Emission Characterization of Foam-Based Abrasive Blasting Media

Test Report

For
Sponge-Jet, Inc.

MRI Project No. 310613.1.001

January 13, 2006

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For
Sponge-Jet, Inc.
235 Heritage Avenue
Suite 2
Portsmouth, New Hampshire 03801

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Preface

This report presents the results from a testing program conducted to compare emissions from Sponge-Jet's media and the abrasive media tested to support Section 13.2.6 of the U. S. Environmental Protection Agency's (EPA's) *Compilation of Air Pollutant Emission Factors* (commonly known as "AP-42"). Dr. Gregory E. Muleski served as MRI's project leader and authored this report.

MIDWEST RESEARCH INSTITUTE

Gregory E. Muleski
Principal Environmental Engineer

Approved:

Roger Starnes, Director
Applied Engineering Division

January 13, 2006

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Section 1.
Introduction

This report describes a program conducted by Midwest Research Institute (MRI) to characterize dust emissions from abrasive blasting operations. Testing occurred the week of September 26, 2005, at the Sponge-Jet, Inc. facility in Portsmouth, New Hampshire.

Sponge-Jet Sponge Media is a composite of conventional abrasives and a sponge-like polyurethane foam. The sponge particle size is typically in the range of 3 to 6.5 mm and contains discrete abrasive particles that range from as large as 16 grit to as fine as 500 grit. Aluminum oxide is the most common abrasive sold in Sponge Media but other abrasives such as plastic, glass bead, steel grit, etc. are also available. The most common combination of abrasive material and size sold in Sponge Media is a 30-grit aluminum oxide (known as "Silver 30").

The polyurethane sponge surrounds the point of abrasive impact, thus forming a micro containment to capture dust and airborne emissions. The sponge also increases worker safety by dramatically reducing ricochet of the abrasive particles. The dust and other particulate matter are separated from the sponge through an on-site recycling procedure. The media's benefits have been recognized through selection/specification by the U.S. Navy, NASA, OSHA, and the Air Force.

The current test program compared particulate matter (PM) emissions from Sponge-Jet's media with emissions from abrasive material evaluated in an earlier program funded by the U. S. Environmental Protection Agency (EPA). The earlier testing formed the basis for Section 13.2.6 ("Abrasive Blasting") in EPA's *Compilation of Air Pollutant Emission Factors* (commonly known as "AP-42") [1]. To the extent practical, MRI relied on the AP-42 background document [2] and the EPA test program [3] in developing the current test program to enable direct comparison with the AP-42 emission factors.

The test program relied on "exposure profiling" which has been recognized by EPA as the technique most appropriate to characterize the broad class of open anthropogenic PM sources. Because the method isolates a single emission source, the open source emission factors with the highest quality ratings in AP-42 are typically based on this approach.

The two particle size ranges of interest in this program are TP (total particulate, all airborne particles regardless of size) and PM-10 (particles no greater than 10 microns in aerodynamic diameter).

The remainder of this report is structured as follows. Section 2 presents background information and provides an overview of the test program. Section 3 presents and discusses the test results. Section 4 lists the references cited. Appendix A presents the draft test plan prepared for the program, while Appendix B contains photos taken during the testing. Appendix C illustrates the data reduction process with an example calculation and Appendix D lists the tare and final weights of filters used.

Section 2.
General Description of the Test Program

This section provides background information as well as a general description of the test program.

2.1 Background Information

Under two work assignments from EPA, MRI developed particulate emission factors for abrasive blasting in a pilot-scale wind tunnel facility. The 1993 test program employed a quasi-stack approach in which emissions were captured by a moving airstream in the wind tunnel. Testing used commercial dry sand blasting equipment to blast three types of mild steel surfaces: automobile hoods of 1980s vintage; clean (previously blast-cleaned) automobile hoods; and heavily rusted tank sides. The test abrasive was flint shot (silica) sand of 30 x 50 mesh. Table 2-1 summarizes the emission factors developed from the tests.

In addition to a comprehensive source test report [3], MRI also drafted a new AP-42 section [1] and background document [2] on abrasive blasting. The AP-42 section drew almost exclusively from the 1993 test data to develop emission factors.

2.2 Test Methodology

The earlier test report [3] described a low-speed wind tunnel used to develop the silica sand emission factors. The current testing program similarly enclosed the blasting operations for testing purposes. However, because the enclosure was sheltered from weather, it did not need to be as well constructed (e.g., marine grade plywood) as in the EPA test program. Two 20-ft portable carports formed the main part of the enclosure. Polyethylene sheeting was draped over the carports and a final section was constructed of OSB (oriented strand board). Figure 2-1 shows a schematic of the test enclosure, while Photos 1 and 2 in Appendix B present two views of the tunnel.

The tested operation removed paint from automobile hoods (as in the 1993 EPA tests). The hoods were placed on the 4-ft by 10-ft steel sheet shown in Figure 2-1 and Photo 3 to protect the concrete floor. The main blasting equipment was positioned outside the tunnel with the hoses fed under the latticework shown in the figure. The latticework (see Photo 1) served to both straighten the flow and provide resistance to achieve the target air speed of 10 mph (at the measurement position).

Table 2-1. Summary[a] of Sand Blasting PM Emission Factors from Reference [3]

Tunnel air speed (mph)	Operation	Test runs	Emission factor (kg/kg sand)		
			Total particulate	PM-10	PM-2.5[b]
5	Preliminary (blaster only[c])	5/8	0.30	–	–
10		3/4	0.049	–	–
15		1/2	0.60	–	–
		Average	**0.32**	–	–
5	Clean Surface	17/18	0.029	0.017	0.0024
10		9/10	0.068	0.0081	0.0022
15		23/24	0.092	0.0045	0.00090
		Average	**0.063**	**0.0099**	**0.0018**
5	Painted surface (auto hoods)	15/16	0.027	0.0059	0.0010
10		7/8	0.070	0.052	0.00086
15		21/22	0.091	0.0091	0.0013
		Average	**0.063**	**0.022**	**0.0011**
5	Oxidized surface	19/20	0.025	0.0057	0.0018
10		11/12	0.026	0.014	0.0011
15		25/26	0.089	0.0030	0.00026
		Average	**0.047**	**0.0074**	**0.0011**

[a] Data taken from Table 2-1 of [3]. Results reported to two significant figures.
[b] PM-2.5 represents particulate matter no greater than 2.5 microns in aerodynamic diameter.
[c] No target substrate used. Only total particulate (TP) measured.

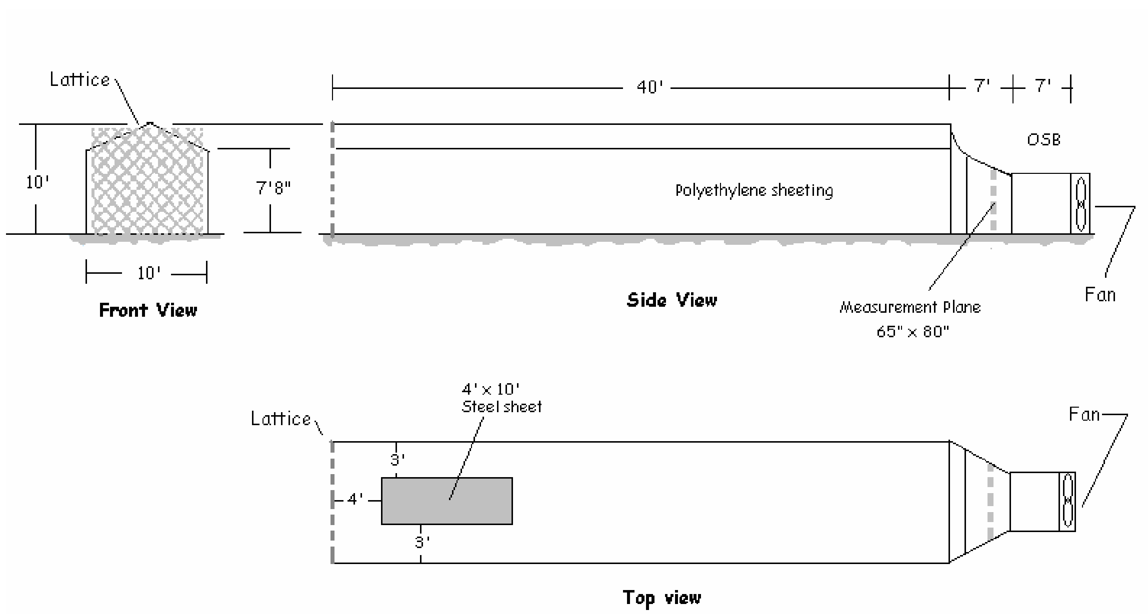

Figure 2-1. Test Enclosure Schematic

The enclosure provided for control of test conditions from one run to another; this aids in comparing results across different abrasive media. An axial "poultry-type" fan[1] drew air through the enclosure and exhausted out through an overhead doorway. Immediately upstream of the exhaust fan, MRI positioned a cyclone preseparator (described below) to sample the PM from the blasting operation.

The air sampling device was a standard high-volume air sampler fitted with a cyclone preseparator (Figure 2-2 and Photo 4). This is the same type of sampler that MRI has used for years to characterize fugitive dust emissions. When operated at a flow rate of 40 acfm, the cyclone preseparator exhibits a D_{50} cutpoint of approximately 10 µmA [4]. In this way, a PM-10 sample is collected on a tare-weighed 8-in by 10-in glass fiber filter. In addition, the cyclone body collects coarse material for comparison to the PM emission factors in AP-42 Section 13.2.6. To determine the weight of material that collects on the interior of the cyclone, the cyclone is washed with distilled water. Upon return to MRI's main laboratories, the entire wash solution was passed through a Büchner-type funnel holding a tared glass fiber filter under suction. This ensures the collection of all suspended material on the filter.

MRI positioned the cyclone inlet at the center of the measurement plane indicated in Figure 2-1. Prior to the start of testing, MRI characterized the airflow at the inlet position (with the sampler in place) with a hand-held contact anemometer.

Exposure profiling relies on a conservation of mass approach to calculate measurement-based emission rates and emission factors. For open sources, the passage of airborne particulate (i.e., the quantity of emissions per unit of source activity) is obtained by 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.

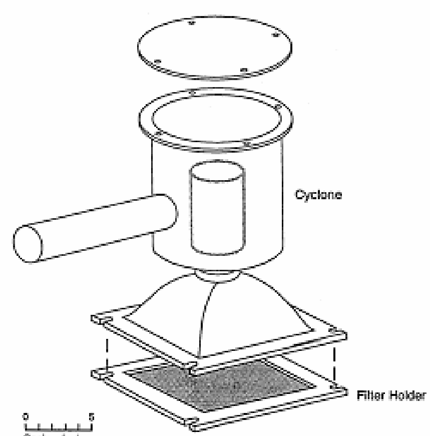

Figure 2-2. Cyclone Preseparator

[1] Grainger Item 3C610, rated at 22,000 cfm "free air."

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 (mass)
Q	=	volumetric flow rate of 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 sampler (volume/time)
a	=	sampler inlet 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 in achieving reliable test results. 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 [5].

For open sources, the net mass emissions during a test is calculated by:

$$M = (C - C_b)\ U\ A\ T \tag{3-3}$$

where:

M	=	net particulate emissions (mass)
C	=	downwind particulate concentration (mass/volume)
C_b	=	background particulate concentration (mass/volume)
U	=	airflow (length/time)
A	=	sampling area (area)
T	=	test duration (time)

At the end of the program, a "background" test was conducted to determine the PM concentration of the makeup air. Background values were subtracted from the measured concentrations.

The emissions *M* may be normalized in several ways, including:

- Substrate surface area cleaned
- Test duration

- Total time that active blasting (i.e., media flowing) occurred
- Mass of media used

The last type of normalization—namely, mass of emissions per unit mass of abrasive media used—allows direct comparison with the factors in AP-42 [1]. Additional comparisons are possible using the results reported in [3].

Appendix C presents an example calculation to illustrate the data reduction process.

Section 3.
Results and Discussion

This section first presents and then discusses results from the testing program.

3.1 Test Results

Table 3-1 lists the parameters associated with each test run. Tests are identified with a run number of the form:

M. U. Z

where M identifies the abrasive type as show below, U indicates how many times the material has been used before (i.e., “0” indicates “virgin” material), and Z is used to distinguish between different tests of the same material. The material code M is as follows

Code	Abrasive Media
1	Sponge Media (Silver 30)
2	Sponge Media (Silver 16)
3	Coal slag
4	Silica sand

Sponge-Jet recommends the addition fresh virgin material with recycled media. Test 1.9.X evaluated a mixture of 83% recycled (nine previous uses) Sponge Media mixed with 17% virgin Sponge Media. Other tests of recycled Sponge Media did not involve the addition of fresh material.

Table 3-1 does not include the blank tests (used to account for handling effects), but does include the background test (used to determine particulate levels in the makeup air to the tunnel). Blank tests involve all steps associated with any other test except that no air passes through filter. No blasting occurred during the background test.

Table 3-2 lists the test results from the runs. Appendix C presents a sample calculation to illustrate the data reduction process.

Table 3-1. Test Parameters

Run	Date	Media	Area cleaned (ft^2)	Air sampling duration[a] (min)	Total time[a] (min) with active blasting	Cleaning rate (ft^2/min)	Ambient air temp (°F)	Baro. pressure (in Hg)	Back plate pressure (in water)	Flow rate (acfm)	Intake vel. (fpm)	Raw concentration (µg/m^3)	
												TP	PM-10
1.0.1	09.26.05	Silver 30 Virgin	13.8	39.75	16.25	0.85	70	29.7	3.00	42.64	946	1560	262
1.0.2			26.2	18.00	11.50	2.28	70	29.7	3.00	42.64	946	10500	998
1.0.3			16.7	18.00	10.00	1.67	72	29.7	3.00	42.8	949	7090	664
1.0.4			18.2	24.25	8.50	2.14	72	29.7	2.95	42.53	943	7760	450
1.3.1	09.27.05	Silver 30 4th Use	11.2	9.75	3.25	3.45	70	29.7	2.90	41.95	931	28500	3110
1.3.2			11.8	10.25	5.00	2.36	70	29.7	2.90	41.95	931	25500	2370
1.3.3			11.8	6.00	5.00	2.36	70	29.7	2.90	41.95	931	23400	3060
1.9.1	09.28.05	Silver 30 10th Use	6.5	17.00	7.25	0.9	62	30.2	2.80	40.02	888	22600	2860
1.9.2			2.7	8.25	2.50	1.08	67	30.1	2.80	40.47	898	24400	1580
1.9.3			4.1	9.50	4.00	1.03	68	30.1	2.80	40.55	899	23700	2160
1.9.X		Silver 30 10th Use MIX[b]	3.1	14.75	3.50	0.89	70	30.1	2.80	40.7	903	6480	855
2.0.1		Silver 16 Virgin	8.8	25.00	16.00	0.55	71	30.1	2.80	40.78	904	1910	242
2.0.2			7.3	14.00	10.50	0.7	74	30.1	2.80	41.01	910	4350	540
3.0.1		Coal Slag	3.2	6.00	2.75	1.16	74	30.1	2.80	41.01	910	63000	5890
3.0.2			8.2	7.50	5.00	1.64	78	30.1	2.80	41.31	916	386000	59700
4.0.1		Silica Sand 50 grit	7.5	6.25	2.00	3.75	76	30.1	2.55	39.35	873	397000	84800
4.0.2			4.2	6.50	1.50	2.8	72	30.1	2.68	39.96	886	402000	76300
4.0.3			3.3	7.00	2.75	1.2	71	30.1	2.63	39.53	877	488000	111000
–	09.29.05	Background	–	69.00	–	–	66	29.9	2.78	40.49	898	304	46

[a] Times recorded to the nearest 15 s (0.25 min).
[b] The media used in this test consisted of 83% Silver 30 recycled after 9 previous uses mixed with 17% of virgin Silver 30.

Table 3-2. Test Results

Run	Date	Media	Area cleaned (ft²)	Air sampling duration[a] (min)	Net concentration (µg/m³) TP	Net concentration (µg/m³) PM-10	Air speed[b] (mph)	IFR	Emission rate[c] (g/min) TP	Emission rate[c] (g/min) PM-10	Emission factor[d] (kg/kg media) TP	Emission factor[d] (kg/kg media) PM-10
1.0.1	09.26.05	Silver 30 Virgin	13.8	39.75	1260	216	10.8	1.00	[e]	[e]	[e]	[e]
1.0.2			26.2	18.00	10200	952	10.8	1.00	9.73	0.907	0.0048	0.000447
1.0.3			16.7	18.00	6790	618	10.8	1.00	6.47	0.589	0.0037	0.000334
1.0.4			18.2	24.25	7460	404	10.8	0.99	7.11	0.385	0.0064	0.000346
1.3.1	09.27.05	Silver 30 4th Use	11.2	9.75	28200	3060	10.8	0.98	26.9	2.92	0.0254	0.00275
1.3.2			11.8	10.25	25200	2320	10.8	0.98	24	2.21	0.0155	0.00143
1.3.3			11.8	6.00	23100	3020	10.8	0.98	22.1	2.88	0.0083	0.00109
1.9.1	09.28.05	Silver 30 10th Use	6.5	17.00	22300	2820	10.8	0.93	21.2	2.68	0.0157	0.00198
1.9.2			2.7	8.25	24100	1530	10.8	0.94	23	1.46	0.0239	0.00152
1.9.3			4.1	9.50	23400	2110	10.8	0.95	22.3	2.01	0.0167	0.0015
1.9.X		Silver 30 10th Use MIX[f]	3.1	14.75	6180	809	10.8	0.95	5.89	0.771	0.0078	0.00102
2.0.1		Silver 16 Virgin	8.8	25.00	1610	196	10.8	0.95	1.53	0.187	0.0008	0.000092
2.0.2			7.3	14.00	4040	494	10.8	0.96	3.85	0.471	0.0016	0.000198
3.0.1		Coal Slag	3.2	6.00	62700	5840	10.8	0.96	[e]	[e]	[e]	[e]
3.0.2			8.2	7.50	385000	59700	10.8	0.96	367	56.9	0.0901	0.0139
4.0.1		Silica Sand 50 grit	7.5	6.25	397000	84700	7.0[b]	1.42	245	52.3	0.125	0.0267
4.0.2			4.2	6.50	402000	76200	7.0[b]	1.44	248	47.1	0.176	0.0333
4.0.3			3.3	7.00	487000	111000	7.0[b]	1.42	301	68.5	0.125	0.0285

[a] Times recorded to the nearest 15 s (0.25 min).

[b] Tunnel air speeds were measured prior to the start of the test program. Makeup airflow changed for the silica sand tests to avoid recirculation of emissions through the facility.

[c] Emissions based on "clock" time (i.e., the air sampling duration) to facilitate comparison with results from Reference [3].

[d] The amount of media used is based on 7 lb/min for Sponge-Jet products and 13.5 lb/min for other abrasive media. Blast times are given in Table 3-1.

[e] These tests served as "shakedown" tests. During the first Sponge-Jet media test, problems were encountered with the flow in the blasting system. The system was switched out for a new unit. Because of the long test duration, the emission rate was substantially lower than the other results. Results from that shakedown test are not included in the summary statistics. Similarly, the first test of coal slag also encountered problems with material flow and has been excluded from the summary statistics.

[f] The media evaluated in this test consisted of 83% Silver 30 recycled after nine previous uses mixed with 17% of virgin Silver 30.

3.2 Discussion

Before comparing results between different media, it is important to first evaluate how well silica sand results match those from earlier EPA efforts. Table 3-3 compares the silica sand emission factors and emission rates values obtained from this study to both those developed in the 1993 EPA test program and those presented in AP-42 Section 13.2.6. In order to facilitate comparisons with the silica sand results from this study, the table includes only Reference [3] data involving removal of paint from auto hoods.

The silica sand data in this study are comparable to the earlier EPA results, with all comparisons within a factor of three. (Most comparisons are much closer.) In four pairwise comparisons of emission factors/rates for the two size ranges, only the TP emission factors differ significantly between the present study and the 1993 program. Note that the TP results from the present study can be expected to be greater than the prior EPA values because the earlier study employed a longer wind tunnel. In other words, the current program provides less opportunity for TP emissions to settle out before reaching the measurement plane than was the case in the 1993 program.

Table 3-3. Comparison of Silica Sand Results With AP-42 and Reference [3]

	TP		PM-10	
	Emission rate[a] (g/min)	Emission factor (kg/kg media)	Emission rate[a] (g/min)	Emission factor (kg/kg media)
Reference [3] Runs (painted hood surface)				
15/16 (5 mph tunnel speed)	140	0.027	31	0.0059
7/8 (10 mph tunnel speed)	330	0.070	240	0.052
21/22 (15 mph tunnel speed)	400	0.091	40	0.0091
Average	290	0.063	100	0.022
Average of 5 & 10 mph tests	240	0.049	140	0.029
Present Study				
Average of tests 4.0.1 through 3 (7 mph speed)	265	0.14	56	0.030
AP-42 Section 13.2.6[b]				
5 mph wind speed	–	0.027	–	0.013
10 mph wind speed	–	0.055	–	0.013
15 mph wind speed	–	0.091	–	0.013

[a] Data taken from Table 6-4 of [3]. Rates converted from kg/hr to g/min.
[b] Values taken from Table 13.2.6-1 and converted from lb/1,000 lb abrasive. AP-42 factors are given for "sand blasting of mild steel panels." No significant dependence of PM-10 emissions on wind speed reported.

Table 3-4 presents the percent reduction observed in average emission factors for Sponge Media as compared to that for virgin silica sand and coal slag. Note that recycled Sponge Media mixed with fresh material reduces TP emissions by 94% and PM-10 emissions by 96%. In other words, when used as recommended (i.e., recycled with fresh material added), Sponge Media provides a control level essentially identical to the 95% value commonly assigned to fabric filtration.

Table 3-4. Percent Reduction in Average Emission Factors for Sponge Media

Condition	Percent reduction based on coal slag		Percent reduction based on silica sand	
	TP	PM-10	TP	PM-10
Virgin	94	97	96	99
10th Use/Mix	91	93	94	96

Table 3-5 shows similar comparisons between Sponge Media and traditional abrasives except that percent reductions are based on average emission rates measured during the present study.

Table 3-5. Percent Reduction in Average Emission Rates for Sponge Media

Condition	Percent reduction based on coal slag		Percent reduction based on silica sand	
	TP	PM-10	TP	PM-10
Virgin	98	99	97	99
10th Use/Mix	98	99	98	99

Both Table 3-4 and Table 3-5 show that emissions for Sponge Media are one to two orders of magnitude lower than that for commonly used abrasive materials. A blasting operation could use up to 100 times as much Sponge Media and still meet any emission limitations based on silica sand or coal slag. For example, Title 30 of the Texas Administrative Code (30 TAC), Section 106.452, limits abrasive use to 150 tons per year, 15 tons per month, and one ton per day. In this case, an operation could use between 10 and 100 tons of Sponge Media per day and emit no more particulate matter than a process using one ton of silica sand per day.

Section 4.
References

1. USEPA. Compilation of Air Pollutant Emission Factors. AP-42. Fifth Edition. Office of Air Quality Planning and Standards. U.S. Environmental Protection Agency, Research Triangle Park, NC, January 1995.

2. Midwest Research Institute. “Emission Factor Documentation for AP-42 Section 13.2.6, Abrasive Blasting.” Final Report, EPA Contract 68-D2-0159, Work Assignment No. 4-02. September 1997.

3. Midwest Research Institute. “Development of Particulate Emission Factors for Uncontrolled Abrasive Blasting Operations.” Revised Source Test Report, EPA Contract 68-D2-0159, Work Assignment No. II-01. February 7, 1995.

4. Baxter, T.E. et al. “Calibration of a Cyclone for Monitoring Inhalable Particulates,” *Journal of Environmental Engineering*. 112(3), 468. 1986.

5. Davies, C. N. “The Entry of Aerosols in Sampling Heads and Tubes.” *British Journal of Applied Physics*. 2:921, 1968.

Appendix A

Test Plan

Technical Memorandum

MIDWEST RESEARCH INSTITUTE

August 16, 2005

To: Michael Merritt, Sponge-Jet

From: Greg Muleski

Subject: Draft Test Plan, MRI Project No. 310613.1.001

This memorandum describes plans for a preliminary testing program to be conducted during the week of September 19, 2005. The testing will develop data on particulate matter (PM) emissions from abrasive blasting operations. In particular, the testing will focus on the relative emission levels using different types of abrasive materials.

EPA's Handbook of Air Pollutant Emission Factors (commonly known as "AP-42") [1] Section 13.2.6-1 "Abrasive Blasting" presents emission factors based on tests of blasting with silica sand. To the extent practical, MRI has incorporated information from (a) the background document [2] underpinning EPA's AP-42 and (b) the EPA test program that developed the silica sand emission factors [3] to enable direct comparison of results from the upcoming test program with past EPA results.

The test program relies on "exposure profiling" technique, has been recognized by EPA as the technique most appropriate to characterize the broad class of open anthropogenic PM sources. Because the method isolates a single emission source, the open source emission factors with the highest quality ratings in AP-42 are typically based on this approach. The appendix describes the quality assurance/quality control procedures to be followed.

Testing Overview. The 1995 test report described a low-speed wind tunnel used to develop the silica sand emission factors. The current testing program will similarly enclose the blasting operations for testing purposes. However, the enclosure will be sheltered from weather and so does not need to be as well constructed (e.g., marine grade plywood) as was the case for the EPA test program. Two "portable carports" will form the main part of the enclosure. An axial "poultry-type" fan will draw an airflow through the enclosure and exhaust outdoors. Immediately upstream of the exhaust fan, MRI will position a cyclone preseparator (described below) to sample the PM from the blasting operation. Figure 1 shows a schematic of the test enclosure.

The enclosure allows one to control conditions from one test to another; this aids in comparing results across different abrasive media. To the extent practical, MRI will hold operational parameters (such blasting rates) as constant as possible. Based on preliminary analysis of concentration data presented in EPA test reports [2,3] and supplied by Sponge-Jet, MRI expects individual tests to last approximately 10 to 30 minutes.

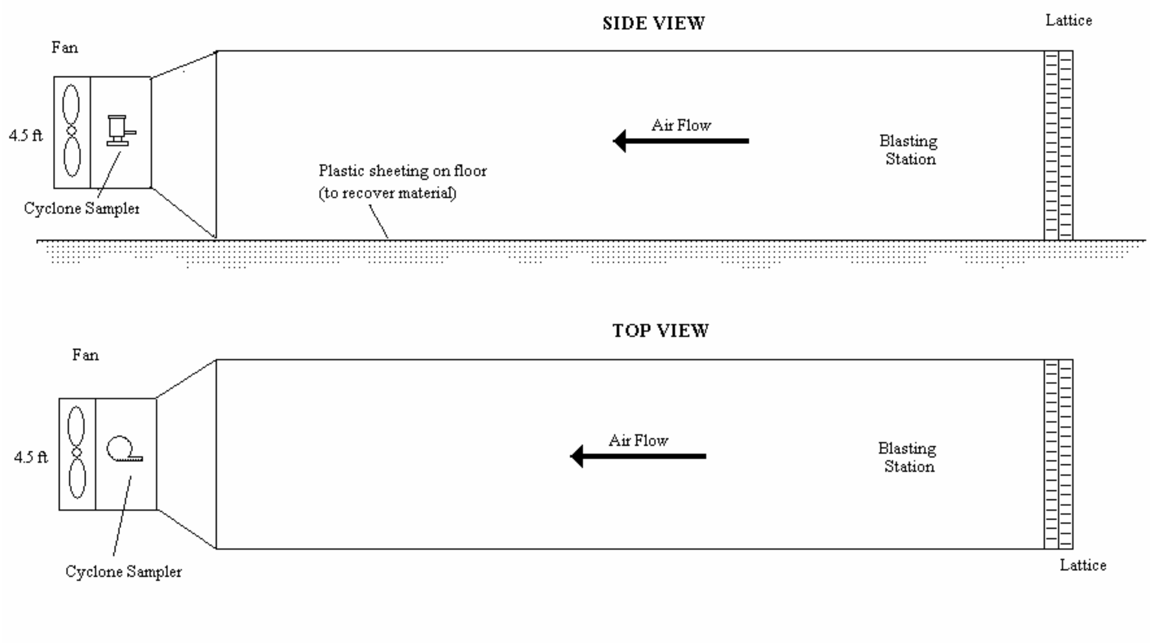

Figure 1. Test enclosure schematic.

The air sampling device is a standard high-volume air sampler fitted with a cyclone preseparator (Figure 2). This is the same type of sampler that MRI has used for years to characterize fugitive dust emissions. The cyclone preseparator exhibits a D_{50} cutpoint of approximately 10 μmA, when operated at a flow rate of 40 acfm [4]. In this way, a PM-10[1] sample is collected on a tare-weighed 8-in by 10-in glass fiber filter. In addition, the cyclone body collects coarse material for comparison to the PM emission factors in AP-42 Section 13.2.6. To determine the weight of material that collects on the interior of the cyclone, the cyclone is washed with distilled water. Upon return to MRI's main laboratories, the entire wash solution is passed through a Büchner-type funnel holding a tared glass fiber filter under suction. This ensures the collection of all suspended material on the filter.

Test Matrix. Testing will consider different abrasive media and substrates. Each substrate/abrasive combination will be considered in replicate tests, with both painted and oxidized steel substrates evaluated. At a minimum, three grades of Sponge Jet will be considered; a second set of tests using bare, virgin abrasive agent will quantify the control efficiency achieved by "containment" with the sponge media. Finally, for direct comparison to results in the EPA test report [3], testing will also evaluate -30/+50 mesh silica sand.

[1] PM-10 forms the basis for a current EPA National Ambient Air Quality Standard for particulate matter.

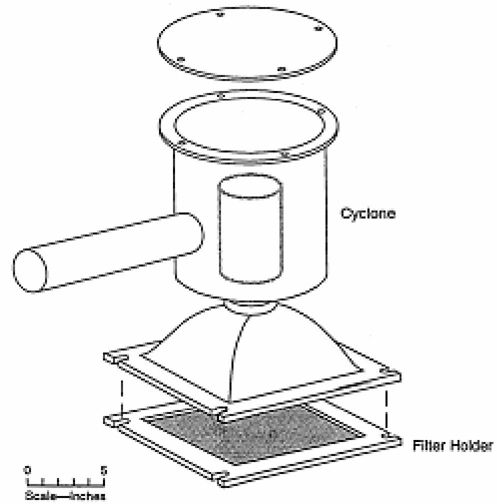

Figure 2. Cyclone preseparator.

References

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2. Midwest Research Institute. "Emission Factor Documentation for AP-42 Section 13.2.6, Abrasive Blasting." Final Report, EPA Contract 68-D2-0159, Work Assignment No. 4-02. September 1997.
3. Midwest Research Institute. "Development of Particulate Emission Factors for Uncontrolled Abrasive Blasting Operations." Revised Source Test Report, EPA Contract 68-D2-0159, Work Assignment No. II-01. February 7, 1995.
4. Baxter, T.E. et al. "Calibration of a Cyclone for Monitoring Inhalable Particulates," *Journal of Environmental Engineering*. 112(3), 468. 1986.

Appendix. 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 identification number. 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). Prior to the initial (tare) weighing, the filter media are equilibrated for 24 hours 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 the hygrothermograph is recalibrated annually against a thermometer and a digital psychrometer. These instruments are also calibrated annually.

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.

Once they have been used, exposed filters are placed in individual glassine envelopes and then into numbered file folders. Groups of file folders are sealed within heavy-duty plastic bags for storage and transport. Exposed and unexposed filters are always kept separate to avoid any cross-contamination. When exposed filters and the associated blanks are returned to the gravimetric laboratory, 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.

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.

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 unique identification numbers.
Conditioning	Equilibrate media for 24 h in clean controlled room with relative humidity of 35% (variation of less than ±5% RH) and with temperature of 21°C (variation of less than ±3°C).
Weighing	Weigh hi-vol filters to nearest 0.1 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 one to nine 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. Handling blank filters in an identical manner to all sample filters allows one to determine systematic weight changes due to handling steps alone. 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 emission test. Blank runs are labeled in the same manner as other tests, although the run sheets indicate that a blank test was conducted. Field filter blanks have 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. After each filter is weighed, 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 final audit limits (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.

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.
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.)
Operation • Timing	Start and stop all downwind samplers during time span not exceeding 1 min.
• Isokinetic sampling (cyclones)	Adjust sampling intake orientation whenever mean wind direction dictates.
	Change the cyclone intake nozzle whenever the mean wind speed approaching the sampler falls outside of the suggested bounds for that nozzle.
• Prevention of static deposition	Cover sampler inlets prior to and immediately after sampling.

[a] "Mean" denotes a 5- to 10-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%.
Digital barometer	Compare against mercury-in-tube barometer. Do not use if more than 0.5 in Hg difference in reading.
Thermometer (mercury or digital)	Compare against NIST-traceable mercury-in-glass. Do not use if more than 3.0 C difference.
Watches/stopwatches	The field test leader will compare an elapsed time (> 1 hr) recorded by his watch against the US 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.

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

Appendix B

Photos From Testing Program

Photo 1. Looking Downstream From Tunnel Entrance (Latticework removed for access)

Photo 2. Exhaust Portion of Tunnel

Photo 3. Blasting Area Inside Tunnel

Photo 4. Sampler Positioned Near Tunnel Exit

Photo 5. Cleaning the Tunnel Between Tests

Photos 6a and 6b. Test Substrates Before and After Cleaning

Photo 7. Exposed Filter for Test Substrates Shown in Photos 6a and 6b

Appendix C

Example Calculation

This example calculation is based on run 1.0.2 which was conducted on September 26, 2005, began at 14:38:00 and ended at 14:56:00. The test duration was thus 18 min. The average temperature during the test was 70°F and the barometric pressure was 29.7 in Hg. A total of 26.2 sq ft (two each of 38" by 27" and 36" by 24") was cleaned from two car hoods. [This information is taken from Run Sheet].

The following table shows the filter net weights calculated for the cyclone sampler:

Substrate	Filter No. (Note 1)	Tare weight (mg) (Note 2)	Final weight (mg) (Note 2)	Net weight (mg)	Blank-corrected net weight (mg) (Note 3)
8 x 10 filter	0541002	4262.45	4285.70	23.25	21.68
Wash filter	0546052	130.246	338.252	208.006	206.696

Notes:

1. Information taken from Field Filter Log.
2. Information taken from filter weight books. Values given in Appendix D.
3. The blank-corrected net weights for 8x10 and wash filters are based on an average blank value of 1.57 and 1.31 mg, respectively.

Concentration values are determined by dividing net catch values by the total volume of air sampled. The volume of air sampled equals the sampling duration multiplied by the volumetric flow rate. Flow rates for air sampler were developed after calibration with a BGI orifice. The calibration was performed on September 26, 2005, and produced the following equation:

$$Q = 25.3\ (\Delta P)^{0.482}$$

where Q = airflow (scfm) and ΔP = backplate pressure drop (in H_2O). The backplate pressure for run 1.0.2 was recorded on the run sheet as 3.00 in H_2O. Thus, as flow rate of

$$Q = 25.3\ (3.00)^{0.482}$$

or 42.9 scfm is found. This is converted to actual conditions through the ideal gas law as shown below:

$$\text{Flow rate (acfm)} = 42.9 \text{ scfm } (29.92 \text{ in Hg} / 29.7 \text{ in Hg}) ([460 + 70] / 537 \text{ R})$$

In this way, an actual flow rate of 42.7 acfm is found. Thus, over the 18-min long test, a total air volume of

$$18 \text{ min x } 42.7 \text{ acfm} = 769 \text{ cu ft} = 21.8 \text{ m}^3$$

was collected. The concentrations obtained are shown below:

PM size range	Net catch (mg)	Concentration ($\mu g/m^3$)
PM-10	21.68	994
TP	228.376 (= 21.68 +206.696)	10,500

The background concentrations were measured during the final test as 46 and 304 $\mu g/m^3$ for PM-10 and TP, respectively. Thus, the net PM-10 and TP concentrations are 994 – 46 = 948 and 10,500 – 304 = 10,200 $\mu g/m^3$, respectively.

At the start of the test program, the airflow at the cyclone intake position was measured as 10.8 mph (950 fpm). The field log shows that the measurement plane is 80" by 65", with an area of 36 sq ft or 3.3 m^2. The total PM-10 mass passing through the opening during the 18-min test is found as

$$948 \ \mu g/m^3 \text{ x } 18 \text{ min x } 950 \text{ ft/min x } 3.3 \ m^2 \text{ x } [0.3048 \text{ m} / 1 \text{ ft}] \text{ x } (1 \text{ g} / 10^6 \ \mu g)$$

or 16.3 g = 0.036 lb. The corresponding TP mass is found as

$$10{,}200 \ \mu g/m^3 \text{ x } 18 \text{ min x } 950 \text{ ft/min x } 3.3 \ m^2 \text{ x } [0.3048 \text{ m} / 1 \text{ ft}] \text{ x } (1 \text{ g} / 10^6 \ \mu g)$$

or 175 g = 0.38 lb.

Emission **rates** based on the 18-min test duration are found as

$$16.3 \text{ g} / 18 \text{ min} = 0.91 \text{ g/min}$$

for PM-10 and

$$175 \text{ g} / 18 \text{ min} = 9.7 \text{ g/min}$$

for TP. The run sheet notes that active blasting occurred between 14:40:30 and 14:52:00, for a total of 11.5 min. Based on a 7 lb/min feed rate for the Sponge-Jet media, this corresponds to 80.5 lb of media used. In that case, the emission **factors** are found as

$$0.036 \text{ lb} / 80.5 \text{ lb media} = 0.00045 \text{ lb/lb media}$$

for PM-10 and

$$0.38 \text{ lb} / 80.5 \text{ lb media} = 0.0048 \text{ lb/lb media}$$

for TP.

Appendix D

Filter Weights

Run	47-mm wash filter				8 x 10 filter			
	Filter No.	Tare wt (mg)	Final wt. (mg)	Net wt. (mg)	Filter No.	Tare wt (mg)	Final wt. (mg)	Net wt. (mg)
1.0.1	0564051	130.045	193.851	63.806	0541001	4281.25	4295.40	14.15
1.0.2	0564052	130.246	338.252	208.006	0541002	4262.45	4285.70	23.25
1.0.3	0564053	129.515	271.037	141.522	0541003	4278.55	4294.60	16.05
1.0.4	0564054	131.270	346.215	214.945	0541004	4286.50	4301.20	14.70
1.3.1	0564055	130.091	425.800	295.709	0541005	4274.70	4312.25	37.55
1.3.2	0564056	128.792	411.279	282.487	0541006	4272.90	4303.30	30.40
1.3.3	0564057	131.644	278.237	146.593	0541007	4307.55	4330.95	23.40
1.9.1	0564058	130.644	512.175	381.531	0541011	4278.85	4335.55	56.70
1.9.2	0564059	130.485	347.834	217.349	0541012	4286.30	4302.80	16.50
1.9.3	0564060	130.822	367.738	236.916	0541013	4276.90	4302.00	25.10
1.9.X	0564061	129.540	226.779	97.239	0541014	4279.15	4295.25	16.10
2.0.1	0564062	130.012	179.768	49.756	0541015	4316.05	4324.60	8.55
2.0.2	0564063	131.265	194.725	63.460	0541016	4313.65	4324.00	10.35
3.0.1	0564064	128.755	528.036	399.281	0541017	4287.70	4330.30	42.60
3.0.2	0564065	259.326	3123.5	2864.18	0541018	4294.20	4819.70	525.50
4.0.1	0564066	129.136	2306.6	2177.46	0541019	4259.30	4851.05	591.75
4.0.2	0564067	128.916	2525.3	2396.39	0541020	4277.60	4840.20	562.60
4.0.3	0564068,69[a]	130.798	3083.34	2952.54	0541021	4301.90	5173.15	871.25
Background	0564070	131.243	153.194	21.951	0541022	4293.55	4298.75	5.20
Blank	0564071	129.338	129.918	0.580	0541023	4295.70	4296.35	0.65
Blank	0564072	129.127	129.869	0.742	0541024	4276.90	4280.20	3.30
Blank	0564073	129.610	132.230	2.620	0541025	4308.00	4308.75	0.75

[a] Two filters used for wash. Weights shown are sums of both.