Field Emission Measurements of Barge Loading and Unloading

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ABSTRACT

Because of explosion hazards, much of the historical measurement database for grain elevators was developed to provide worst-case design criteria for dust collection devices (such as cyclones and baghouses). However, from an air pollution aspect, it is the amount of dust that escapes from the elevator and is released to the ambient atmosphere that is of interest. A 1995 testing program confirmed suspicions that prior factors severely overestimated the air pollution emissions from elevators and provided the basis for the more accurate emission factors now in AP-42.

Tests discussed in this paper extend measurement methods applied at inland elevators to operations involving barges and marine vessels, with the following objectives:

1. Develop scientifically defensible PM (uncontrolled) emission factors for grain handling operations involving barges and marine vessels.
2. Explore the effect that different operational features have on emission levels.
3. Collect information on the size distribution of PM emissions from barge/vessel operations.

Barges and marine vessels present significant challenges to successful field testing because of limited space in which to deploy equipment. As in 1995, this program required a coordinated planning process between the National Grain and Feed Association, its member companies, and EPA's Office of Air Quality Planning and Standards.

INTRODUCTION

At present, the U. S. Environmental Protection Agency's (EPA's) guidance document *Compilation of Air Pollutant Emission Factors*[1] (commonly referred to as "AP-42") does not contain any emission factors referenced to barge and marine vessel operations. This paper describes a field-testing program to develop particulate matter (PM) emission factors for grain handling operations involving barges and marine vessels (ships).

The field program applied the same measurement methodology used in earlier field test programs at grain facilities performed for both the U.S. Environmental Protection Agency (EPA) and the National Grain and Feed Foundation (NGFF). The tests for EPA were conducted in 1994 under an Emission

Measurement Center contract[2] with Midwest Research Institute (MRI). Prior to the start of testing, representatives of EPA, MRI, private industry, the Nebraska Grain and Feed Association, and the Nebraska Department of Environmental Quality met in Lincoln, Nebraska. A major focus of the meetings was formulation of general emission testing methodology that could be applied to grain elevator sources. In particular, the group sought to remove the bias toward overestimation evident in the AP-42 emission factors available at the time. Industry had expressed similar concerns through the National Grain and Feed Association (NGFA) regarding the accuracy of and characterization of emission estimates in AP-42.

The group recognized the need to distinguish between emission sources controlled with aspirated capture/collection systems and those not so equipped. For sources with aspirated systems, established EPA source testing methods can be used to determine PM concentrations from the control device. The measurements obtained using the EPA source testing methods reliably reflect (controlled) PM emitted to the ambient atmosphere.

On the other hand, control device inlet measurements do not accurately reflect emissions from uncontrolled sources because the suction applied by the control device pulls or strips additional dust from the grain stream. Thus, emission factors based on inlet measurements obtained using EPA-established testing methods suitable for control devices, are likely to be biased high for uncontrolled fugitive sources, as noted in the version of AP-42 Section 9.9.1 drafted in 1994[3].

After the 1994 scoping program, EPA's Emission Measurement Center instructed MRI to prepare a “generic” test plan[4] that described testing strategies to develop grain emission factors for ambient air pollution purposes. The plan included test methods selected to best characterize the uncontrolled (i.e., non-aspirated) emissions that escape the elevator building and contribute to ambient air particulate concentrations. MRI applied these “generic” test strategies in a 1995 National Grain and Feed Foundation (NGFF) field testing program[5] at inland elevators. The NGFF program comprised 54 tests conducted on four different grains and at three grain elevators. Testing relied on two basic equipment deployment schemes, one for 29 “external” source tests—such as receiving and shipping—and the other for the 25 “internal handling” sources. After extensive review, those tests now form the basis for almost all emission factors (rail and truck operations and internal headhouse sources) contained in AP-42 Table 9.9.1-1.

Testing discussed in this paper represents an extension of the 1995 test program, with a focus on the "external" sources related to barge and vessel operations. Facilities located along navigable rivers load barges with grain for transfer to other river facilities including export facilities. The barges are usually covered with fiberglass or metal “fliptops” or with metal “rolltop” covers. Loading occurs through an open hatch door. At the export facility, the entire barge cover is removed and the grain is unloaded with a marine leg bucket elevator or a continuous barge unloading (CBU) unit (such as those manufactured by Heyl & Patterson, Link Belt, or others).

The final handling step at an export facility loads grain into ships for overseas transport. Although several ship loading systems from different manufacturers are currently used in the industry, the major distinctions deal with which portions of the system (typically far removed from the load-out point) that are moveable. With reference to the load-out point directly above the open hold, there are two main types of spout geometry–inclined ("sloped") spouts and vertical spouts.

DEVELOPMENT OF TEST MATRIX

The test program was designed to achieve the following objectives:

- Develop scientifically defensible PM (uncontrolled) emission factors for grain handling operations involving barges and marine vessels.
- Explore the effect that the following different operational features have on emission levels.
- Collect information on the size distribution of PM emissions from barge/vessel operations.

Overall guidelines applicable to each source operation of interest included:

- A test program following general guidelines[6] for AP-42. Testing was conducted for uncontrolled sources. Thus, during test periods, control devices were to be deactivated.
- A test program that spanned common ranges of loading and unloading practices and equipment.
- A test program designed to identify potential differences in emissions during the loading/unloading cycles.
- Replicate tests.

Barge Loading Tests

For barge loading, it was important that testing take into account the following features:

- Sites along the upper and lower Mississippi River system were tested to account for any operational differences that might occur due to river heights or conditions.
- Testing of barge loading emissions focused on "fliptop" barges. "Rolltops" constitute a relatively small (and declining) fraction of barge covers in use.   Rolltop barges are no longer manufactured for use in the grain industry due to their higher cost as well as operational and safety concerns.
- Grain is typically loaded on barges by a spouting system fed by conveyors. This testing program considered a range of spout heights (approximately 20 to 40 ft) that typically occur in the industry to account for potential variations in emissions due to this parameter.
- Because emissions may vary as the barge draft increases (i.e., depth of the barge in the water as a result of loading), testing was performed at the three points – a) near one end of the mostly empty barge (early in the loading cycle); b) near the middle of the barge (roughly halfway through the loading cycle); and c) near the other end of the mostly full barge (late in the loading cycle).

- Because emissions may vary as the grain level rises beneath an individual door, testing was conducted near the beginning and near the end of loading through a particular door.

Barge Unloading Tests

The barge unloading portion of the test program considered two types of systems commonly used by the industry—the marine leg and CBU equipment. Because marine legs represent a small and decreasing fraction of the equipment in use, more emphasis was placed on the CBU systems than on marine legs.

Ship Loading Tests

The ship loading phase of the test program was designed to address the following points:

- Testing considered both types of loading spout geometry. Greater emphasis was placed on vertical spout systems than on sloped spouts because vertical spouts are used more frequently for loading vessels.
- Because emissions may vary over the loading cycle, tests were conducted at different points in the cycle: a) when the hold was mostly empty; b) when the hold was roughly half full; and c) near the end of the loading cycle.

Note that testing did not consider "topping-off" operations when the very last portion of grain was placed in the ship hold. In this way, test results are generally applicable throughout the loading cycle. Topping off represents only a very small fraction of the ship loading operation (typically the last 4 feet in a 50 to 60 foot deep ship hold). Wind interference during the topping off operation is likely to greatly hinder effective emission testing and the development of reliable test data. Furthermore, in topping off, the grain falls only a short distance and PM is emitted from only a small point rather than over the entire horizontal area of the hold opening. To keep the sampling array close to the emission point would require placing samplers within the hold area, which of course is impractical.

TEST METHODOLOGY

This program addressed "fugitive" emission sources that release air pollutants to the ambient atmosphere by means other than a stack, vent or duct. The exposure profiling concept represents a measurement technique that is potentially applicable to any fugitive emission source, provided that the following conditions are met:

1) Sampling equipment can be placed physically close to the source.

2) The contribution of the emission source can be isolated from upwind (background) levels of the pollutant.

3) There is sufficient air movement to convey the emitted pollutant to the sampling array.

The exposure profiling technique relies on simultaneous multipoint measurement of both concentration and air flow over the effective area of the emission plume in a mass flux measurement scheme. In this way, exposure profiling applies the same basic measurement concept as does traditional stack sampling. In comparison to most stack sources, however, fugitive sources do not produce emissions that are thoroughly mixed in a well-defined, constant airflow. For these reasons, exposure profiling cannot employ a single probe traversing the plume cross-sectional area.

Instead, the method relies on simultaneous multipoint sampling of mass concentration and airflow over the effective area of the emission plume because, unlike stack sources, both the emission rate and the airflow are non-steady. Thus, the calculation scheme used with mass flux profiling requires combining numerous measurements (concentration and air flow) taken at separated points to spatially encompass the plume. An integrated value of the measurements is used to represent total mass being emitted by the source operation.

Because exposure profiling relies on ambient winds to transport the pollutant from the source to the sampling array, the measurement technique does not modify the source or affect the manner in which it would normally operate. This situation should be compared to other measurement techniques that attempt to: a) first enclose the fugitive source, b) actively evacuate the enclosure, and c) apply a stack sampling method to determine emission levels. Clearly, the enclosure affects the source by artificially shielding it from the ambient winds (which are known to influence material transfer emission levels).

FIELD TEST PROGRAM

Sixty emission tests were conducted during November and December 2000. Test site parameters for the runs are provided in Tables 1, 2, and 3 for ship loading, barge unloading, and barge loading tests, respectively. These tables list the start time and duration of each test as well as the type of grain involved and equipment used.

The exposure profiling method was applied to each of the three source categories. Owing to the different source geometries, the method was adapted to reconcile the size of the emission source with the space available for sampling equipment. Figure 1 illustrates the 2-dimensional sampling array used to characterize ship loading emissions. The array consists of 6 high-volume PM-10 samplers deployed at two heights each at three positions along the downwind edge of the source. The array also includes R. M. Young Gill-type (model 27106) anemometers deployed at two heights to determine the wind profile. In addition to these two fixed-axis anemometers, an R. M. Young portable wind station (model 05305) was used to record wind speed and direction at the 3.0 m height downwind. All wind data were accumulated into 5-min averages logged with a 26700 series R. M. Young programmable translator.

Figure 2 shows the equipment deployment for a typical barge loading test. Clearly, barges offered far less space to accommodate sampling equipment than did ships (Figure 1). Barge unloading tests relied on an array of four PM-10 samplers arranged in a 2-dimensional array. Furthermore, because of the limited space available, wind speeds were monitored with two Davis vane anemometers. Compared to the Gill anemometer, this device's compact size allows easier and safer deployment when only limited space is available.

Compared to uncovered barges and ship holds, an open hatch on a barge cover presents a much smaller emission source. Thus, the barge loading tests required a different sampling arrangement than did the other two source categories. Figure 3 shows a typical barge loading emission test. In these tests, a channel (with two sides plus a top) was placed atop an open barge fliptop door Each channel was open to the wind and had a rectangular cross-sectional area of approximately 5 ft x 7 ft. Because of the small cross-sectional area, a single sampler was positioned at the center of each channel. Also, because of the limited space available, a Davis vane anemometer was used to measure air flow near the center of the opening.

At the time of this writing, data reduction of the November and December tests has not been completed. Additional details and results will be presented at the conference.

REFERENCES

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5. Midwest Research Institute. "Emission Factors for Grain Elevators," MRI Project No. 3889 and 4672. Prepared for National Grain and Feed Foundation. January 1997.
6. *Procedures for Preparing Emission Factor Documents.* U. S. Environmental Protection Agency, Research Triangle Park, NC. EPA-454/R-95-015. May 1997.

Table 1. Test Site Parameters – Ship Loading

Run	Date	Loading Equipment	Ship Name	Grain[a]	Start Time	Duration (min)
DD-01	11/7/00	Buehler	Siletta	No. 2 YC	11:10:30	10.00
DD-02	11/7/00	Buehler	Siletta	No. 2 YC	12:14:30	21.00
DD-03	11/7/00	Buehler	Siletta	No. 2 SRW	13:54:00	23.00
DD-04	11/7/00	Buehler	Siletta	No. 2 SRW	14:42:15	12.00
DD-05	11/7/00	Buehler	Siletta	No. 2 SRW	15:51:15	13.50
DD-06	11/7/00	Buehler	Siletta	No. 2 SRW	16:27:30	9.00
DD-11	11/10/00	PECO	Golden Harvest	No. 2 YC	20:13:30	13.50
DD-12	11/10/00	PECO	Golden Harvest	No. 2 YC	20:56:00	21.00
DD-13	11/11/00	PECO	Golden Harvest	No. 2 YC	12:47:00	15.50
DD-14	11/11/00	PECO	Golden Harvest	No. 2 YC	13:26:00	7.25
DD-17	11/13/00	PECO	Great Prestige	No. 2 YC	16:52:00	15.00
DD-18	11/13/00	PECO	Great Prestige	No. 2 YC	18:00:00	15.00
DD-21	11/19/00	Sloped spout	Navios Mariner	No. 2 YSB	15:07:45	15.00
DD-22	11/19/00	Sloped spout	Navios Mariner	No. 2 YSB	15:55:00	12.75
DD-23	11/19/00	Sloped spout	Navios Mariner	No. 2 YSB	16:25:00	22.75
DD-24	11/19/00	Sloped spout	Navios Mariner	No. 2 YSB	18:40:15	16.00
DD-25	11/19/00	Sloped spout	Navios Mariner	No. 2 YSB	19:23:00	13.50
DD-26	11/19/00	Sloped spout	Navios Mariner	No. 2 YSB	20:08:15	17.50
DD-27	11/20/00	Sloped spout	Navios Mariner	No. 2 YSB	11:50:30	18.00
DD-28	11/20/00	Sloped spout	Navios Mariner	No. 2 YSB	12:30:30	12.00
DD-29	11/20/00	Sloped spout	Navios Mariner	No. 2 YSB	13:13:45	14.00

[a] YC = yellow corn, SRW = soft red wheat, YSB = yellow soybean

Table 2. Test Site Parameters – Barge Unloading

Run	Date	Unloading Equipment	Barge No.	Grain[a]	Start Time	Duration (min)
DD-101	11/8/00	Heyl Patterson	ART 486	No 2 YC	14:16:00	10.50
DD-102	11/8/00	Heyl Patterson	ART 486	No 2 YC	14:38:15	10.75
DD-103	11/8/00	Heyl Patterson	ART 486	No 2 YC	15:07:00	10.25
DD-104	11/9/00	Heyl Patterson	ATM 2012	No 1 YC	10:13:45	14.50
DD-105	11/9/00	Heyl Patterson	ATM 2012	No 1 YC	10:48:45	11.25
DD-106	11/9/00	Heyl Patterson	ART 2012	No 1 YC	11:14:15	6.75
DD-111	11/12/00	Heyl Patterson	CPD 9711	No. 2 YSB	12:54:00	5.00
DD-112	11/12/00	Heyl Patterson	CPD 9711	No. 2 YSB	13:14:00	4.50
DD-113	11/12/00	Heyl Patterson	CPD 9711	No. 2 YSB	13:29:30	5.50
DD-114	11/12/00	Heyl Patterson	CC 7832	No. 1 YSB	16:16:30	5.50
DD-115	11/12/00	Heyl Patterson	CC 7832	No. 1 YSB	16:38:45	10.25
DD-116	11/12/00	Heyl Patterson	CC 7832	No. 1 YSB	17:12:45	7.25
DD-121	11/15/00	Marine leg	SUN 204	No. 3 YSB	12:30:30	2.50
DD-122	11/15/00	Marine leg	SUN 204	No. 3 YSB	12:54:00	2.50
DD-123	11/15/00	Marine leg	SUN 204	No. 3 YSB	13:09:30	2.50

[a] YC = yellow corn, YSB = yellow soybean

Table 3. Test Site Parameters – Barge Loading

Run	Date	Loading Cycle	Grain[a]	Start Time	Duration (min)
DD-201	11/30/00	Start	No. 3 YSB	10:22:00	11.75
DD-202	11/30/00	Start	No. 3 YSB	10:38:45	9.75
DD-203	11/30/00	Start	No. 3 YSB	11:00:00	8.00
DD-204	11/30/00	Start	No. 3 YSB	11:21:00	11.00
DD-205	11/30/00	Middle	No. 3 YSB	12:58:00	11.25
DD-206	11/30/00	Middle	No. 3 YSB	[b]	7.25
DD-207	11/30/00	Middle	No. 3 YSB	13:49:00	7.75
DD-208	11/30/00	Middle	No. 3 YSB	14:04:00	7.25
DD-209	11/30/00	End	No. 3 YSB	15:04:00	15.00
DD-210	11/30/00	End	No. 3 YSB	15:24:30	8.50
DD-211	11/30/00	End	No. 3 YSB	15:42:30	6.25
DD-212	11/30/00	End	No. 3 YSB	16:04:00	7.75
DD-221	12/2/00	Start	No. 2 YC	9:05:00	10.50
DD-222	12/2/00	Start	No. 2 YC	9:23:15	6.75
DD-223	12/2/00	Start	No. 2 YC	10:00:00	7.50
DD-224	12/2/00	Start	No. 2 YC	10:13:00	3.00
DD-225	12/2/00	Middle	No. 2 YC	11:49:00	7.50
DD-226	12/2/00	Middle	No. 2 YC	12:02:15	5.75
DD-227	12/2/00	Middle	No. 2 YC	12:30:00	6.00
DD-228	12/2/00	Middle	No. 2 YC	12:41:00	4.00
DD-229	12/2/00	End	No. 2 YC	14:13:45	7.25
DD-230	12/2/00	End	No. 2 YC	14:25:00	7.00
DD-231	12/2/00	End	No. 2 YC	14:51:00	7.00
DD-232	12/2/00	End	No. 2 YC	15:03:15	7.75

[a] YC = yellow corn, YSB = yellow soybean

[b] Two start times because testing briefly interrupted due to unfavorable conditions.

Figure 1. Sampling array used for ship loading tests.

Figure 2. Sampler deployment for barge unloading tests.

Figure 3. Barge loading test.

Keywords

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Barge
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PM-10
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