:00 a.m.

As discussed in preceding sections, point values of exposure are integrated over the height of the plume to develop emission factors. The results of integrating the exposure values in Table 4-3 are shown in Table 4-4, together with the road surface silt loading data collected during the field exercise. Note that in only two runs (CI-7 and CI-8) was net mass attributed to the test source so that emission factors could be calculated. Also shown are the AP-42 emission factors predicted by Equation 1-1.

Table 4-3. Plume Sampling Data

Run	Sampler height (m)/ location[a]	Flow rate (acfm)	Measured PM-10 concentration ($\mu g/m^3$)	Wind speed (mph)	Downwind PM-10 exposure (mg/cm^2)	Net[b] PM-10 exposure (mg/cm^2)
CI-1	1.3 DW	37.7	19.9	4.83	0.0692	–[b]
	2.7 DW	37.8	22.6	5.94	0.097	–
	4.1 DW	37.3	27.9	6.57	0.1322	–
	6.0 DW	38.2	16.9	7.15	0.0872	–
	2.7 UW	38.1	35.6			
CI-2	1.3 DW	37	25.2	4.83	0.0879	–
	2.7 DW	37.1	16.7	5.94	0.0714	–
	4.1 DW	37.7	23.4	6.57	0.1108	–
	6.0 DW	37.6	21.4	7.15	0.1103	–
	2.7 UW	38.1	35.6			
CI-3	1.3 DW	38.8	24.3	6.06	0.095	–
	2.7 DW	38.8	25.1	7.49	0.1208	–
	4.1 DW	38.3	23.1	8.3	0.1236	–
	6.0 DW	39.2	21.8	9.05	0.1271	–
	2.7 UW	38.1	35.6			
CI-4	1.3 DW	38	24.4	6.06	0.0954	–
	2.7 DW	38.1	25.9	7.49	0.1248	–
	4.1 DW	38.9	24.7	8.3	0.1318	–
	6.0 DW	38.6	20.2	9.05	0.1178	–
	2.7 UW	38.1	35.6			
CI-7	1.3 DW	38	32.3	4.45	0.069	0.0068
	2.7 DW	37.9	27.6	5.36	0.0711	–
	4.1 DW	37.4	23.8	5.88	0.0672	–
	6.0 DW	38.5	23.7	6.35	0.0721	–
	2.7 UW	37.8	29.1			
CI-8	1.3 DW	37.2	31.3	4.45	0.0669	0.0047
	2.7 DW	37.4	33.3	5.36	0.0857	0.0108
	4.1 DW	38.1	28.6	5.88	0.0807	–
	6.0 DW	37.9	26.1	6.35	0.0797	–
	2.7 UW	37.8	29.1			
CI-11	1.3 DW	37.5	42.2	4.22	0.0597	–
	2.7 DW	37.6	51.9	4.98	0.0867	–
	4.1 DW	37	46.6	5.42	0.0847	–
	6.0 DW	38	37.3	5.81	0.0727	–
	2.7 UW	37.4	53.9			
CI-12	1.3 DW	36.8	50.8	4.22	0.0719	–
	2.7 DW	37	49	4.98	0.0818	–
	4.1 DW	37.6	42.2	5.42	0.0767	–
	6.0 DW	37.4	38.6	5.81	0.0753	–
	2.7 UW	37.4	53.9			

[a] DW = downwind, UW = upwind.

[b] "–" indicates that no net mass was attributed to the test source. Zero value assumed in integration.

Table 4-4. Measurement-Based PM-10 Emission Factors[a]

Run	Traffic rate (veh/hr)	Mean vehicle[b] weight (tons)	Silt loading[c] (g/m^2)	Measured emission factor (lb/vmt)	AP-42 predicted emission factor (lb/vmt)
CI-1	45	26	0.06	–[a]	0.043
CI-2	45	26	0.06	–	0.043
CI-3	60[d]	27	0.06	–	0.045
CI-4	60[d]	27	0.06	–	0.045
CI-7	47	27	0.05	0.0036	0.040
CI-8	47	27	0.05	0.0066	0.040
CI-11	56	27	0.025	–	0.025
CI-12	56	27	0.025	–	0.025

[a] "–" Indicates that no net mass attributed to the test source.
[b] Mean vehicle weight based on 80,360 and 27,060 lb for full and empty trucks, respectively. Vehicle weights and silt loading values supplied by Blair facility.
[c] Data provided by Blair facility.
[d] Facility provided additional "drone" traffic during this test period.

4.2 Discussion of Test Results

As noted above, emission factors could be determined for only two runs (CI-7 and -8). In both cases, the measured emission factor was found to be substantially less than the value predicted by the AP-42 predictive equation (Equation 1-1). One could reasonably expect that Equation 1-1 would not provide acceptable estimates, given the following observations:

- First, **in contrast to the sources tested in developing the AP-42 emission data base, re-entrained road dust is not the dominant factor in the profiles measured** at Blair. Figure 4-1 plots the downwind PM-10 exposure versus height for the eight tests. For re-entrained road dust, the peak exposure occurs close to ground level. In other words, one would expect the profiles in the figure to have peak values at a height between 1 and 2 m. By contrast, the figure shows that peak values typically occur near the 3- to 4-m height. Peak values high in the plume suggest that diesel exhaust is a more important emission mechanism than is re-entrained road dust.
- Next, **the source conditions encountered during the Blair tests lie far outside the range of test results underlying the AP-42 paved road emission factor** model. Figure 4-2 plots combinations of surface silt loading (sL) and mean vehicle weight (W) in the AP-42 data as well as in the current testing program. Note that the sL-W combinations encountered during the test program are well outside the cluster of points in the AP-42 data set. This is similar to the situation illustrated earlier in connection with Figure 1-1. That is to say, the tests in the AP-42 data base do not reference conditions experienced at the Blair facility.

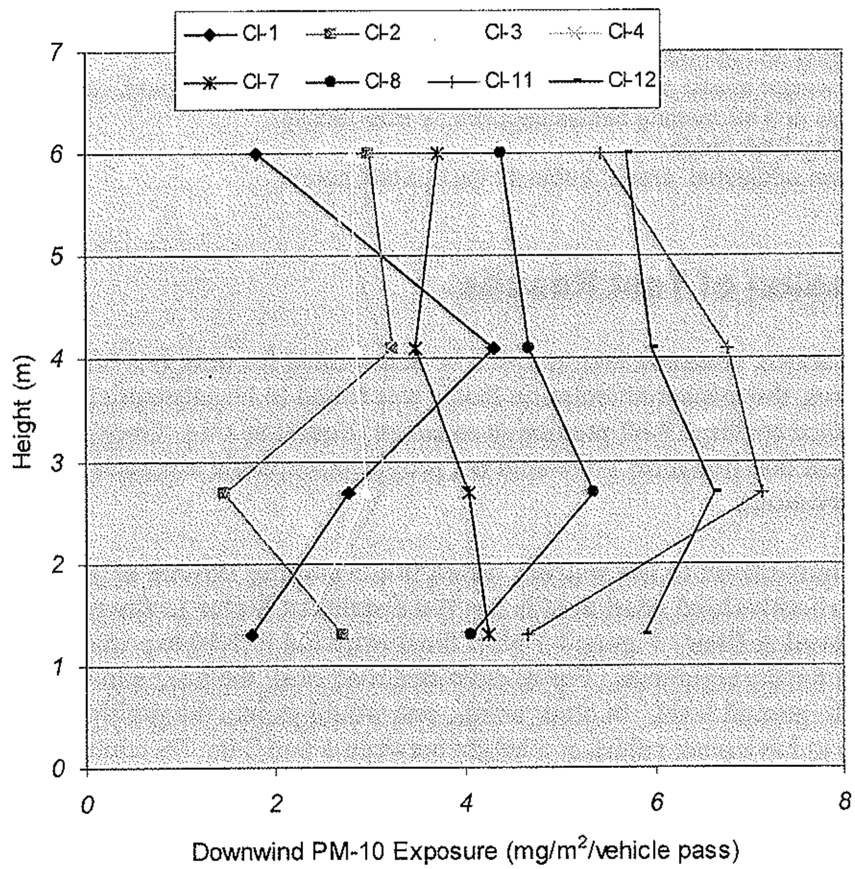

Figure 4-1. PM-10 Exposure Profiles

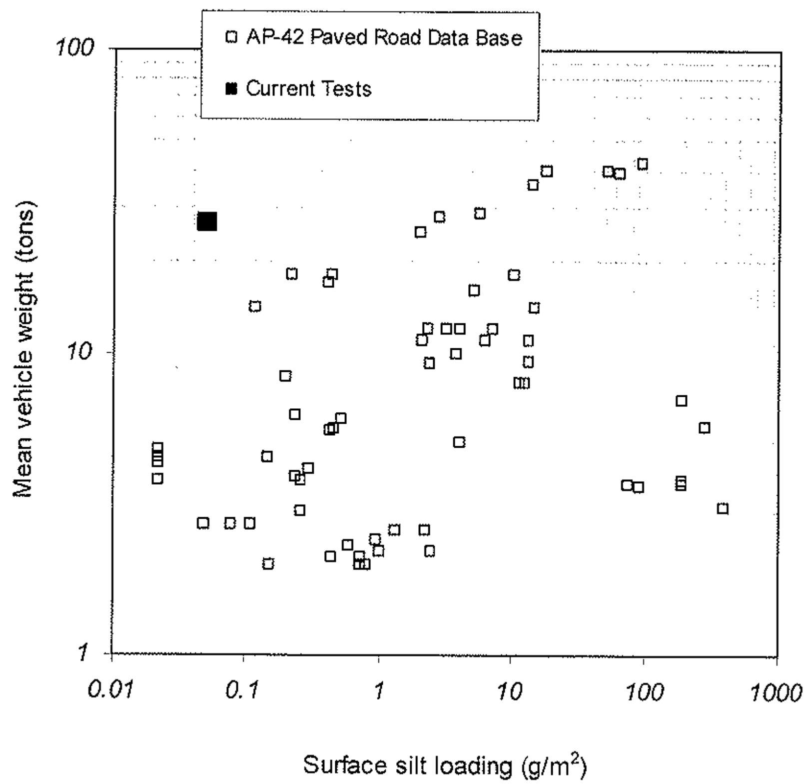

Figure 4-2. Comparison of sL-W Combinations

Taken together, these points indicate the shortcomings of the AP-42 equation when applied to paved roads at the Blair plant. Unlike tests in the AP-42 data base, re-entrained surface material was not the dominant source of emissions in the tests at Blair. In other words, the basic premise of Equation 1-1—namely, that PM-10 emissions are directly related to surface loading—does not apply. As such, one cannot expect Equation 1-1 to adequately describe paved road emissions at Blair.

Furthermore, the combination of source conditions—speed, silt loading, and mean vehicle weight—present at Blair fall far outside what would considered "typical" in the AP-42 data base. The point made earlier in Section 1 bears repeating here: AP-42 emission factors are best viewed as representative of the population average. Because the model would be applied to source conditions far outside the underlying data base, one would ascribe low confidence to emission estimates for Blair based on Equation 1-1.

As noted in Section 2, EPA guidance recognizes that site-specific emission tests provide a far more reliable characterization of actual emission levels at a plant than do AP-42 emission factors. Thus, the overall mean measured emission factor of 0.0051 lb/vmt from Table 4-4 provides a more accurate representation of paved road emissions at Blair than does the AP-42 model.

Section 5.
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Appendix A

Quality Assurance/Quality Control Procedures

A.1 Sample Handling and Traceability Requirements

The majority of environmental samples collected during the test program consist of particulate matter captured on a filter medium. Analysis is gravimetric, as described in the following paragraphs.

To maintain sample integrity, the following procedure was used. Each filter was stamped with a unique 7-digit identification number. SOP (standard operating procedure) MRI-8403 describes the numbering system that is employed. A file folder is also stamped with the identification number and the filter is placed in the corresponding folder.

Particulate samples are collected on glass fiber (or quartz) filters (8 in by 10 in) or on glass fiber impaction substrates (4 in by 5 in). Prior to the initial (tare) weighing, the filter media are equilibrated for 24 hr at constant temperature and humidity in a special weighing room. Temperature and humidity levels are given in Table A-1. The room contains a hygrothermograph to provide a permanent record of equilibration conditions. The chart is changed weekly and recalibrated (as necessary) against wet and dry bulb thermometers. Those thermometers are checked annually against traceable units.

During weighing, the balance is checked at frequent intervals with standard (Class S) weights to ensure accuracy. The filters remain in the same controlled environment until a second analyst reweighs them as a precision check. A minimum of ten percent (10%) (with an absolute minimum of three blanks per test site) of the filters used in the field serve as blanks to account for the effects of handling. The QA guidelines pertaining to preparation of sample collection media are presented in Section A-3.

The filters are placed in their like-numbered folders. Groups of approximately 50 are sealed in heavy-duty plastic bags and stored in a heavy corrugated cardboard box equipped with a tight-fitting lid. Unexposed filters are transported to the field in the same truck as the sampling equipment and are then kept in the field laboratory.

Once they have been used, exposed filters are placed in individual glassine envelopes and then into numbered file folders. Groups of up to 50 file folders are sealed within heavy-duty plastic bags and then placed into a heavy-duty cardboard box fitted with a lid. Exposed and unexposed filters are always kept separate to avoid any cross-contamination. When exposed filters and the associated blanks are returned to the main MRI laboratory in Kansas City, they are equilibrated under the same conditions as the initial weighing. After reweighing, a minimum of 10% of each type is audited to check weighing accuracy.

In order to ensure traceability, all filter and material sample transfers are recorded in a notebook or on forms. The following information are recorded: the assigned sample codes, date of transfer, location of storage site, and the names of the persons initiating and accepting the transfer.

A.2 Analytical Method Requirements

All analytical methods required for this testing program are inherently gravimetric in nature. That is to say, the final and tare weights are used to determine the net mass of particulate captured on filters and other collection media. The tare and final weights of blank filters are used to account for the systematic effects of filter handling.

The following procedures are followed whenever a sample-related weighing is performed:

- An accuracy check at the minimum of one level, equal to approximately the tare and actual weight of the sample or standard. Standard weights should be class S or better.
- The observed mass of the calibration weight (not including the tare weight) must be within 1.0% of the reference mass.
- If the balance calibration does not pass this test at the beginning of the weighing, the balance should be repaired or another balance should be used. If the balance calibration does not pass this test at the end of a weighing, the samples or standards should be reweighed using a balance that can meet these requirements.

A.3 Quality Control Requirements

Routine audits of sampling and analysis procedures are to be 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 audited include gravimetric analysis, flow rate calibration, data processing, and emission factor 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.

To prepare hi-vol filters for use in the field, filters are weighed under stable temperature and humidity conditions. After they are weighed and have passed audit weighing, the filters are packaged for shipment to the field. Table A-1 outlines the general requirements for conditioning and weighing sampling media. Note that a second, independent analyst performs the audit weights.

Table A-1. 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 h in clean controlled room with relative humidity of 40% (variation of less than ±5% RH) and with temperature of 23°C (variation of less than ±1°C).
Weighing	Weigh hi-vol filters to nearest 0.05 mg.
Auditing of weights	Independently verify final weights of 10% of filters and substrates (at least four from each batch). Reweigh entire batch if weights of any hi-vol filters deviate by more than ±2.0 mg. For tare weights, conduct a 100% audit. Reweigh any high-volume filter whose weight deviates by more than ±1.0 mg.
Collection of blanks	Conduct at least one complete blank test for every 1 to 9 emission tests. A minimum of 3 blank filters is necessary for each test site/source combination.
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.

As indicated in Table A-1, a minimum of 10% field blanks are collected for QC purposes. This is accomplished by conducting one blank test for every 1-to-9 emission tests conducted. A blank test is conducted in exactly the same manner as an emission test except that no air is passed through the filters after they are loaded into the sampling devices. Instead, they are immediately recovered and handled the same as any exposed filter from an actual emission test. Blank runs are labeled in the same manner as other tests, although the run sheets indicate that a blank test was conducted.

Handling blank filters in an identical manner to all sample filters allows one to determine systematic weight changes due to handling steps alone. A field blank filter is loaded into a sampler and then immediately recovered without any air being passed through the media. This technique has been successfully used in many MRI programs to account for systematic weight changes due to handling.

After the particulate matter samples and blank filters are collected and returned from the field, the collection media are placed in the gravimetric laboratory and allowed to come to equilibrium. Each filter is weighed, allowed to return to equilibrium for an additional 24 hr, and then a minimum of 10% of the exposed/blank filters are reweighed. If a filter fails the audit criterion, the entire lot is allowed to condition in the gravimetric laboratory an additional 24 hr and then reweighed. The tare and first weight criteria for filters (Table A-1) are based on an internal MRI study conducted in the early 1980s to evaluate the stability of several hundred 8- x 10-in glass fiber filters used in exposure profiling studies.

A.4 Instrument/Equipment Testing, Inspection and Maintenance

Inspection and maintenance requirements for sampling equipment are provided in Table A-2. Material presented in italics discusses how these requirements were met during the study.

A.5 Instrument Calibration and Frequency

Calibration and frequency requirements for the balances used in the gravimetric analyses are given in Table A-1.

Requirements for high-volume (hi-vol) sampler flow rates rely on the use of secondary and primary flow standards. The Roots meter is the primary volumetric standard and the BGI orifice is the secondary standard for calibration of hi-vol sampler flow rates. The Roots meter is calibrated and traceable to a NIST standard by the manufacturer. The BGI orifice is calibrated against the primary standard on an annual basis. Before going to the field, the BGI orifice is first checked to assure that it has not been damaged. In the field, the orifice is used to calibrate the flow rate of each hi-vol sampler. (For samplers with volumetric flow controllers, no calibration is possible and the orifice is used to audit the nominal 40 acfm flow rate.) Table A-2 specifies the frequency of calibration and other QA checks regarding air samplers.

Table A-3 outlines the QC checks employed for miscellaneous instrumentation needed. Material presented in italics discusses how these requirements were met during the study.

A.6 Inspection/Acceptance Requirements for Supplies and Consumables

The primary supplies and consumables for this field exercise consist of the air filter and collection media. Prior to stamping and initial weighing (Table A-1), each filter is visually inspected and is discarded for use if any pin-holes, tears, or other damage is found.

A.7 Data Acquisition Requirements

In addition to the field samples, MRI also collected information on the physical size and operational parameters of equipment used in the field exercise. To the extent practical and appropriate, physical characteristics are obtained from the manufacturer or the manufacturer's literature. Physical dimensions are measured and recorded.

Table A-2. Quality Assurance Procedures for Sampling Equipment

Activity	QA check/requirement[a]
Maintenance • All samplers	Check motors, brushes, gaskets, timers, and flow measuring devices at each plant prior to testing. Repair/replace as necessary. *Sampling devices were cleaned and checked prior to loading truck and upon arrival at plant.*
Calibration • Volumetric flow controller (VFC)	Prior to start of testing at each regional site, ensure that flow determined by calibration orifice and the look-up table for each volumetric flow controller agrees within 7%. Alternately, develop a separate calibration curve for each VFC. For 20 acfm devices (particle size profiling), calibrate each sampler against the orifice prior to use for each regional site and every two weeks thereafter during test period. (Orifice calibrated against displaced volume test meter annually.) *VFC calibration records have been included in copy of field data sheets. Calibration curves developed for each VFC are included on diskette with field data and data reduction.*
Operation • Timing	Start and stop all downwind samplers during time span not exceeding 1 min. *All downwind samplers were started / stopped within 1 minute.*
• Isokinetic sampling (cyclones)	Adjust sampling intake orientation whenever mean wind direction dictates. *Wind direction relative to line source monitored immediately before and throughout test. Rotation of sampling arrays noted on field run sheets.* Change the cyclone intake nozzle whenever the mean wind speed approaching the sampler falls outside of the suggested bounds for that nozzle. *Wind speed throughout range of sampling heights monitored immediately before and throughout the test. Use of nozzles (if any) indicated on field run sheets.*
• Prevention of static deposition	Cover sampler inlets prior to and immediately after sampling. *Samplers were uncovered immediately before start of test and filters recovered immediately after end of test.*

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

Table A-3. Quality Assurance for Miscellaneous Instrumentation

Instrumentation	QA check/requirement[a]
Digital manometers	Compare reading against water-in-tube manometers over range of operating pressures, using "Y" or "T" connectors and flexible tubing. Do not use units which differ by more than 7%. *Two units were used during tests. Maximum deviations for unit Y7543 and unit Y7542 were 3.7 and 4.0%, respectively.*
Digital barometer	Compare against mercury-in-tube barometer. Do not use if more than 0.5 in Hg difference in reading. *Deviation of altimeter/barometer Y-0918 was 0.16 in Hg (0.55% deviation).*
Thermometer (mercury or digital)	Compare against NIST-traceable mercury-in-glass. Do not use if more than 3.0 C difference. *Deviation for Hg-in-glass unit was 0.8 °F (0.4 °C) low.*
Gill anemometers and wind station	Conduct a 4-point calibration of each unit over the range of 2 to 20 mph both before the field exercise and upon return to MRI's main laboratories. Use factory-specified devices for calibration of wind speed and direction. *Pre- and post-test calibrations records have been supplied as part of field run sheets.*
Watches/stopwatches	The field test leader will compare an elapsed time (> 1 hr) recorded by his watch against the U.S. Naval Observatory master clock. Do not use if more than 3% difference. All crew members will synchronize watches (to the nearest minute) at the start of each test day. *Crew chief watch was checked against 135 min elapsed time, with deviation of 0.0%. Crew member watches and wind data acquisition device were reset to crew chief watch each day.* *Two stopwatches used during tests. Both compared against USNO-determined elapsed time of 1:56:52. "Spalding" unit read 1:56:52 and "SyncroSport" unit read 1:56:50.82 (0.0 and 0.02% deviation, respectively).*

[a] Activities performed prior to going to the field, except as noted.

Table A-4. 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. (Exception made in the case of a source protected by a roof or other enclosure).
2. Mean wind speed during sampling moves outside the 4 to 20 mph acceptable range for more than 20% of the sampling time.
3. The angle between the mean wind direction and the perpendicular to the measurement plane exceeds 45° for more than 20% of the sampling time.

   See Table 4-1 in body of report. Several tests suspended and restarted once acceptable wind conditions returned. Runs CI-9,10 abandoned due to unfavorable wind conditions.
4. Daylight is insufficient for safe equipment operation. (Exception made in case of adequate artificial lighting.)
5. Source conditions deviates from predetermined criteria (e.g., loading equipment malfunction, water splashing, truck spills).

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

Appendix B

Detailed Test Data

Run	Date	Cyclone inlet height (m) (DW = downwind, UW =upwind)	VFC ID	Sampler start time(s)	Sampler stop time(s)	Sampling duration (min)	Avg. ambient air temp. (deg. F)	Avg. baro. press. (in. Hg)	Avg. filter pressure (in. H_2O)	Filter Number	Tare weight (g)	Final weight (g)	Blank-corrected Net Catch (mg)	Cal Coeff #1 (scfm)	Cal Coeff #2 –	Flow rate (acfm)	Measured (raw) conc. (µg/m³)	Wind speed (mph)	Measured downwind PM-10 exposure (mg/cm²)
CI-1	08/14/02	1.3	76	6:46	11:15	269	70	29.2	19.6	453002	4.3704	4.3756	5.71	46.85	0.0766	37.7	19.9	4.83	0.0692
A Trailer		2.7 DW	67	6:46	11:15	269	70	29.2	20.5	453003	4.377	4.383	6.51	46.38	0.0717	37.8	22.6	5.94	0.0970
East		4.1 DW	66	6:46	11:15	269	70	29.2	19.6	453004	4.3707	4.3781	7.91	45.89	0.0738	37.3	27.9	6.57	0.1322
		6.0 DW	70	6:46	11:15	269	70	29.2	19.6	453005	4.4132	4.4176	4.91	46.41	0.0695	38.2	16.9	7.15	0.0872
		2.7 UW	75	6:45	15:58	553	77	29.2	19.9	453001	4.3714	4.3921	21.21	47.37	0.0809	38.1	35.6		
CI-2	08/14/02	1.3 DW	68	6:46	11:15	269	70	29.2	19.5	453006	4.3939	4.4005	7.11	46.69	0.0821	37.0	25.2	4.83	0.0879
B Trailer		2.7 DW	78	6:46	11:15	269	70	29.2	19.6	453007	4.4099	4.4141	4.71	46.29	0.0781	37.1	16.7	5.94	0.0714
West		4.1 DW	74	6:46	11:15	269	70	29.2	20.2	453008	4.3918	4.398	6.71	46.96	0.0766	37.7	23.4	6.57	0.1108
		6.0 DW	71	6:46	11:15	269	70	29.2	20.2	453009	4.4056	4.4112	6.11	46.99	0.0784	37.6	21.4	7.15	0.1103
		2.7 UW	75	6:45	15:58	553	77	29.2	19.9	453001	4.3714	4.3921	21.21	47.37	0.0809	38.1	35.6		
CI-3	08/14/02	1.3 DW	70	11:58	15:58	240	85	29.2	19.9	453010	4.3953	4.4012	6.41	46.85	0.0766	38.8	24.3	6.06	0.0950
A Trailer		2.7 DW	78	11:58	15:58	240	85	29.2	20.7	453011	4.3959	4.4020	6.61	46.38	0.0717	38.8	25.1	7.49	0.1208

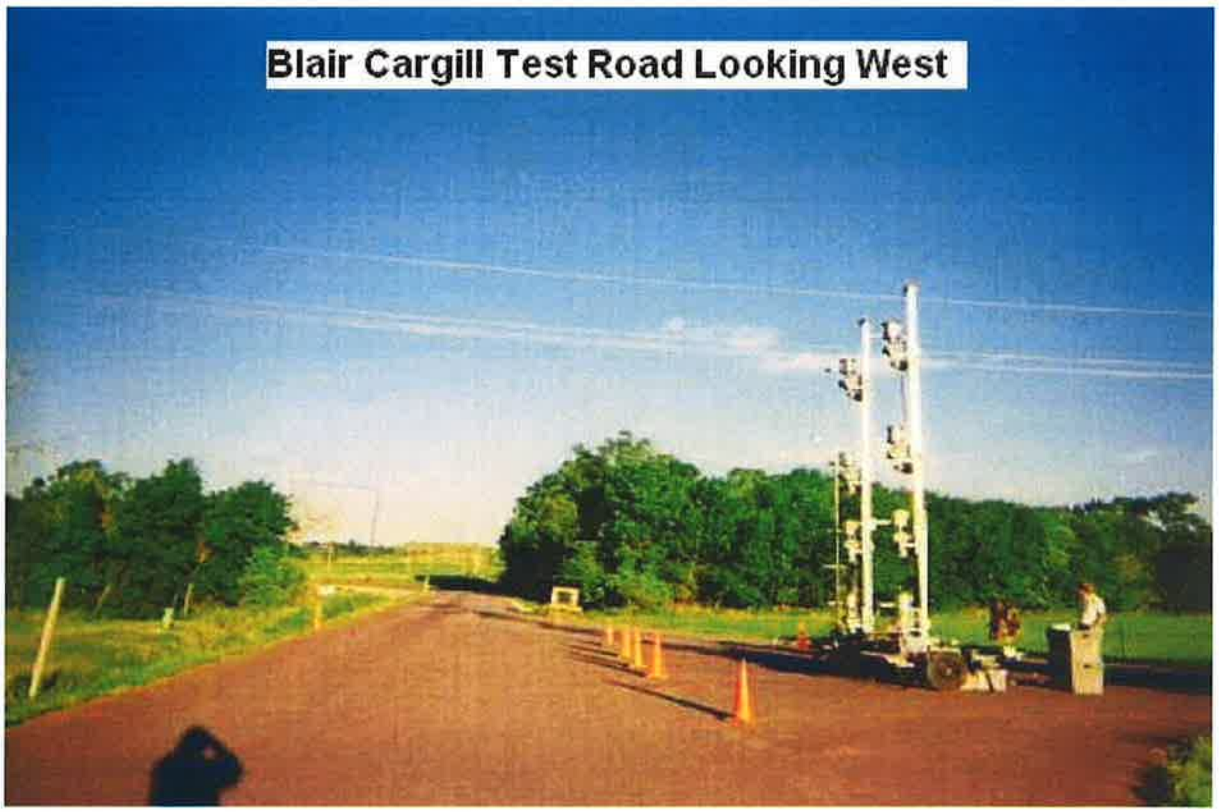
Run	Date	Cyclone inlet height (m) (DW = downwind, UW =upwind)	VFC ID	Sampler start time(s)	Sampler stop time(s)	Sampling duration (min)	Avg. ambient air temp. (deg. F)	Avg. baro. press. (in. Hg)	Avg. filter pressure (in. H_2O)	Filter Number	Tare weight (g)	Final weight (g)	Blank-corrected Net Catch (mg)	Cal Coeff #1 (scfm)	Cal Coeff #2 –	Flow rate (acfm)	Measured (raw) conc. (μg/m³)	Wind speed (mph)	Measured downwind PM-10 exposure (mg/cm²)
East		4.1 DW	71	11:58	15:58	240	85	29.2	20.1	453012	4.4042	4.4097	6.01	45.89	-0.0738	38.3	23.1	8.30	0.1236
		6.0 DW	67	11:58	15:58	240	85	29.2	20.2	453013	4.4308	4.4361	5.81	46.41	-0.0695	39.2	21.8	9.05	0.1271
		2.7 UW	69	6:45	15:58	553	77	29.2	19.9	453001	4.3714	4.3921	21.21	47.37	-0.0809	38.1	35.6		
CI-4	08/14/02	1.3 DW	66	11:58	15:58	240	85	29.2	19.9	453014	4.4211	4.4269	6.31	46.69	-0.0821	38.0	24.4	6.06	0.0954
B Trailer		2.7 DW	74	11:58	15:58	240	85	29.2	19.9	453015	4.4153	4.4215	6.71	46.29	-0.0781	38.1	25.9	7.49	0.1248
West		4.1 DW	75	11:58	15:58	240	85	29.2	19.9	453016	4.4201	4.4261	6.51	46.96	-0.0766	38.9	24.7	8.30	0.1318
		6.0 DW	76	11:58	15:58	240	85	29.2	20.2	453017	4.4151	4.4199	5.31	46.99	-0.0784	38.6	20.2	9.05	0.1178
		2.7 UW	77	6:45	15:58	553	77	29.2	19.9	453001	4.3714	4.3921	21.21	47.37	-0.0809	38.1	35.6		
Note 1 CI-5,6 are blank runs																			
CI-7	8/15/2002	1.3 DW	76	6:40,7:31	7:00, 10:10	179	70	29.0	19.7	453027	4.3762	4.3819	6.21	46.85	-0.0766	38.0	32.3	4.45	0.0690
A Trailer		2.7 DW	67	6:40,7:31	7:00, 10:10	179	70	29.0	21.2	453028	4.3984	4.4032	5.31	46.38	-0.0717	37.9	27.6	5.36	0.0711
East		4.1 DW	66	6:40,7:31	7:00, 10:10	179	70	29.0	20.4	453029	4.3988	4.4028	4.51	45.89	-0.0738	37.4	23.8	5.88	0.0672
		6.0 DW	70	6:40,7:31	7:00, 10:10	179	70	29.0	19.3	453030	4.3519	4.3560	4.61	46.41	-0.0695	38.5	23.7	6.35	0.0721
		2.7 UW	75	6:44, 7:31	7:01,11:12	238	70	29.0	20.3	453026	4.4050	4.4129	7.41	47.37	-0.0809	37.8	29.1		

Run	Date	Cyclone inlet height (m) (DW = downwind, UW =upwind)	VFC ID	Sampler start time(s)	Sampler stop time(s)	Sampling duration (min)	Avg. ambient air temp. (deg. F)	Avg. baro. press. (in. Hg)	Avg. filter pressure (in. H_2O)	Filter Number	Tare weight (g)	Final weight (g)	Blank-corrected Net Catch (mg)	Cal Coeff #1 (scfm)	Cal Coeff #2 –	Flow rate (acfm)	Measured (raw) conc. (µg/m^3)	Wind speed (mph)	Measured downwind PM-10 exposure (mg/cm^2)
CI-8	8/15/2002	1.3 DW	68	6:40,7:31	7:00, 10:10	179	70	29.0	19.6	453031	4.3508	4.3562	5.91	46.69	–0.0821	37.2	31.3	4.45	0.0669
B Trailer		2.7 DW	78	6:40,7:31	7:00, 10:10	179	70	29.0	19.4	453032	4.3723	4.3781	6.31	46.29	–0.0781	37.4	33.3	5.36	0.0857
West		4.1 DW	74	6:40,7:31	7:00, 10:10	179	70	29.0	19.7	453033	4.3718	4.3768	5.51	46.96	–0.0766	38.1	28.6	5.88	0.0807
		6.0 DW	71	6:40,7:31	7:00, 10:10	179	70	29.0	19.8	453034	4.3666	4.3711	5.01	46.99	–0.0784	37.9	26.1	6.35	0.0797
		2.7 UW	75	6:44, 7:31	7:01,11:12	238	70	29.0	20.3	453026	4.4060	4.4129	7.41	47.37	–0.0809	37.8	29.1		
Note 2: CI-9,10 were abandoned after winds turned to the north																			
CI-11	8/16/2002	1.3 DW	70	8:56,10:13,11:02	10:05,10:57,11:14	125	72	29.4	20.1	453044	4.3854	4.3905	5.61	46.85	–0.0766	37.5	42.2	4.22	0.0597
A Trailer		2.7 DW	78	8:56,10:13,11:02	10:05,10:57,11:14	125	72	29.4	21.0	453045	4.4034	4.4098	6.91	46.38	–0.0717	37.6	51.9	4.98	0.0867
East		4.1 DW	71	8:56,10:13,11:02	10:05,10:57,11:14	125	72	29.4	20.4	453046	4.3951	4.4017	6.11	45.89	–0.0738	37.0	46.6	5.42	0.0847
		6.0 DW	67	8:56,10:13,11:02	10:05,10:57,11:14	125	72	29.4	20.1	453047	4.4001	4.4046	5.01	46.41	–0.0695	38.0	37.3	5.81	0.0727
		2.7 UW	69	9:00	11:15	135	72	29.4	20.4	453043	4.4094	4.4166	7.71	47.37	–0.0809	37.4	53.9		
CI-12	8/16/2002	1.3 DW	66	8:56,10:13,11:02	10:05,10:57,11:14	125	72	29.4	20.4	453048	4.4038	4.4099	6.61	46.69	–0.0821	36.8	50.8	4.22	0.0719
B Trailer		2.7 DW	74	8:56,10:13,11:02	10:05,10:57,11:14	125	72	29.4	19.7	453049	4.3981	4.4040	6.41	46.29	–0.0781	37.0	49.0	4.98	0.0818

Run	Date	Cyclone inlet height (m) (DW = downwind, UW =upwind)	VFC ID	Sampler start time(s)	Sampler stop time(s)	Sampling duration (min)	Avg. ambient air temp. (deg. F)	Avg. baro. press. (in. Hg)	Avg. filter pressure (in. H_2O)	Filter Number	Tare weight (g)	Final weight (g)	Blank-corrected Net Catch (mg)	Cal Coeff #1 (scfm)	Cal Coeff #2 --	Flow rate (acfm)	Measured (raw) conc. (μg/m^3)	Wind speed (mph)	Measured downwind PM-10 exposure (mg/cm^2)
West		4.1 DW	75	8:56,10:13,11:02	10:05,10:57,11:14	125	72	29.4	20.6	453050	4.4016	4.4067	5.61	46.96	0.0766	37.6	42.2	5.42	0.0767
		6.0 DW	76	8:56,10:13,11:02	10:05,10:57,11:14	125	72	29.4	20.6	453051	4.3924	4.3970	5.11	46.99	0.0784	37.4	38.6	5.81	0.0753
		2.7 UW	77	9:00	11:15	135	72	29.4	20.4	453043	4.4094	4.4166	7.71	47.37	0.0809	37.4	53.9		

Blank Filter Data (Runs CI-5,-6).

Filter Number	Tare Wt. (mg)	Final Wt. (mg)	Net Wt. (mg)
453018	4418.80	4418.20	-0.60
453019	4428.50	4428.00	-0.50
453020	4419.70	4417.90	-1.80
453021	4416.50	4415.30	-1.20
453022	4406.70	4406.40	-0.30
453023	4417.80	4417.80	0.00
453024	4404.30	4404.90	0.60
453025	4404.40	4404.10	-0.30
		Mean	**-0.513**
		Std Dev	**0.730**



Blair Cargill Test Road Looking West


Blair Cargill Equipment Array Looking Upwind


Blair Cargill - Two Trucks Passing at Once


Blair Cargill - Vacuum Truck