| | |
|---|---|
| AP42 Section: | 13.2.2 |
| Background Chapter | 4 |
| Reference: | 3 |
| Title: | PM-10, PM2.5, PM-1 Emission Factors for Haul Roads at Two Stone Crushing Plants, National Stone Association, Washington, D.C., November 1995. |

13.22.
CH 4
#3

# $PM_{10}$, $PM_{2.5}$ & $PM_1$ EMISSION FACTORS FOR HAUL ROADS AT TWO STONE CRUSHING PLANTS

If you average concentration over height, do you over/under estimate mean exposure?

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AIR POLLUTION CONTROL SYSTEMS ENGINEERING

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## *HAUL ROAD EMISSION FACTOR TESTS*

### *1. SUMMARY*


The National Stone Association (NSA) has sponsored emission factor tests at two stone crushing plant quarries. The primary objective of these tests was to accurately measure $PM_{10}$, $PM_{2.5}$, and $PM_1$ emissions from a controlled haul road (standard wet suppression) at a stone quarry. These tests were part of the NSA-U.S. EPA program to determine accurate emission factors for the stone crushing industry. The quarries selected were Martin Marietta Aggregates Plants in Garner and Lemon Springs (also denoted as Sanford), North Carolina. The test sites were selected since there were safe and appropriate test locations on the haul road, since the proximity of the sites close to the RTP area of North Carolina reduced testing costs, and since the proximity of the sites to RTP allowed EPA representatives to visit the testing sites without excessive travel costs. The sites were chosen from a number of locations visited by representatives from NSA, EPA, and Air Control Techniques, P.C.

Air Control Techniques, P.C. used an upwind-downwind profiling method in the sampling programs. EPA Method 201A was used to measure the concentration of $PM_{10}$ particulate in the sample gas stream up to a height of 30 feet above the haul road. An ambient Hi-Vol monitor, cascade impactor and a nephelometer were used to measure the upwind concentration of $PM_{10}$, $PM_{2.5}$ and $PM_1$ particulate up to a height of 30 feet above the road surface. Following standard gravimetric analysis, the Method 201A filters (downwind sampling location) were analyzed for particle size distribution and combustion products (diesel exhaust) by polarizing light microscopy. Cascade impactors and a nephelometer were also used in the downwind location to measure particle size distribution data in the $PM_{10}$, $PM_{2.5}$, and $PM_1$ size ranges. The results of the emission factors tests are presented in Table 1-1.


are these UC or C?

TABLE 1-1 HAUL ROAD EMISSIONS

| Plant | Emission Factor Size Range | Pounds of Emission per Vehicle Mile Traveled | Average of both haul roads tested, lbs /VMT |
|---|---|---|---|
| Garner, Martin Marietta | ≤1.0 Microns | 0.10 | |
| Lemon Springs, Martin Marietta | ≤1.0 Microns | 0.14 | 0.12 |
| Garner, Martin, Marietta | ≤2.5 Microns | 0.23 | |
| Lemon Springs, Martin Marietta | ≤2.5 Microns | 0.57 | 0.40 |
| Garner, Martin Marietta | ≤10 Microns | 0.79 | |
| Lemon Springs, Martin Marietta | ≤10 Microns | 1.74 | 1.26 |

is Lemon higher than Garner because ... (See Photos 2-4 to 2-6) basis for statement

The controlled (wet suppression) $PM_{10}$ emission factor results are slightly higher than emission factors calculated using the unpaved road equation in Section 11.19.3 of AP-42 and higher than results from a haul road emission factor test conducted in October 1994. These relatively high results are due primarily to the very high ambient temperatures and wind speeds experienced during the test program. The tests were completed during the month of August following a 28 day period of ambient temperatures exceeding 90 degrees Fahrenheit. On several of the test days at Garner, the ambient temperatures exceeded 100°F during parts of the tests. The tests at both plants were also completed while hurricane Frederick was stalled off the coast of North Carolina. This created higher than normal test site wind speeds that averaged 5.5 miles per hour and had gusts in excess of 20 miles per hour. The high ambient temperature and high wind speed resulted in rapid evaporation of the road surface moisture. The haul road watering cycle was altered from the plant's regular schedule in order to determine the maximum amount of time required before the test section of haul road began to emit dust. In other words, the haul road test section was purposely not watered on a normal or routine basis during the test period. This was considered necessary to match the normal wet suppression system practices throughout the year. However, the combined effect of the severe weather conditions and the need to minimize watering frequency during the 6-hour tests resulted in unrepresentatively high particulate emissions.

The $PM_{10}$ emission factors presented in Table 1-1 are based on the Method 201A filter catches. However, polarizing light microscopy analyses were used to determine the content of combustible particles on the filters. This combustible material is not stone dust and, therefore, has been factored out of the emission factors.

The $PM_{2.5}$ and $PM_1$ emissions were considerably lower than the $PM_{10}$ emissions. At the present time, there is no comparable emission factor data for the emissions of $PM_{2.5}$ and $PM_1$ from stone crushing plant haul roads. There is also no predictive equation available for these categories of particulate emissions. It should also be noted that 6 hour cascade impactor runs have never been done to the contractor's knowledge. For this reason the $PM_{2.5}$ and $PM_1$ data is considered marginally reliable due to the filter losses over the long sampling period.

"master of obvious" type stmt.

not the case for many states which do not inventory off-road dust emissions.

# 2. SAMPLING LOCATIONS AND PROCEDURES

## 2.1 OBJECTIVES AND TEST MATRIX

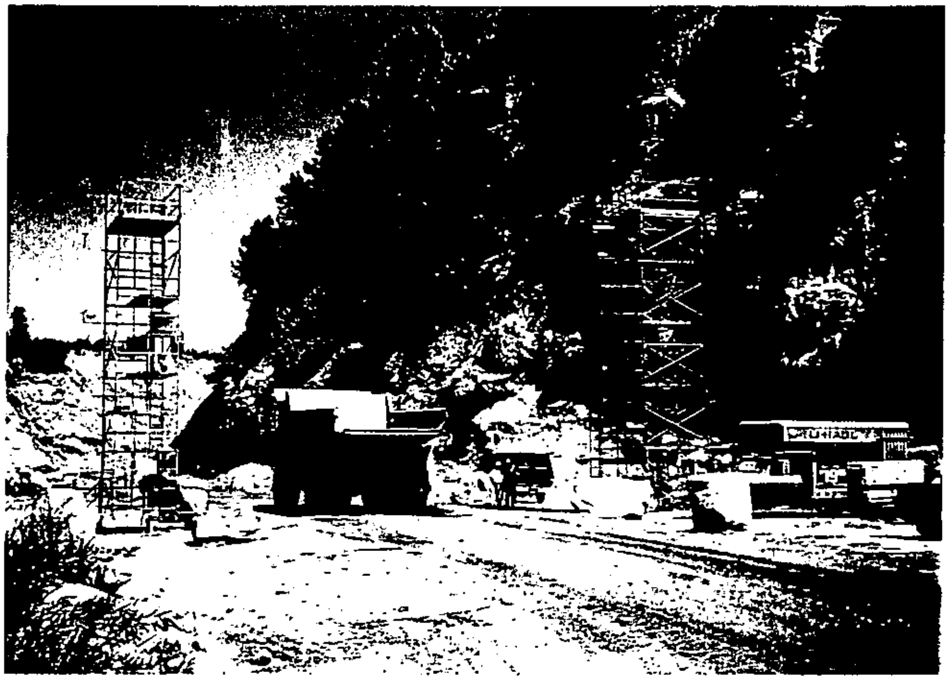
The primary objective of these tests was to accurately measure $PM_{10}$, $PM_{2.5}$, and $PM_1$ emissions from a controlled haul road (standard wet suppression) at a stone quarry. The specific objectives included the following:

- Capture the emissions entrained by the haul trucks for a thirty foot high section of haul road without significantly affecting the emissions rate.
- Determine the $PM_{10}$ emissions concentrations using EPA Federal Reference Method 201A.
- Determine the $PM_{2.5}$, and $PM_1$ emission concentrations using cascade impactors and an MIE nephelometer.
- Calculate the haul road emission rates using the measured gas flow rates across the haul road.
- Measure the road surface moisture content, stone size distribution, truck speeds, process rates, ambient temperatures, barometric pressures, relative humidities, wind speeds, and wind directions.

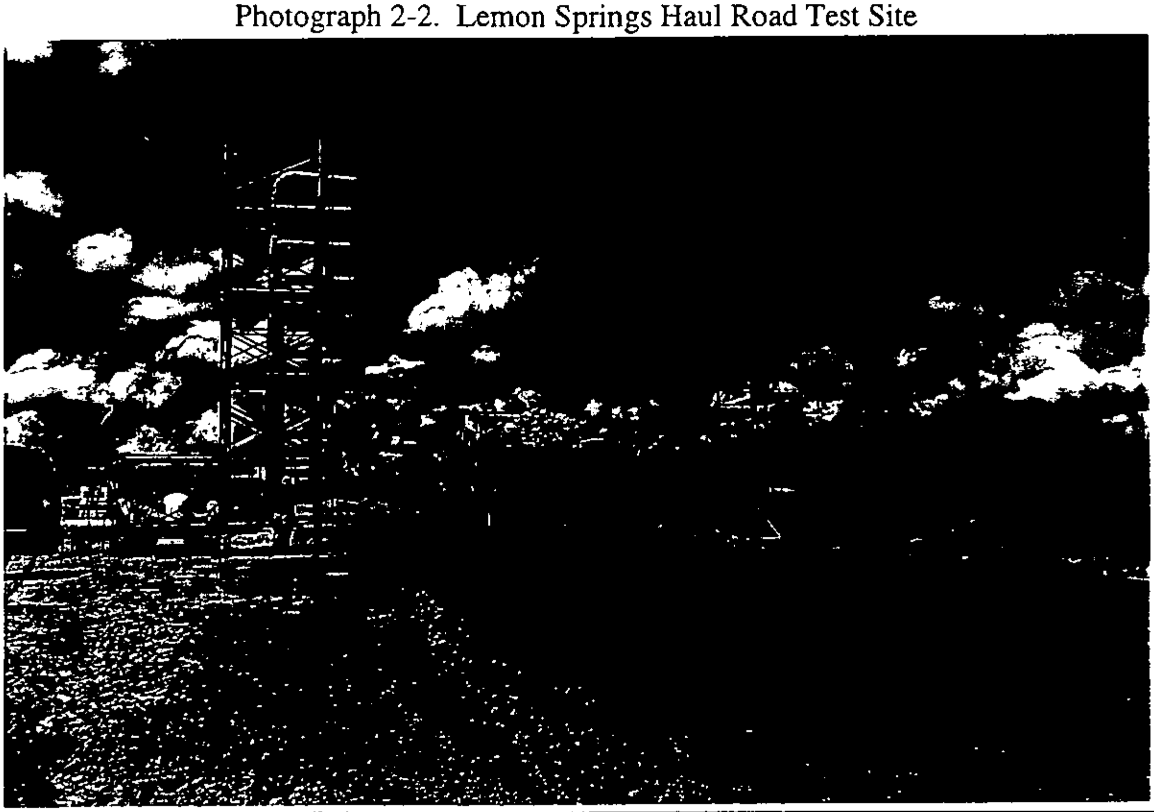
## 2.2 PROCESS DESCRIPTION AND OPERATION

The Martin Marietta Garner and Lemon Springs Plants produce crushed granite used for construction and road paving. Rock blasted from various locations in the quarry is trucked to a primary jaw type crusher located near the quarry pit. The haul road from the pit to the primary crusher was measured to be 1.25 miles at Garner and 1.03 miles at Lemon Springs (round trip). The tests were located in areas where there was enough open space to set up the sampling system and to stay away from cliffs on either side of the road, however the Garner test location was close to cliffs on either side of the haul road. The test locations may not have been ideal for characterizing the entire haul road, however they were the only locations that were consistent with the space and safety requirements. Once the trucks passed by the sampling system, they dumped their load of stone into the primary crusher and returned past the sampling structure on their way back to the pit. Photographs 2-1 (Garner) and 2-2 (Lemon Springs) show the portions of the haul roads tested at each plant.

Photograph 2-1. Garner Haul Road Test Site



Photograph 2-2. Lemon Springs Haul Road Test Site



## *2.3 WET SUPPRESSION FUGITIVE DUST CONTROL*

Wet suppression is used for fugitive dust control of the haul roads. The plants use a 7,000 gallon water spray truck that traverses the haul roads on an as needed basis under normal conditions. The water truck was observed to make passes approximately every 2.5 to 3 hours. Constant utilization of the water spray truck is not necessary to maintain controlled (wet suppression in use) conditions. A pass by the water spray truck can sufficiently control dust emissions due to moisture soaking into the material of the haul road for a period of several hours. Once the surface of the road is wet, there are little or no visible emissions. The amount of wet suppression required by the spray truck is dependent on present ambient conditions and the composition of the road material. Over wetting the road can cause muddy conditions and waste water.

## *2.4 SAMPLING AND EMISSION TESTING PROCEDURES*

NSA and EPA have sponsored a number of studies concerning $PM_{10}$ emissions from stone crushing plants. In October 1994, a haul road was tested at the Wake Stone Corporation Quarry in Knightdale, North Carolina. The two additional haul road emission factor tests were conducted in August 1995 to supplement the AP-42 data base. The haul roads tested were at the Garner and Lemon Springs, North Carolina Quarries operated by Martin Marietta Aggregates. The test sites were selected by representatives of NSA, EPA, and Air Control Techniques, P.C.

The primary objective of these tests was to accurately measure $PM_{10}$, $PM_{2.5}$, and $PM_1$ emissions from haul roads using wet suppression dust control techniques. This is the first test program in the NSA-EPA test series to include $PM_{2.5}$ and $PM_1$ emissions. These were added due to possible changes in the National Ambient Air Quality Standards for particulate matter.

An upwind-downwind profiling method was selected. This test procedure is conceptually similar to other haul road tests previously included in AP-42. The specific techniques for conducting the tests were designed by Air Control Techniques and modified based on detailed negotiations with EPA. Photographs 2-3 through 2-6 show the upwind and downwind test structures at Garner and Lemon Springs respectively.

The particulate-containing air downwind from the haul road was captured in a set of 10 sampling nozzles arranged vertically as shown in Figure 2-1. The first nozzle was 1.5 feet above the ground, and the top nozzle was 30 feet above the ground. The nozzles were spaced approximately 38 inches apart (center-to-center). Each of the nozzles had a flow control damper so that the capture velocity in each nozzle could be adjusted to match the variation in wind speed over the 30 feet distance above the haul road. The sampling assembly was designed in a balanced draft manner with a slight bias for higher flows in the top four nozzles. This was necessary to match the expected wind speed profile. Dampers were used for fine adjustment of the air flows.

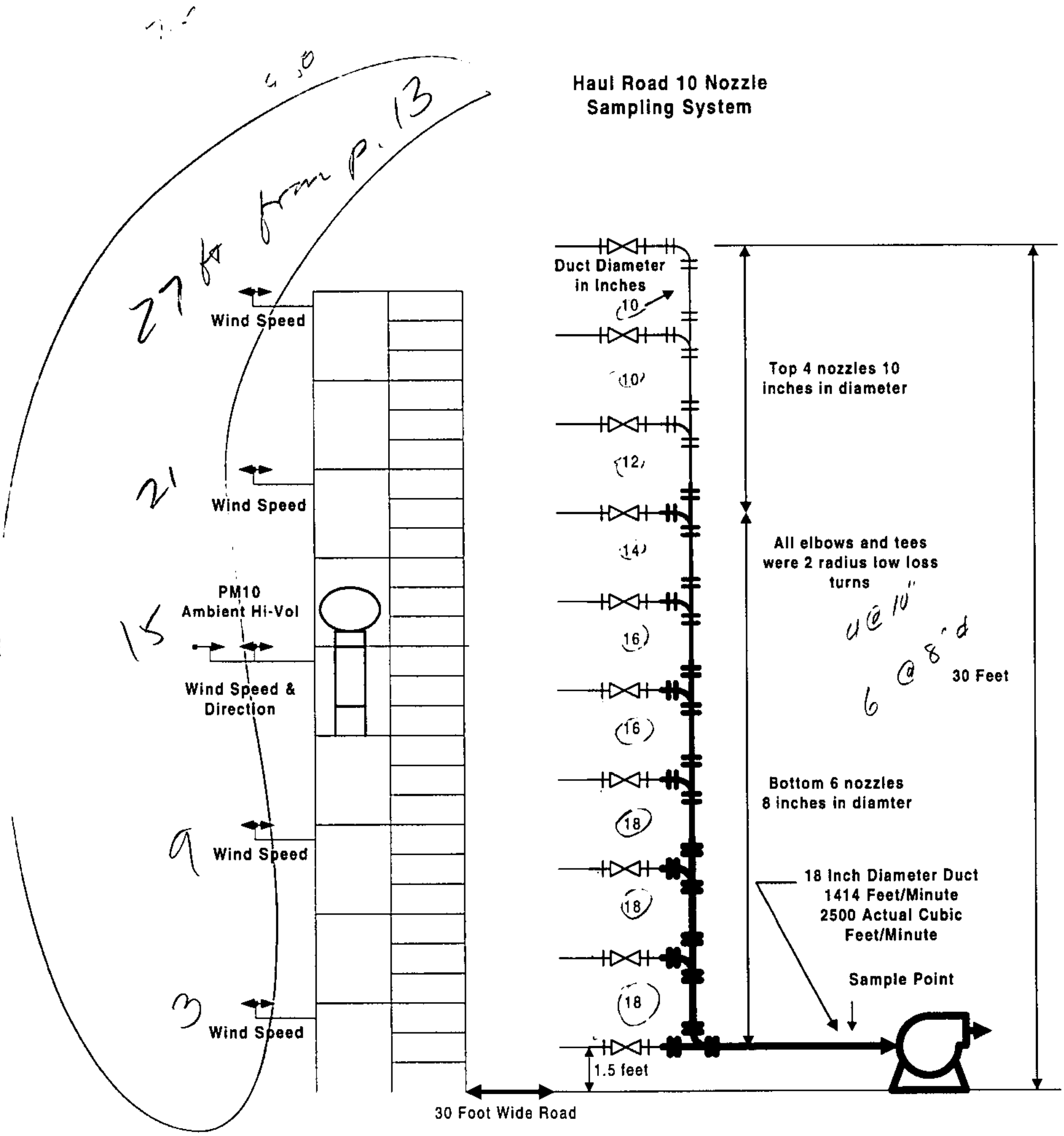


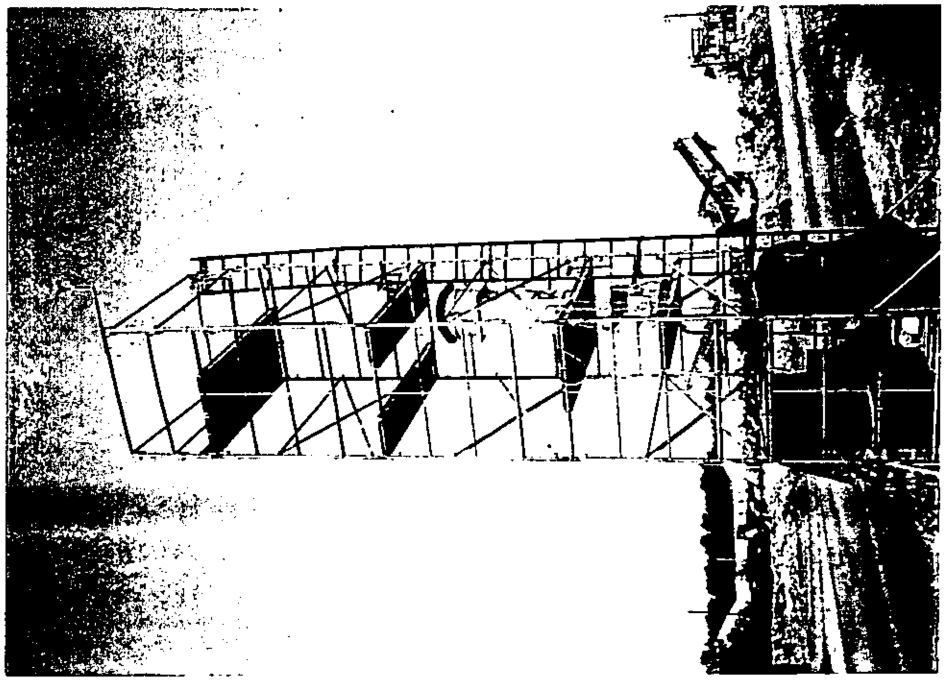

Figure 2-1. Downwind Sampling Assembly

Photograph 2-3. Garner Upwind Sampling Structure

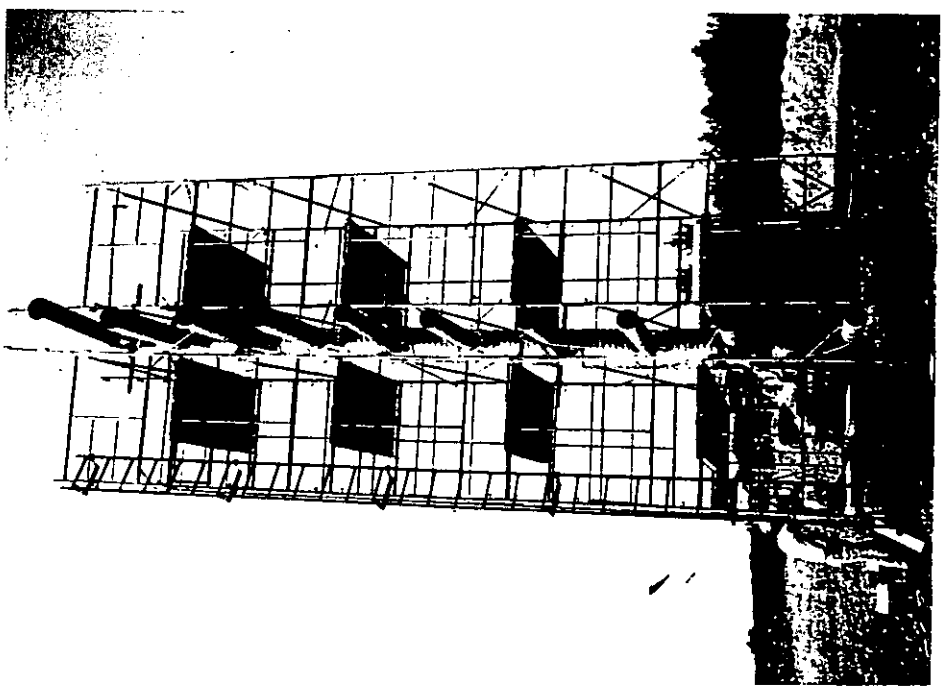
Photograph 2-4. Garner Downwind Sampling Structure


how close is bench wall ?

Photograph 2-5. Lemon Springs Upwind Sampling Structure



Photograph 2-6. Lemon Springs Downwind Sampling Structure



The centrifugal fan used to control gas flow through the hood system was sized for an average capture velocity of 440 feet per minute (5 mph). The velocities in the nozzles and adjoining ductwork were maintained below 1,000 feet per minute to minimize wall losses due to particle impaction. A total gas flow rate of approximately 2,500 ACFM was maintained through the hood system.

The vertical sampling assembly on the downwind side was supported by a 30 foot high scaffold erected approximately 10 feet downwind from the haul road. There was also a scaffold tower on the upwind side for the five meteorological stations, an ambient Hi-Vol monitor, and the cascade impactor sampling equipment.

### *2.4.1 Sampling Methods and Equipment*

Reference Method 201A was used to monitor the $PM_{10}$ emissions from the haul road. In this method, particulate matter greater than 10 microns in diameter is collected in a cyclone. Particulate matter deposited in the probe downstream of the cyclone and on the filter is defined as $PM_{10}$ emissions. This procedure was used in all of the previous emission factor tests conducted as part of the NSA-EPA emission factor test program.

Method 201A sampling was performed in the 18 inch diameter horizontal section upstream of the fan. The Method 201A sampling ports were 8 diameters downstream and 2 diameters upstream from the nearest disturbance. There were two sampling ports spaced 90° apart. Method 201A sampling procedures were used. The filters used in the M201A sampling head were composed of mixed cellulose acetate so that polarizing light microscopy (PLM) could be used to evaluate the presence of combustion products and organic debris. Following standard gravimetric analysis for particulate matter, the filters were analyzed using PLM.

What does this mean?

Cascade impactors were used to monitor the particle size distribution at the upwind and downwind sample locations. This data was used to determine the mass concentration of particles in the $PM_{10}$, $PM_{2.5}$, and $PM_1$ size ranges. Single point cascade impactor measurements were made at the point of average velocity. As a result, no flow changes were made in the impactor that might have caused particle re-entrainment and difficult-to-interpret results.

An Mie, Inc. nephelometer was used to supplement data in the $PM_{10}$, $PM_{2.5}$, and $PM_1$ size ranges. This instrument provided a real-time indication of particulate matter concentrations. Ports were provided in the main duct and all of the nozzles in the sampling assembly. Nephelometer measurements were also made at the five levels on the upwind sampling structure. These measurements were used as a double check for the ambient $PM_{10}$ Hi-Vol measurements.

The nephelometer data was used to verify the ambient $PM_{10}$, $PM_{2.5}$, and $PM_1$ concentrations measured by the cascade impactors and ambient Hi-Vol monitor. The nephelometer data also qualitatively determined the emission rate and particle size distribution differences at different levels above the haul road.

## *2.5 MONITORING OF HAUL ROAD CONDITIONS*

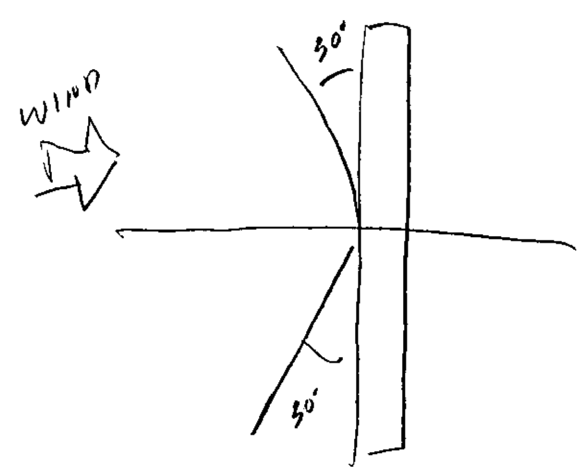
There are a number of variables that could have influenced the particulate emission rates from the haul roads.

- Road surface moisture level
- Road silt content
- Road particulate size distribution
- Number of truck passes along the haul road
- Wind speed
- Wind direction
- Truck speed

Four of these variables were used as criteria in determining if a test should be started (or continued). Table 2-1 outlines the required test conditions variables that were used as test-no test criteria.

TABLE 2-1. TEST, NO-TEST CRITERIA

| Variable | Required Conditions |
|---|---|
| Frequency of truck passage | Minimum 10 trips / hour |
| Road moisture content | >0.5% and $\leq$ 10% |
| Wind speed | $\geqq$ 1 mph sustained winds and$\leq$ 15 mph gusts |
| Wind direction | Predominantly toward the sampling structure (120 degree sector) |



# 3. RESULTS

## 3.1 ROAD SURFACE STONE MOISTURE LEVELS AND SILT CONTENTS

The road surface moisture levels and silt contents for the haul road emission tests are summarized in Table 3-1. The detailed moisture and silt data for each of the test runs at Garner and Lemon Springs are presented in Tables 3-2 and 3.3. All of the road surface moisture levels were within the criteria established at the beginning of the test program.

The road material was gathered from the haul road at various representative locations several times during the test to determine how the percent moisture changed during the test. The procedures outlined in Appendices C.1 and C.2 of the Fifth Edition of AP-42 were followed. The sample was weighed, dried overnight in an oven at 230°F, and reweighed. The weight loss during the drying cycle was used to calculate the moisture content. The road surface contains a high percentage of finely crushed stone and silt, which has a large surface area and, therefore, a greater ability to absorb moisture than larger stone. During the tests, the color of the road surface was used to qualitatively evaluate moisture levels. Short term changes in stone moisture were indicated by shifts between brown to gray. These variations occurred in all of the tests.

TABLE 3-1. SUMMARY OF MOISTURE & SILT CONTENT DATA

| Plant | Average Moisture Content | Average Silt Content |
|---|---|---|
| Garner | 6.42 | 7.39 |
| Lemon Springs | 4.90 | 7.35 |
| Average | 5.66 | 7.37 |

TABLE 3-2. GARNER PARTICLE SIZE DISTRIBUTION

| Run Number | G-HRS-3 | G-HRS-4 | G-HRS-5 | G-HRS-6 | G-HRS-7 | G-HRS-8 |
|---|---|---|---|---|---|---|
| Date of Test | 8/15/95 | 8/15/95 | 8/16/95 | 8/16/95 | 8/17/95 | 8/17/95 |
| Corresponding M201A Test Time | 0745-1459 | 0745-1459 | 0730-1414 | 0730-1414 | 0710-1314 | 0710-1314 |
| Time Sample Taken | 07:51 | 13:34 | 07:37 | 13:25 | 09:10 | 12:10 |
| % > 0.75 inches | 35.85 | 10.58 | 8.70 | 41.45 | 3.65 | 24.21 |
| % > 0.375 inches | 17.86 | 16.28 | 21.87 | 17.63 | 9.66 | 24.91 |
| % > 0.187 inches | 9.41 | 11.54 | 15.85 | 6.32 | 10.66 | 8.15 |
| % > 0.0937 inches | 4.26 | 6.67 | 8.27 | 4.19 | 7.46 | 3.62 |
| % > 0.0029 inches (200 Mesh) | 25.19 | 47.91 | 38.41 | 23.89 | 61.35 | 32.15 |
| Pan % < 200 Mesh ( % Silt Content)[1] | 7.43 | 7.01 | 6.90 | 6.56 | 7.22 | 9.23 |
| % Moisture[2] | 5.67 | 6.24 | 2.07 | 5.23 | 11.73 | 7.63 |

[1] Average silt content for all six samples was 7.39.
[2] Average moisture content for all six samples was 6.43 percent.

TABLE 3-3. LEMON SPRINGS PARTICLE SIZE DISTRIBUTION

| Run Number | S-HRS-1 | S-HRS-2 | S-HRS-3 | S-HRS-4 |
|---|---|---|---|---|
| Date of Test | 8/24/95 | 8/25/95 | 8/26/95 | 8/29/95 |
| Corresponding M201A Test Time | 1250-1653 | 0810-1540 | 0650-0728[3] | 0650-1426 |
| Time Sample Taken | 15:42 | 10:43 | 07:11 | 10:58 |
| % > 0.75 inches | 0.00 | 7.88 | 6.93 | 9.13 |
| % > 0.375 inches | 20.34 | 17.05 | 14:39 | 31.21 |
| % > 0.187 inches | 29.06 | 20.16 | 29.97 | 31.23 |
| % > 0.0937 inches | 17.85 | 12.55 | 15.59 | 7.16 |
| % > 0.0029 inches (200 Mesh) | 26.10 | 32.55 | 25.59 | 15.83 |
| Pan % < 200 Mesh ( % Silt Content)[1] | 6.65 | 9.81 | 7.52 | 5.43 |
| % Moisture[2] | 3.97 | 6.44 | 4.09 | 5.09 |

[1] Average silt content for all six samples was 7.35.
[2] Average moisture content for all six samples 4.90 percent.
[3] Run stopped due to rain, restarted 8/29/95.

Road surface moisture levels were controlled by plant personnel operating the water spray truck. Photograph 3-1 shows the water spray truck in use. Tables 3-3 and 3-4 outline the water truck utilization times.

Photograph 3-1. Water Spray Truck

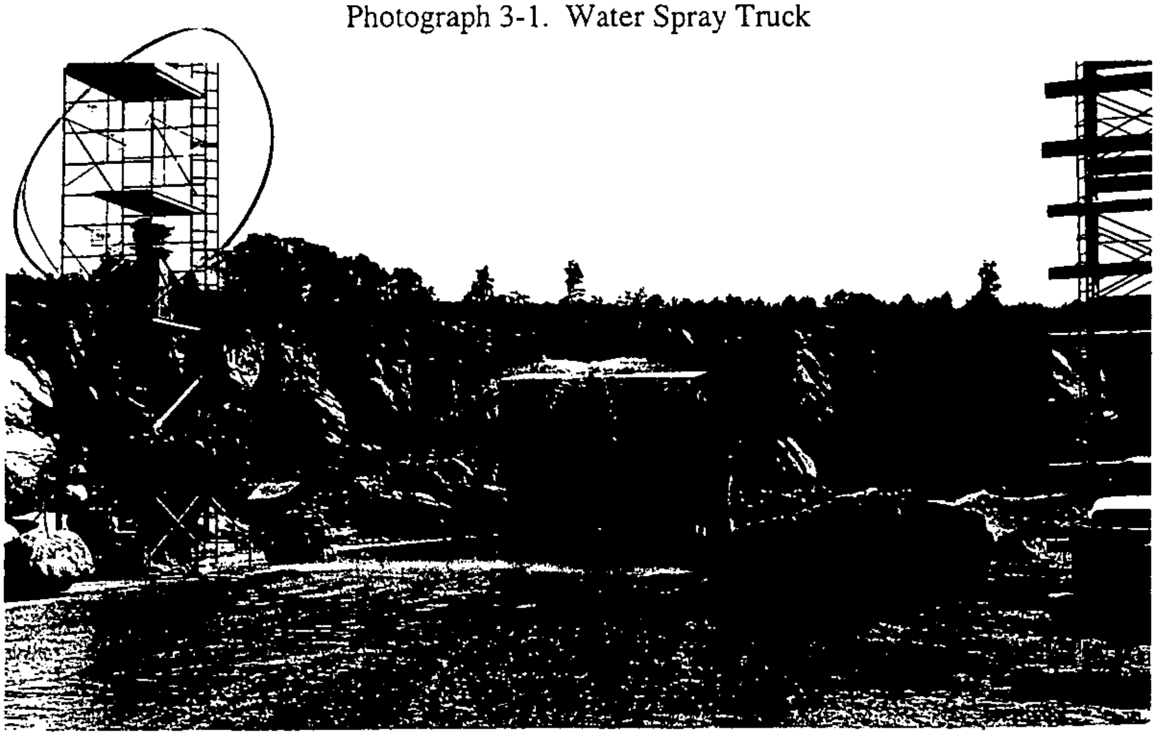


TABLE 3-4. GARNER, WATER SPRAY, SPRAY TIMES

| Date | Test Time Start/Stop | Time Water Spray Truck Passed | Ambient Temperature, °F | Average Wind Speed, MPH |
|---|---|---|---|---|
| 8/15/95 | 0745 - 1459 | 1049 | 87 | 7.2 |
| 8/15/95 | 0745 - 1459 | 1319 | 96 | 3.6 |
| 8/16/95 | 0730 - 1414 | 0808 | 74 | 4.2 |
| 8/16/95 | 0730 - 1414 | 1017 | 81 | 6.2 |
| 8/16/95 | 0730 - 1414 | 1236 | 102 | 8.0 |
| 8/17/95 | 0710 - 1314 | 1059 | 87 | 9.0 |
| 8/17/95 | 0710 - 1314 | 1312 | 97 | 8.4 |

TABLE 3-5. LEMON SPRINGS WATER SPRAY, SPRAY TIMES

| Date | Test Time Start/Stop | Time Water Spray Truck Passed | Ambient Temperature, °F | Average Wind Speed, MPH |
|---|---|---|---|---|
| 8/24/95 | 1250 - 1653 | 1438 | 91 | 9.0 |
| 8/25/95 | 0810 - 1540 | 852 | 88 | 0.6 |
| 8/25/95 | 0810 - 1540 | 1056 | 90 | 5.0 |
| 8/25/95 | 0810 - 1540 | 1335 | 95 | 5.8 |
| 8/25/95 | 0810 - 1540 | 1440 | 99 | 1.8 |
| 8/26/95 | 0650 - 0728 | N/A[1] | 72 | 7.4 |
| 8/29/95 | 0826 - 1426 | 1231 | 81 | 5.4 |

[1] Test stopped due to rain, testing ~~restarted~~ 8/29/95

### *3.2 WIND SPEED AND DIRECTION*

The wind speed was monitored at five elevations (3, 9, 15, 21, and 27 feet) ~~on~~ the upwind side of the haul road. Wind direction was monitored only at the 15 foot elevation. ~~The wind speed~~ and direction were measured to verify the capture of $PM_{10}$ in the sampling system. Table 3-6 summarizes the average wind speeds recorded during the six tests

what type of winds?

TABLE 3-6. WIND SPEED AVERAGES

| Test Site | Wind Speed Average, mph |
|---|---|
| Garner | 5.74 |
| Lemon Springs | 5.07 |
| Average | 5.41 |

P14 missing

refer to photo 3-1; upper 2 monitors don't appear to match well w/ DW side

TABLE 3-9. GARNER TRUCK SPEEDS

| Truck Make | Seconds to travel 100 Feet | Speed in mph | Direction of Travel |
|---|---|---|---|
| # 1 Caterpillar R-35 | 3.54 | 19.26 | Loaded Up Hill |
| # 1 Caterpillar R-35 | 3.66 | 18.62 | Unloaded Down Hill |
| Terex R-35 | 2.89 | 23.59 | Loaded Up Hill |
| # 3 Caterpillar R-35 | 3.64 | 18.73 | Loaded Up Hill |
| Terex R-35 | 4.58 | 14.89 | Unloaded Down Hill |
| # 2 Caterpillar R-35 | 3.93 | 17.35 | Loaded Up Hill |
| # 2 Caterpillar R-35 | 3.94 | 17.31 | Unloaded Down Hill |
| # 1 Caterpillar R-35 | 3.48 | 19.59 | Loaded Up Hill |
| # 1 Caterpillar R-35 | 4.11 | 16.59 | Unloaded Down Hill |
| # 3 Caterpillar R-35 | 4.53 | 15.05 | Unloaded Down Hill |
| Terex R-35 | 2.98 | 22.88 | Loaded Up Hill |
| # 2 Caterpillar R-35 | 3.35 | 20.35 | Loaded Up Hill |
| Terex R-35 | 4.03 | 16.92 | Unloaded Down Hill |
| # 1 Caterpillar R-35 | 3.42 | 19.94 | Loaded Up Hill |
| # 2 Caterpillar R-35 | 4.15 | 16.43 | Loaded Up Hill |
| # 1 Caterpillar R-35 | 3.47 | 19.64 | Unloaded Down Hill |
| # 2 Caterpillar R-35 | 4.02 | 16.96 | Unloaded Down Hill |
| # 3 Caterpillar R-35 | 4.13 | 16.51 | Unloaded Down Hill |
| Terex R-35 | 3.12 | 21.85 | Loaded Up Hill |
| Terex R-35 | 3.63 | 18.78 | Unloaded Down Hill |
| Average speed of all trucks | | 18.55 | |

769?

TABLE 3-11. LEMON SPRINGS RECORDED TRUCK SPEEDS

| Truck Make | Seconds to travel 100 Feet | Speed in mph | Direction of Travel |
|---|---|---|---|
| # 1 Euclid R-35 | 5.00 | 13.63 | Loaded Up Hill |
| # 1 Euclid R-35 | 3.15 | 21.65 | Unloaded Down Hill |
| # 2 Euclid R-35 | 5.66 | 12.05 | Loaded Up Hill |
| Caterpillar R-35 | 5.10 | 13.37 | Loaded Up Hill |
| # 2 Euclid R-35 | 3.47 | 19.65 | Unloaded Down Hill |
| # 1 Euclid R-35 | 5.04 | 13.53 | Loaded Up Hill |
| Caterpillar R-35 | 3.74 | 18.23 | Unloaded Down Hill |
| # 1 Euclid R-35 | 3.10 | 21.99 | Unloaded Down Hill |
| # 2 Euclid R-35 | 5.44 | 12.53 | Loaded Up Hill |
| Caterpillar R-35 | 5.47 | 12.46 | Loaded Up Hill |
| # 2 Euclid R-35 | 3.44 | 19.82 | Unloaded Down Hill |
| Caterpillar R-35 | 3.49 | 19.54 | Unloaded Down Hill |
| # 1 Euclid R-35 | 5.04 | 13.53 | Loaded Up Hill |
| # 1 Euclid R-35 | 3.30 | 20.66 | Unloaded Down Hill |
| # 2 Euclid R-35 | 5.50 | 12.40 | Loaded Up Hill |
| Caterpillar R-35 | 4.81 | 14.18 | Loaded Up Hill |
| # 2 Euclid R-35 | 3.64 | 18.73 | Unloaded Down Hill |
| Caterpillar R-35 | 3.17 | 21.51 | Unloaded Down Hill |
| # 1 Euclid R-35 | 4.76 | 14.32 | Loaded Up Hill |
| # 1 Euclid R-35 | 2.89 | 23.59 | Unloaded Down Hill |
| Average speed of all trucks | | 16.87 | |

### 3.5 $PM_{10}$, $PM_{2.5}$, AND $PM_1$ EMISSION FACTORS

#### 3.5.1 $PM_{10}$ Emission Factors

The haul road $PM_{10}$ emission factors were calculated by subtracting the measured upwind ambient $PM_{10}$ Hi-vol sampler concentrations from the measured downwind Method 201A sampling system concentrations(grains/DSCF). Prior to subtracting these two numbers, the downwind concentration was corrected for combustion particles resulting from diesel exhaust. This concentration was then multiplied by the temperature corrected total air flux crossing the road,(cubic feet per minute) in order to find the emissions from the haul road. This was multiplied by the length of the test in order to determine the total amount of particulate from the haul road. The total amount of particulate emitted was then divided by the total vehicle miles traveled on the haul road to yield pounds of $PM_{10}$ per vehicle mile traveled. Equation 3-1 shows the calculation for the second run at the Garner plant. Tables 3-12 and 3-13 present the Garner and Lemon Springs $PM_{10}$ emissions data. It should be noted that the three test runs at Garner were labeled as M201A-2,3, and 4. The first run, labeled as M201A-1 was aborted due to a sampling problem.

An Mie, Inc. nephelometer was used to supplement data in the $PM_{10}$, $PM_{2.5}$, and $PM_1$ size ranges. This instrument provided a real-time indication of particulate matter concentrations. Ports were provided in the main duct and all of the nozzles in the sampling assembly. Nephelometer measurements were also made at the five levels on the upwind sampling structure. These measurements were used as a double check for the ambient $PM_{10}$ Hi-Vol measurements. The nephelometer data was used to verify the ambient $PM_{10}$, $PM_{2.5}$ and $PM_1$ concentrations measured by the cascade impactors and ambient Hi-Vol monitor. The nephelometer data also qualitatively determined the emission rate and particle size distribution differences at different levels above the haul road.

Do they check for mineral/organic content in UW samples?

% or fraction?

Equation 3.1 Haul Road Emission Factor Calculation
Run Number G-UW-M201A-3 8/15/95

180 μg/m³

w/o 0.3 → 53 μg/m³ net

127

((0.0000785 gr/DSCF *downwind conc.* * 0.30 *percent mineral & organic particulate*) - 0.000023 gr/DSCF upwind conc.)
= ~~0.00000055 gr/DSCF~~ → gives net conc = 1.2 μg/m³

(3300 feet *length of haul road* * 28.5 feet *sampling tower height* *(410.08 feet / minute *wind speed* * cosine 41.28° *wind angle*))
= 28,983,656 cubic feet/minute

pretty marginal

1.1

[0.00000055 gr/DSCF * (28,983,656 cubic feet per minute * ((460 + 68)/(460 + 88))) * 355.75 minutes *test time*]
= (5464.04 gr / test) / (7000 grains / pound)
= 0.78057 lbs / test

θ

(204 vehicle passes * 3300 feet ~~travel~~ / vehicle pass) / 5280 feet / mile
= ~~127.5 vehicle miles traveled~~

how do they do this

0.78057 lbs / test / 127.5 vehicle miles traveled

= 0.00612 pounds of ~~PM~~$_{10}$ / vehicle mile ~~traveled~~

UW do we

is this w/ organic correction?

TABLE 3-12. GARNER HAUL ROAD $PM_{10}$ EMISSIONS

| Test Data | Run Numbers | | |
|---|---|---|---|
| | G-U-AMB-2 G-DW-M201A-2 | G-U-AMB-3 G-DW-M201A-3 | G-U-AMB-4 G-DW-M201A-4 |
| Method 201A Data | | | |
| Upwind Concentration Grains/DSCF | 0.000023 | 0.000021 | 0.000026 |
| Downwind Concentration Grains/DSCF | 0.000024 | 0.000122 | 0.000062 |
| Average Wind Speed Feet/Minute | 410.080 | 546.480 | 558.800 |
| Average Wind Angle | 41.3° | 18.2° | 2.1° |
| Test Time Minutes | 356 | 360 | 360 |
| Vehicle Miles Traveled VMT per Test | 127.50 | 153.13 | 125.00 |
| Pounds of $PM_{10}$ / VMT | 0.0061 | 1.60 | 0.76 |
| Nephelometer Data $PM_{10}$ | | | |
| Upwind Concentration Grains/DSCF | 0.000031 | 0.000017 | 0.000022 |
| Average of Peak and Stable Readings Downwind Concentration Grains/DSCF | 0.000071 | 0.000042 | 0.000046 |

why such a big variation in (1 test to next)?

TABLE 3-13. LEMON SPRINGS HAUL ROAD $PM_{10}$ EMISSIONS

| Test Data | Run Numbers | | |
|---|---|---|---|
| | S-U-AMB-1 S-DW-M201A-1 | S-U-AMB-2 S-DW-M201A-2 | S-U-AMB-3 S-DW-M201A-3 |
| Method 201A Data | | | |
| Upwind Concentration Grains/DSCF | 0.000006 | 0.000009 | 0.000013 |
| Downwind Concentration Grains/DSCF | 0.000304 | 0.000298 | 0.000116 |
| Average Wind Speed Feet/Minute | 439.120 | 324.720 | 574.640 |
| Average Wind Angle | 0.0° | 40.4° | 10.0° |
| Test Time Minutes | 240 | 300 | 360 |
| Vehicle Miles Traveled VMT per Test | 65.92 | 128.75 | 86.52 |
| Pounds of $PM_{10}$ / VMT | 2.99 | 0.49 | 1.74 |
| Nephelometer Data $PM_{10}$ | | | |
| Upwind Concentration Grains/DSCF | 0.000009 | 0.000007 | 0.000023 |
| Average of Peak and Stable Readings Downwind Concentration Grains/DSCF | 0.000023 | 0.000031 | 0.000031 |

### 3.5.2 $PM_{2.5}$ and $PM_1$ Emission Factors

The haul road $PM_{2.5}$ and $PM_1$ emission factors were calculated by subtracting the measured upwind ambient $PM_{2.5}$ and $PM_1$ cascade impactor concentrations from the measured downwind cascade impactor sampling system concentrations (grains/DSCF). After subtracting these two numbers, the result was corrected for combustion particles (see section 3.8) for each size range. This data was supplied by polarizing light microscopy analysis. Tables 3-14 through 3-17 present the $PM_{2.5}$ and $PM_1$ emissions from the cascade impactor as well as the nephelometer data.

TABLE 3-14. GARNER HAUL ROAD $PM_{2.5}$ EMISSIONS

| Test Data | Run Numbers | | |
|---|---|---|---|
| | G-UW-PS-2<br>G-DW-PS-2 | G-UW-PS-3<br>G-DW-PS-3 | G-UW-PS-4<br>G-DW-PS-4 |
| Cascade Impactor Data | | | |
| Upwind Concentration Grains/DSCF | 0.000183 | 0.000145 | 0.000045 |
| Downwind Concentration Grains/DSCF | 0.000210 | 0.000073 | 0.000256 |
| Average Wind Speed Feet/Minute | 410.080 | 546.480 | 558.800 |
| Average Wind Angle | 41.3° | 18.2° | 2.1° |
| Test Time Minutes | 356 | 360 | 360 |
| Vehicle Miles Traveled VMT per Test | 127.50 | 153.13 | 125.00 |
| Pounds of $PM_{2.5}$/ VMT | 0.02695 | -0.62555 | 0.44060 |
| Nephelometer Data $PM_{2.5}$ | | | |
| Upwind Concentration Grains/DSCF | 0.000024 | 0.000014 | 0.000020 |
| Average of Peak and Stable Readings Downwind Concentration Grains/DSCF | 0.000075 | 0.000020 | 0.000062 |

this is at higher than the PM10 # given in Table 3-12

TABLE 3-15. LEMON SPRINGS HAUL ROAD $PM_{2.5}$ EMISSIONS

| Test Data | Run Numbers | | |
|---|---|---|---|
| | S-UW-PS-1<br>S-DW-PS-1 | S-UW-PS-2<br>S-DW-PS-2 | S-UW-PS-3<br>S-DW-PS-3 |
| Cascade Impactor Data | | | |
| Upwind Concentration Grains/DSCF | 0.000172 | 0.000018 | 0.000055 |
| Downwind Concentration Grains/DSCF | 0.000292 | 0.000196 | 0.000167 |
| Average Wind Speed Feet/Minute | 439.120 | 324.720 | 574.640 |
| Average Wind Angle | 0.0° | 40.4° | 10.0° |
| Test Time Minutes | 240 | 300 | 360 |
| Vehicle Miles Traveled VMT per Test | 65.92 | 128.75 | 86.52 |
| Pounds of $PM_{2.5}$/ VMT | 0.24424 | 0.13654 | 1.32157 |
| Nephelometer Data $PM_{2.5}$ | | | |
| Upwind Concentration Grains/DSCF | 0.000007 | 0.000006 | 0.000019 |
| Average of Peak and Stable Readings Downwind Concentration Grains/DSCF | 0.000020 | 0.000022 | 0.000078 |

TABLE 3-16. GARNER HAUL ROAD $PM_1$ EMISSIONS

| Test Data | Run Numbers | | |
|---|---|---|---|
| | G-UW-PS-1<br>G-DW-PS-1 | G-UW-PS-2<br>G-DW-PS-2 | G-UW-PS-3<br>G-DW-PS-3 |
| Cascade Impactor Data | | | |
| Upwind Concentration Grains/DSCF | 0.000073 | 0.000095 | 0.000038 |
| Downwind Concentration Grains/DSCF | 0.000167 | -0.000007 | 0.000146 |
| Average Wind Speed Feet/Minute | 410.080 | 546.480 | 558.800 |
| Average Wind Angle | 41.3° | 18.2° | 2.1° |
| Test Time Minutes | 356 | 360 | 360 |
| Vehicle Miles Traveled VMT per Test | 127.50 | 153.13 | 125.00 |
| Pounds of $PM_1$ / VMT | 0.06263 | -0.43642 | 0.13594 |
| Nephelometer Data $PM_1$ | | | |
| Upwind Concentration Grains/DSCF | 0.000018 | 0.000010 | 0.000012 |
| Average of Peak and Stable Readings Downwind Concentration Grains/DSCF | 0.000022 | 0.000017 | 0.000059 |

this is 2X bigger than PM2.5 and 10X bigger than PM10

TABLE 3-17. LEMON SPRINGS HAUL ROAD $PM_1$ EMISSIONS

| Test Data | Run Numbers | | |
|---|---|---|---|
| | S-UW-PS-1<br>S-DW-PS-1 | S-UW-PS-2<br>S-DW-PS-2 | S-UW-PS-3<br>S-DW-PS-3 |
| Cascade Impactor Data | | | |
| Upwind Concentration Grains/DSCF | 0.000137 | 0.000035 | 0.000039 |
| Downwind Concentration Grains/DSCF | 0.000191 | 0.000107 | 0.000106 |
| Average Wind Speed Feet/Minute | 439.120 | 324.720 | 574.640 |
| Average Wind Angle | 0.0° | 40.4° | 10.0° |
| Test Time Minutes | 240 | 300 | 360 |
| Vehicle Miles Traveled VMT per Test | 65.92 | 128.75 | 86.52 |
| Pounds of $PM_1$ / VMT | 0.03623 | 0.01538 | 0.35971 |
| Nephelometer Data $PM_1$ | | | |
| Upwind Concentration Grains/DSCF | 0.000006 | 0.000004 | 0.000011 |
| Average of Peak and Stable Readings Downwind Concentration Grains/DSCF | 0.000020 | 0.000018 | 0.000018 |

If it's upwind, then that should "minimize" any capture.

### 3.6 AMBIENT $PM_{10}$ CONCENTRATIONS

The emission factors shown in Tables 3-12 through 3-17 were calculated by subtracting the upwind (ambient) particulate concentration from the downwind concentration. The upwind $PM_{10}$ levels were monitored during the haul road tests using an Andersen type ambient Hi-Vol $PM_{10}$ monitor. It was positioned on the upwind side of the haul road at the 15 foot level in order to minimize any capture of emissions from haul trucks. The ambient $PM_{10}$ monitor is conceptually similar to the Method 201A sampling train. The unit has a cyclonic precollector followed by a filter. A constant gas flow rate is maintained through the unit. The ambient $PM_{10}$ monitor was operated throughout the entire emission tests. The ambient levels of $PM_{10}$ were subtracted from the measured $PM_{10}$ emission rates from the haul road. Table 3-18 summarizes the ambient $PM_{10}$ concentrations for both plants tested.

TABLE 3-18. $PM_{10}$ HI-VOL AMBIENT $PM_{10}$ CONCENTRATIONS

| Test Site | Run Number | Time of Test, Minutes | Flow Rate, DSCFM | Catch Weight, Grams | $PM_{10}$ Concentration, Grains/DSCF |
|---|---|---|---|---|---|
| Garner | G-U-AMB-2 | 392 | 43.0 | 0.0253 | 0.000023 |
| Garner | G-U-AMB-3 | 410 | 43.0 | 0.0243 | 0.000021 |
| Garner | G-U-AMB-4 | 347 | 43.5 | 0.0256 | 0.000026 |
| Lemon Springs | S-U-AMB-1 | 242 | 43.0 | 0.0041 | 0.000006 |
| Lemon Springs | S-U-AMB-2 | 332 | 43.0 | 0.0083 | 0.000009 |
| Lemon Springs | S-U-AMB-3 | 405 | 43.0 | 0.0150 | 0.000013 |

Table 3-19 compares the ambient Hi-Vol $PM_{10}$ concentrations with the nephelometer data. The two independent sets of data agree well. The slight differences are believed to be due to the nephelometer's sensitivity to the fog and haze present during portions of the tests.

TABLE 3-19. COMPARISON OF UPWIND NEPHELOMETER DATA WITH AMBIENT $PM_{10}$ CONCENTRATIONS

| Test Site | Ambient $PM_{10}$ Nephelometer Average Concentration at 5 levels, Grains/DSCF µg/m³ | Ambient $PM_{10}$ Hi-Vol Concentration, Grains/DSCF | % Difference from Ambient Hi-Vol ($PM_{10}$ Only) |
|---|---|---|---|
| Garner | 0.000031 71 | 0.000023 53 | -34.8 [1] |
| Garner | 0.000017 39 | 0.000021 48 | 19.0 |
| Garner | 0.000022 50 | 0.000026 60 | 15.4 |
| Lemon Springs | 0.000009 20 | 0.000006 14 | -50.0 [2] |
| Lemon Spring | 0.000007 16 | 0.000009 20 | 22.2 |
| Lemon Springs | 0.000023 53 | 0.000013 30 | -76.9 [3] |

[1] Weather conditions were noted as being foggy and overcast during measurements.
[2] Weather conditions were noted as being sunny but partly cloudy during measurements.
[3] Weather conditions were noted as being hazy and overcast during measurements.

## 3.7 NEPHELOMETER RESULTS

An Mie, Inc. nephelometer was used to supplement data in the $PM_{10}$, $PM_{2.5}$, and $PM_1$ size ranges. This instrument provided a real-time indication of particulate matter concentrations. The nephelometer data also can be used as a double-check for the ambient upwind $PM_{10}$. Nephelometer data in the $PM_{10}$, $PM_{2.5}$, and $PM_1$ size ranges has been included in Tables 3-12 through 3-17. Table 3-20 summarizes steady state and peak concentrations.

TABLE 3-20. HAUL ROAD NEPHELOMETER RESULTS

| Test Date | $PM_1$ Concentration of 10 levels, Grains/DSCF | $PM_1$ Peak Concentration of 10 levels, Grains/DSCF | $PM_{2.5}$ Concentration of 10 levels, Grains/DSCF | $PM_{2.5}$ Peak Concentration of 10 levels, Grains/DSCF | $PM_{10}$ Concentration of 10 levels, Grains/DSCF | $PM_{10}$ Peak Concentration of 10 levels, Grains/DSCF |
|---|---|---|---|---|---|---|
| 8/15/95[1] | 0.000015 | 0.000029 | 0.000039 | 0.000111 | 0.000052 | 0.000090 |
| 8/16/95 | 0.000008 | 0.000026 | 0.000010 | 0.000029 | 0.000016 | 0.000067 |
| 8/17/95 | 0.000033 | 0.000084 | 0.000036 | 0.000087 | 0.000022 | 0.000071 |
| 8/24/95[2] | 0.000004 | 0.000036 | 0.000006 | 0.000034 | 0.000008 | 0.000037 |
| 8/25/95 | 0.000004 | 0.000032 | 0.000008 | 0.000035 | 0.000011 | 0.000050 |
| 8/29/95[3] | 0.000011 | 0.000025 | 0.000018 | 0.000060 | 0.000017 | 0.000044 |

Note: See Appendix for specific measurements.
[1] Weather conditions were noted as being foggy and overcast during measurements.
[2] Weather conditions were noted as being sunny but partly cloudy during measurements.
[3] Weather conditions were noted as being hazy and overcast during measurements.

## 3.8 PLM ANALYSES

The test location at the Garner quarry was located at the approximate mid-point on a long gradual grade leading to the primary crusher. Most of the trucks coming up this grade had to shift to a lower gear just prior to or at the sampling location. This caused short spikes of heavy exhaust in the sample area. The diesel exhaust emissions observed at this site were not representative of the diesel particulate emissions over the entire length of the haul road. Haul road trucks were videotaped during one of the tests to demonstrate the highly nonrepresentative nature of the diesel emissions at the location of the Garner sampling platform. Similar, but less severe, shifting related emission problems were encountered at the Lemon Springs site. Future emission factor test programs on haul roads should be conducted at multiple test locations along the haul road in order to avoid this problem.

In order to calculate the actual stone dust emissions, it was necessary to determine the diesel particulate fraction of the total particulate sample and subtract this amount prior to calculating the $PM_{10}$, $PM_{2.5}$ and $PM_1$ emission factors.

A mixed cellulose acetate filter was used ~~in the~~ Method 201A sampling trains in order to facilitate the PLM analyses. These analyses were conducted by Research Triangle Institute. The results of these analyses are shown in Tables 3-21, 3-22, and 3-23.

why not count UW sample as well?

TABLE 3-21. SIZE DISTRIBUTION OF PARTICULATE MATERIAL

| Sample ID | % of Total Particles <1μm | % of Total Particles 1μm to 2.5μm | % of Total Particles 2.5μm to 10μm | % of Total Particles >10μm |
|---|---|---|---|---|
| G-DW-M201A-2 | 60 | 30 | 7 | 3 |
| G-DW-M201A-3 | 30 | 30 | 30 | 10 |
| G-DW-M201A-4 | 60 | 20 | 15 | 5 |
| S-DW-M201A-1 | 20 | 40 | 40 | 0 |
| S-DW-M201A-2 | 35 | 45 | 15 | 5 |
| S-DW-M201A-3 | 30 | 50 | 15 | 5 |

TABLE 3-22. COMPOSITION OF PARTICULATE MATERIAL

| Sample ID | Description of Filter | Composition of Particulate Material | | | |
|---|---|---|---|---|---|
| | | % Mineral Particles | % Combustion Products | % Organic Debris | Comments |
| G-DW-M201A-2 | Charcoal gray color | 10% of total mass | 60% of tot. part. 70% of tot. mass | 20% of total mass | small particles (<1μm) dominant |
| G-DW-M201A-3 | Light olive/tan color | 30% of total mass | 15% of tot. part. 50% of tot. mass | 20% of total mass | |
| G-DW-M201A-4 | Charcoal gray color | 10% of total mass | 60% of tot. part. 70% of tot. mass | 20% of total mass | small particles (<1μm) dominant |
| S-DW-M201A-1 | Light olive/gray color | 40% of total mass | 15% of tot. part. 40% of tot. mass | 20% of total mass | |
| S-DW-M201A-2 | Charcoal gray color | 20% of total mass | 70% of tot. part. 70% of tot. mass | 10% of total mass | |
| S-DW-M201A-3 | Light olive gray to tan | 50% of total mass | 20% of tot. part. 30% of tot. mass | 20% of total mass | |

TABLE 3.23. DISTRIBUTION OF PARTICLE TYPE BY SIZE

| Sample ID | Mineral Particles as a % Size Fraction | | | |
|---|---|---|---|---|
| | <1μm | 1-2.5μm | 2.5-10μm | >10μm |
| G-DW-M201A-2 | 10 | 10 | 30 | 30 |
| G-DW-M201A-3 | 90 | 90 | 30 | 5 |
| G-DW-M201A-4 | 10 | 20 | 40 | 30 |
| S-DW-M201A-1 | 20 | 20 | 50 | 0 |
| S-DW-M201A-2 | 10 | 20 | 30 | 40 |
| S-DW-M201A-3 | 70 | 50 | 60 | 30 |
| Sample ID | Combustion Particles as a % of Size Fraction | | | |
| G-DW-M201A-2 | 90 | 90 | 60 | 20 |
| G-DW-M201A-3 | 10 | 10 | 60 | 90 |
| G-DW-M201A-4 | 90 | 80 | 50 | 50 |
| S-DW-M201A-1 | 80 | 80 | 40 | 0 |
| S-DW-M201A-2 | 90 | 80 | 70 | 40 |
| S-DW-M201A-3 | 30 | 50 | 30 | 50 |
| Sample ID | Organic Particles as a % of Size Fraction | | | |
| G-DW-M201A-2 | 0 | 0 | 10 | 50 |
| G-DW-M201A-3 | 0 | 0 | 10 | 5 |
| G-DW-M201A-4 | 0 | 0 | 10 | 20 |
| S-DW-M201A-1 | 0 | 0 | 10 | 0 |
| S-DW-M201A-2 | 0 | 0 | 0 | 20 |
| S-DW-M201A-3 | 0 | 0 | 10 | 20 |

# 4.0 QA/QC ACTIVITIES

## 4.1 QC PROCEDURES

The specific internal quality assurance and quality control procedures used during this test program are described in this section. Temperature, moisture, barometric pressure, wind speed and direction data collection. equipment are discussed in Section 4.2. Section 4.3 discusses QA audits. Section 4.4 discusses the particulate sampling procedures. Section 4.5 discusses sample volumes and the Federal Register's acceptable criteria. Equipment calibration procedures are described in Section 4.6. Data validation is discussed in Section 4.7.

## 4.2 TEMPERATURE, MOISTURE, BAROMETRIC PRESSURE, WIND SPEED & WIND DIRECTION DETERMINATION

Ambient moisture was determined by using the wet bulb-dry bulb technique. A sling psychrometer was used for deterring the ambient temperature and relative humidity. Moisture was calculated from these measurements. The sling psychrometer uses two mercury in glass thermometers. The barometric pressure was monitored using a barometer which was checked daily with the Raleigh-Durham Airport. The wind speed and direction was monitored using a MAXIMUM™ wind speed and direction instruments.

## 4.3 QA AUDITS

Meterbox calibration audits were performed according to Method 5, Section 4.4. All of the equipment pre-test and post-test results are presented in Appendix J.

## 4.4 PARTICULATE SAMPLING QC PROCEDURES

Quality control procedures for particulate sampling ensure high quality ambient air concentrations and emissions data. Ambient air concentrations are determined by dividing the mass analyte (particulate) collected by the standardized volume of gas sampled. Sampling QC procedures that ensure that a representative amount of the analytes are collected by the sampling system include the following.

- The sampling rate was within 20 percent of isokinetics for Method 201A.
- Properly prepared glassware was used for recovering samples.
- All sampling nozzles were manufactured and calibrated according to EPA standards.
- The sampling rate of the ambient high volume sampler was within 10% of 39.91 cubic feet per minute via the calibration curve in Appendix J.
- The collection shim of the high volume sampler was cleaned and regreased after each test using only DOW #316 silicone release spray as per the method.
- Filters were weighed, handled, and stored in a manner to prevent contamination.
- Recovery procedures were completed in a clean environment.

## *4.5 SAMPLE VOLUME*

All sampling runs met the results acceptability criteria as defined by Section 6.3.5 of Method 201A. The isokinetic rates were within ±20 percent. A summary of the sample rates and percent isokinetics for the Method 201A tests are presented in Table 4.1.

TABLE 4-1. AVERAGE DELTA H AND ISOKINETIC RESULTS

| Run Number | Percent Isokinetic (%) | Delta H (Avg) |
|---|---|---|
| G-DW-M201A-2 | 103.0 | 0.655 |
| G-DW-M201A-3 | 99.9 | 0.658 |
| G-DW-M201A-4 | 105.7 | 0.657 |
| S-DW-M201A-1 | 100.0 | 0.666 |
| S-DW-M201A-2 | 100.9 | 0.662 |
| S-DW-M201A-3 | 94.4 | 0.642 |

## *4.6 TEMPERATURE MEASURING DEVICE CALIBRATION*

Accurate temperature measurements are required during source sampling. Reference mercury in glass stem thermometers were used to verify all temperature readings and they were calibrated using the procedure described in Section 3.4.2 of EPA Document 600/4-77-027b.

## *4.7 DATA VALIDATION*

All data and/or calculations for flow rates and emission rates are made using a computer software and are validated by an independent check. All calculations are spot checked for accuracy and completeness. In general, all measurement data are validated based on the following criteria.

- Process conditions during sampling or testing.
- Acceptable sample collection procedures.
- Consistency with expected other results
- Adherence to prescribed QC procedures.