NORTH AMERICA
STEVEDORING

February 24, 2015

Mr. Otis Omenazu, Chief Air Engineer
Department of Health, City of Chicago
333 S. State Street, Suite 200
Chicago, IL 60604

Re: Variance Application, June 11, 2014
Bulk Material Storage Rules and Regulations
North American Stevedoring Company, LLC (NASCO)
9301 South Kreiter Avenue, Chicago, IL 60617

Dear Mr. Omenazu,

Thank you for the opportunity to provide additional information you requested in your letter of January 26, 2015 regarding the referenced applications. We provide this information within the thirty days allowed in your letter. The additional information is organized to align with your inquiry with attachments provided as appropriate.

1. **Accordingly, please provide detailed information as required by Section 8.0(2)(b) of the Bulk Material Rules including maps, diagrams and any other pertinent supporting information.**

This section requests: i) *"a description of the process or activity for which the variance is requested,"* and ii) *"pertinent data on location, size, and the population and geographic area affected by, or potentially affected by, the process or activity."*

The description of the process is provided in the Fugitive Dust Plan (FDP) as Attachment A and is supplemented with additional information provided herein and attached. The pertinent data is shown by a demographic profile of the surrounding area based on the 2010 Census and is from the United States Environmental Protection Agency (USEPA) ECHO Data Base (Attachment B). Demographic data presented is for a radius of one mile from the coordinates of the address location of the Port of Illinois, which are the western portion of the property. Bulk Solids Handling activities are confined to the northeastern portion of the property, which is more than half a mile from nearest residences. An aerial is included with Attachment B to show the distance to nearest residences. At a distance of one-half mile or more, no residential receptor or property use can be adversely impacted by activities for which a variance is sought.

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2. **Please provide additional details to support NASCO's request not to install a dust monitoring network, including evidence of the effectiveness of NASCO's current Fugitive Dust Plan. If available please include any scientific studies or reports and any site-specific technical evaluations. Please also be sure to include citations and supporting calculations for all sources of emissions data and other information upon which you rely. In addition, please provide detailed evidence that installing the monitors would cause an unreasonable hardship.**

An engineer's estimate for installation of the dust monitoring network appears as Attachment C. This network would include one met station and four dust stations with radio telemetry. Units are battery powered with solar charging. Costs for installation are $90K and annual operating, maintenance and reporting costs are $109K per year. Assuming a five-year equipment life, the annual costs are about $127K per year. The market rate that NASCO is allowed to charge for handling Bulk Solid Materials (BSM) is about $15 per ton. In 2014, NASCO handled 41,500 tons per year of ferromanganese and fluorspar. Based on this volume of business, cost for monitoring would increase the price NASCO must charge by 20 percent. This will be sufficient to cause customers to seek other outlets. NASCO considers this loss of business and revenue an unreasonable hardship.

The FDP (the Plan) is effective in mitigating dust from BSM activities. Enclosed are the sweeping logs for 2014 (Attachment D) and daily logs (Attachment E) which demonstrate the Plan is being implemented and that activities do not create public nuisance or adversely impact the surrounding area, environment, or property uses.

On January 15, 2015, the Compliance Commitment Agreement (CCA) between Illinois Environmental Protection Agency (IEPA) and NASCO became effective (VN A-2014-00002) (Attachment F). This CCA resolved allegations regarding failure to obtain air permits and pay fees. By signing the CCA, the Facility agreed to not handle or store petroleum based or metallurgical coke. Compliance activities include implementation of the Fugitive Dust Plan as submitted to Chicago Department of Public Health (CDPH), with the following specific additions:

- Address storage and handling of salt,
- Spilled material will be cleaned up immediately, and
- Materials under the FDP will not be stored outside except for immediate transfer or load out.

The CCA does not cover bulk materials handled at the Facility but not addressed in the FDP such as steel, lumber or Blast Furnace Iron (BFI). CCA and the requirement to maintain the FDP is binding on NASCO and any successor, and IEPA can enforce against violations of its terms and conditions.

3. **Please provide additional information quantifying the exact amount, in cubic yards, of BFI, or pig iron, that are stored at the facility at any one time. Please also provide detailed information demonstrating that particulates that slough off of these materials will not create a public nuisance or adversely impact the surrounding area, surrounding environment, or surrounding property uses.**

In 2014, the amount of BFI stored at the Facility at any one time ranged from 2000 to 40,000 tons. Amount handled in 2014 was 136,000 tons. Some BFI was loaded to trucks but most was loaded to lake barges.

BFI is a dense, heavy material which does not generate particulate matter as do bulk solid materials such as coke or coal. To the extent material does separate from BFI, it is gravel-like and with a trace occurrence of particles having dimensions below that of coarse sand (1000 microns). Therefore, these materials are not characterized as particulate matter (PM), which has dimensions two orders of magnitude lower at 10 microns (PM_{10}).

Transportation, storage and handling for BFI results in some material breaking off the ingots. A metal screen with 1.5 inch openings is used to separate these smaller shapes from the ingots before shipping to their owner. Once a truckload or two (<40 tons) of screenings are accumulated, they are shipped for use by another customer. Screenings are never stored outside in quantities approaching the de minimis value of 25 cubic yards. Screenings range in nominal size of 1.5 inches to the size of coarse sand (~1000 microns). There can be trace amounts (<1 percent) of particles as small as fine sand (>100 microns).

The screenings are identical chemically and physically to BFI and are six times heavier than the coke and coal materials that are the focus of the City of Chicago (the City)'s BSM regulations. BFI materials do not mobilize in a way that it can leave the Facility, nor can they become airborne, be scattered by the wind, create opacity greater than ten percent, or cause visible dust at the property line.

In order to demonstrate this we can use the accepted protocol for calculation of emission of dust from storage piles found in Chapter 13 of AP-42, Compilation of Air Pollutant Emission Factors.(1)

"Dust emissions may be generated by wind erosion of open aggregate storage piles and exposed areas within an industrial facility."

For particulates to be mobilized and emissions to occur, friction velocity at the surface due to wind must exceed the threshold friction velocity ($u_{t)}$) of the material stored at the surface. USEPA proposes a logarithmic wind speed profile be applied to the "fastest mile" wind velocity at 10 meters, u_{10} in meters per second (m/s) above the surface to yield the friction velocity, u^* (m/s) at the surface using the following equation (4) : $u^* = 0.053\ u_{10}$

For example, a "fastest mile" wind velocity of 15 m/s (34 miles per hour [mph]) yields a friction velocity of $u^* = (0.053)(15) = 0.8$ m/s. At this wind velocity, materials with a threshold friction velocity, u_t below 0.8 m/s may generate dust.

USEPA provides threshold friction velocities for coal at 0.55 m/s (Table 13.2.5-2). This suggests coal dust may be emitted from coal piles exposed to winds over 10 m/s (23 mph). This suggestion is generally consistent with visual observations that elevated wind velocities can generate visible dust from the surface of exposed coal or coke piles.

The relationship of one material's threshold friction velocity to another has been shown (Shao, Y., 2000) to be a function of the square root of the ratio of their specific gravities. For example, the specific gravity for coal and pig iron are 1.2 and 7.0, respectively, so the ratio, r of their threshold friction velocities will be $r = (7.0 / 1.2)^{1/2} = 2.4$. Given u_t of 0.55 for coal; the value for pig iron is $u_t = 1.3$. Equating this to friction velocity $u^* = u_t = 1.32 = (0.053)(u_{10})$, where u_{10} is 25 m/s or 57 mph.

A sustained wind velocity of 57 mph at 10 meters height is calculated as necessary for any emissions to be generated from trace particulates in storage piles of BFI. This would be a gale force wind.

This outcome is consistent with field observations that BFI materials do not become airborne, nor are they scattered by the wind. Wind cannot cause BFI to mobilize and generate particulate that could create a public nuisance or adverse impacts to the surrounding area, environment or property uses.

In accordance with accepted protocols of USEPA, BFI cannot *become airborne or be scattered by the wind.* Therefore BFI does not conform to the ordinance definition of BSM, and is not subject to ordinance requirements. Please see attached Reference articles:

1) AP-42 Chapter 13, Section 13.2.5, November 2006).
2) Shao, Yaping; A Simple Expression for Wind Erosion Threshold Friction Velocity; *Journal of Geophysical Research*, Vol 105, No. D17, Pages 22,437-22,443, September, 16 2000.

4. **Accordingly, please provide a detailed response, for each type of material handled at the facility, explaining why compliance with one of the four options for controlling dust at the transfer points is not feasible. In addition, please provide evidence of the effectiveness of the proposed alternative measures.**

The FDP, Section 6.0 describes measures to control dust. The variance request regarded only the limitation on transfer of moist material (>3 percent) when some clients specify a lower moisture (i.e. 2.5 percent). For ferromanganese and fluorspar other measures employed to ensure compliance with the opacity limit of 10 percent include the following:

- Total enclosure of bulk solid material stored in a warehouse except when unloading or loading;
- Transfers conducted in a manner to minimize the exposed drop;
- Railcar loading conveyor enclosed;
- Immediate cleanup of spill residues;
- No storage of BSM outdoors unless under immediate transfer or load out;
- No loading or unloading if winds create visible emissions at property line; and
- Covered trucks and enclosed hopper cars.

Terminal operations present some limitations to implementing all dust control measures listed. NASCO cannot enclose the ship or barge. Neither commodity should get wet, so water spray is not an option. The material must be segregated inside the warehouse and this accomplished though transport by pay loaders or dump trucks which cannot be fitted with air pollution control equipment. However, each storage and transfer activity uses all practicable control measures.

Trucks are loaded by pay loaders, which can minimize the exposed drop. Enclosed hopper rail cars are loaded by a mobile, air-cooled diesel powered, conveyor system. The main components include a ten cubic yard material hopper that feeds the 35-foot enclosed conveyor belt with a belt driven shaker plate that regulates material flow. The conveyor is height adjustable, ranging from 10 feet in height to 30 feet to enable minimizing the exposed drop.

5. **Thus, if NASCO believes that the materials submitted adequately demonstrate that the current measures are effective to ensure that trucks do not cause track-out from the facility onto the public way, then please withdraw this variance request. If CDPH determines that additional measures are required, these may be addressed in the Fugitive Dust Plan.**

Thank you for clarifying that Section 3.0(8)(d) of the ordinance allows the FDP to specify other measures to ensure no track out. We were concerned about the practicability of the wheel wash/rumble strip requirement due to the volume of outbound departures, which were 35,000 in 2014. Of these, BSM trucks departing the Facility numbered 1175, about 3 percent.

Section 6 of the FDP specifies implementation of alternative measures and these have proven effective, based on documentation provided of street sweeping and daily logs. We hereby withdraw the variance request for wheel wash and rumble strips.

NASCO is in the process of making agreements with the City and the Port Authority to take over control and maintenance of the roadway, and giving NASCO greater ability to assure routine street sweeping is implemented through the portion adjoining 95th street.

Public Comments:

Thank you for offering us the chance to respond to comments to the record made by interested parties. We believe this letter, together with the FDP, addresses the issues raised in these comments. Additional observations are provided below:

i. Aerial photos of the facility that are not recent will not reflect changes eliminating most bulk solid materials. Under the CCA with the IEPA, unloaded material may be staged near the dock for less than twenty-four hours.
ii. The Material Safety Data Sheet (MSDS) for BSM addresses hazards of the iron in its molten state and while being processed. Product BFI is inert and presents no more hazard than does iron oxide rust on iron and steel structures, which occur throughout the urban area in very close proximity to receptors.
iii. Based on conservative USEPA published emission factors (AP-42) and processing of BSM at the Facility, particulate emissions (PM_{10}) are estimated to be less than 750 pounds per year. The State of Illinois does not require air permits for construction or operation for a facility with annual emissions below 10,000 pounds per year. Facilities that emit more than this and do require permits, are rarely required to perform ambient air monitoring for PM_{10}. The nearest monitoring station for PM_{10} is at Washington Park.

The dredge spoils site just east of the property is a major source of particulate, and emissions has no ambient monitors.

We are now operating under the procedures described in the FDP. We now manage only two bulk solid materials at the Facility, fluorspar and ferromanganese. Materials are managed within enclosures or under procedures to minimize fugitive dust as set forth in the Plan.

Thank you for your attention to this matter. Please contact me if you have any questions or wish to have a Health Department representative visit the Facility.

Sincerely,

Steven H. Mosher, Vice President
NASCO

Attachments:
A. Fugitive Dust Plan
B. Demographic Profile (ECHO Report); Aerial
C. Cost Estimate for Dust Monitoring (BAM-1020)
D. Sweeping Logs
E. FDP Daily Logs
F. Compliance Commitment Agreement VN A-2014-00002

References:
1. AP-42 Chapter 13, Section 13.2.5, November 2006)
2. Shao, Yaping; A Simple Expression for Wind Erosion Threshold Friction Velocity; *Journal of Geophysical Research*, Vol 105, No. D17, Pages 22,437-22,443, September, 16 2000.

ATTACHMENT A

FUGITIVE DUST PLAN

FUGITIVE DUST PLAN

NORTH AMERICAN STEVEDORING COMPANY, LLC
9301 SOUTH KREITER AVENUE
IROQUIS LANDING, PORT OF CHICAGO
CHICAGO, COOK, ILLINOIS

Submitted by:

NORTH AMERICAN STEVEDORING COMPANY, LLC

NORTH AMERICA
STEVEDORING COMPANY, LLC

June 2014

Fact Sheet

This Fugitive Dust Plan for North American Stevedoring Company, LLC (NASCO) documents best management practices employed to prevent fugitive dust. The Facility is located at the marine terminal at Iroquois Landing in the Illinois Port District along the Calumet River and Lake Michigan. Most commercial goods arriving at this marine terminal are not bulk solid materials, such as lumber, steel, iron, zinc and aluminum.

Bulk Solid Materials (BSM) handled at this Facility are ferromanganese and fluorspar; up to 15,000 tons can be stored within buildings. BSM arrive by barge or ship and are loaded out to trucks or railcars. Management practices include inspections, roadway sweeping, spill cleanup, minimum drop distances, enclosed conveyors, loading within buildings and vehicle tarping. Practices are intended to conform to the City of Chicago Air Pollution Control Rules and Regulations. The terminal has never had a complaint regarding particulate matter, fugitive dust, opacity or visible emissions.

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FIGURE

Figure 1 Bulk Solid Materials Facility Map

ATTACHMENT

Attachment 1- Bulk Solid Materials Log

1.0 INTRODUCTION

This Fugitive Dust Plan has been prepared for North American Stevedoring Company, LLC (NASCO) to mitigate potential impacts to air quality resulting from fugitive dust associated with the Iroquois Landing Marine Loading Terminal operations. The plan provides a description of the facility operations and a list of Bulk Solid Materials (BSM) handled at the Iroquois Landing Marine Loading Terminal. The Fugitive Dust Plan will be operated in compliance with the City of Chicago Department of Public Health Article II - Air Pollution Control Rules and Regulations for Control of Emissions from the Handling and Storage of Bulk Material Piles dated March 13, 2014. The Fugitive Dust Plan will be updated on an annual basis and submitted to the Department of Public Health for review and approval on or before January 31 every year. Additionally, the facility will submit an amended Fugitive Dust Plan within thirty days of any changes, modifications, or additions of the approved Fugitive Dust Plan.

2.0 FACILITY OPERATIONS

The Iroquois Landing Marine Loading Terminal is located at the mouth of the Calumet River and Lake Michigan, approximately 12.5 miles from downtown Chicago and receives a variety of cargoes from different cargo vessels. Cargos handled at the Iroquois Landing Marine Loading Terminal include salt, steel products, lumber, fluorspar, zinc, aluminum, pig iron, ballast rock, and break wall stone. The cargos arrive via bargesand ships, and depart by ocean-going vessels, rail cars, and trucks. The Iroquois Landing Marine Loading Terminal is equipped with cargo-loading machinery such as forklifts, reach stackers, and mobile and overhead cranes. The Iroquois Landing Marine Loading Terminal possesses a Certificate of Operation which was issued in accordance with Section 11-4-660 of the Municipal Code of Chicago.

Materials which meet the definition of BSM are handled and stored in a 17-acre portion of the Iroquois Landing Marine Loading Terminal. The portion of the Iroquois Landing Marine Loading Terminal which handles the BSM will be referred to as the Facility. A map of the Facility is provided in Figure 1.

3.0 BULK SOLID MATERIALS (BSM) HANDLED

A list of BSM has been prepared in accordance with the definition provided in the March 13, 2014 City of Chicago Department of Public Health – Rules and Regulations for Bulk Materials Storage. The definition of BSM reads:

> *Bulk Solid Material means any solid substance or material that can be used as a fuel or as an ingredient in a manufacturing process that may become airborne or be scattered by the wind and that, except for coke and coal, is stored at a Facility in any amount equal to or greater than 25 cubic yards at any one time, including but not limited to ores, coal, and coke, including petcoke and metcoke, but shall not include salt, grains, Construction and Demolition Materials, materials that are handled or stored pursuant to recycling, reprocessing, or waste handling Facility permit under Chapter 11-4 of the Code, or materials used in manufacturing cement at a facility that has obtained a construction*

permit and prevention of significant deterioration approval from the Illinois Environmental Protection Agency.

Cargos handled at the Facility include salt, steel products, lumber, fluorspar, zinc, aluminum, pig iron, ferromanganese, ballast rock, and break-wall stone.

- Aluminum, lumber, zinc, steel products, ballast rock, and the break-wall stone do not generate particulate dust matter and are not included in this Fugitive Dust Plan.
- Salt is excluded from the definition of BSM and is not included in this Fugitive Dust Plan.
- Blast Furnace Iron (BFI or pig iron) does not meet the definition of a BSM because residues are too dense to become airborne or be scattered by the wind. Additional information regarding pig iron is presented separately.
- Materials handled at the Facility that meet the BMS definition include ferromanganese and fluorspar.

Ferromanganese normally arrives in 3,000-ton shipments by ship. Each month from April to December, the facility unloads one to two ships, or 3,000 to 6,000 tons of ferromanganese. The ferromanganese is unloaded at the marine terminal and temporarily (for less than 24 hours) staged in piles along the dock, then transferred using a front loader to bays within the A House building. Within the A House building, the ferromanganese may be bagged into super sacks. The bagging operation has a dust collection system designed and operated to contain fines within the units for transfer to packaging or disposal. Approximately 95-percent of the ferromanganese ships out as loose bulk in dump trucks. Approximately 5-percent of the ferromanganese ships out in super sacks on flatbed trucks. Maximum ferromanganese inventory can reach 10,000 tons and rarely goes below 1,000 tons. Approximately 34,000 tons of ferromanganese were handled in 2012 and 44,000 tons were handled in 2013.

Fluorspar normally arrives in 1,600-ton shipments by barge. The fluorspar is unloaded at the marine terminal and temporarily staged (for less than 24 hours) in piles along the dock and then transferred using a front loader to bays within the A House or the Grey Tent. In the A House, the fluorspar may be dried to 2.5-percent moisture prior to loading into railcars. The drying operation includes a dust collection system designed and operated to contain fines within the units for transfer. The dryer was not used during 2013. Approximately 75-percent of the fluorspar ships out in enclosed railcars, 100 tons at a time. It takes two hours to load a railcar. The remainder of the fluorspar ships out in dump trucks.

The Facility historically handled petroleum coke, metallurgical coke, synthetic gypsum, and coke breeze. The Facility no longer handles these materials, and they are not included in this Fugitive Dust Plan.

4.0 TRUCK ROUTES AND PROCEDURES

Truck routes within one quarter mile of the perimeter of the Facility and used to transport material to and from the Facility are shown on Figure 1. All truck routes located within one quarter-mile of the facility are paved and located within the Iroquois Landing Marine Loading Terminal.

To minimize dust during transport, trucks handling or transporting BSM will adhere to the following measures prior to leaving the facility:

- All truck drivers will adhere to the posted speed limit within the facility which is no more than eight miles per hour.
- All truck drivers will verify that any part of any tractor, trailer, or tire exterior surface is free of loose materials.
- Exiting trucks will be visually observed at the weigh scale station.
- BSM loading vehicles are also routinely visually inspected for loose material.

5.0 BULK SOLID MATERIAL STORAGE CAPACITY

The Iroquois Landing Marine Loading Terminal occupies a 100-acre parcel with 3,000 linear feet of ship and barge berthing space having a navigation depth of 27 feet. There are two 100,000-square foot transit sheds and one 30,000-square foot transit shed with direct truck and rail access. The Iroquois Landing Marine Loading Terminal has outside storage space covering over 90 acres, warehouses equipped with loading docks totaling over 245,000 square feet (ft^2) and a climate controlled building of 25,560 ft^2 equipped with a 30 MT gantry crane. About 100 acres of land adjacent to the terminal are available for use as additional outside storage space.

The Bulk Storage Facility occupies 17 acres of the Terminal with four structures; The A-House, Grey Tent, Green Tent and Blue Tent. BSM are not handled in the Green Tent or Blue Tent. The total indoor storage capacity is 14,500 tons.

Storage Name	**Bulk Solid Material**	**Storage Capacity (tons)**
Grey Tent	Fluorspar	2,500
A House	Ferromanganese/Fluorspar	12,000
Total		**14,500**

6.0 FUGITIVE DUST CONTROL MEASURES

The Facility has Fugitive Dust control measures in place for the cargos handled that meet the definition of BSM, including ferromanganese and fluorspar. These measures are intended to conform to operation and maintenance practices set forth in Part B, Section 3.0 of the City of Chicago Air Pollution Control Rules and Regulations.

6.1 CONVEYORS

Conveyors used at the Facility to transfer BSM are covered or enclosed in order to reduce fugitive dust emissions to the maximum extent practicable.

6.2 TRANSFER POINTS

In order to assure compliance with the 10-percent opacity limit, the Facility transfers BSM as moist materials and in a manner that minimizes the exposed drop. Materials are stored and transferred with a moisture content above 3-percent. For a given customer, some fluorspar may be dried to 2.5 percent prior to loading into enclosed hopper railcars. A variance has been requested to permit the Facility to transfer this material into the railcars at 2.5-percent moisture.

6.3 VEHICLE COVERING AND OTHER DUST CONTROL

Bulk solid material is loaded once measures are in place to prevent the material from escaping from the vehicle:

a) Before departing, truck trailers are covered with a tarp, and secured so BSM is not exposed to the wind.

b) Railcar loading is done with closed conveyors, minimum drop distances, and enclosed hopper cars.

6.4 VEHICLE LEAKING

No loading of BSM is done such that a vehicle leaks BSM onto internal roads or into waterways. If a leak of BSM occurs, spilled material is removed as soon as practical the same day, with residue cleaned up by street sweeping or other appropriate measures.

6.5 TRUCK LOADING AND UNLOADING

Loading of trucks occurs at A House and north of the Grey Tent. Material is moved from enclosed storage immediately to the truck being loaded. Loading is done within A House during inclement weather (high wind, rains). Truck tires are inspected at the weigh scale on departure to assure BSM is not tracked out. The Facility normally conducts no truck unloading. In a rare event of inventory shortfall, BSM has arrived by truck and immediately moved into enclosures.

6.6 RAILCAR LOADING AND UNLOADING

The Facility conducts railcar loading of BSM consistent with measures for transfer points and in a manner that minimizes the exposed drop and with moist materials (except under variance). Enclosed hopper cars are used.

6.7 BARGE AND SHIP LOADING AND UNLOADING

To ensure compliance with the 10-percent opacity limit, the Facility will perform all barge and ship unloading of BSM in a manner that minimizes the exposed drop. BSM, as received, generally meet the definition of moist material.

6.8 PAVING

Facility roads used for transporting Bulk Storage Materials are paved. The asphalt pavement is not susceptible to becoming windborne, and is sufficient to bear the expected level of traffic at the Facility.

6.9 ROADWAY CLEANING

Street sweeping is conducted on paved roads within the property:

a) The street sweeper is equipped with a water spray for use during no-freezing weather, and a vacuum system to mitigate Fugitive Dust during street sweeping;

b) The street sweeping frequency will be one time daily when the Facility is open for business, unless the roads are free and clear of bulk solid material that could become airborne; and

c) Each day the Facility documents whether the roads are free and clear of bulk solid material that could become airborne. The record shows the date and time when the street sweeping was performed.

6.10 SPILLED MATERIAL

The Facility maintains areas within the Facility not regularly used for storage of material free of any spilled or misplaced material by removing such material by the end of each work shift.

7.0 RECORDKEEPING SYSTEM

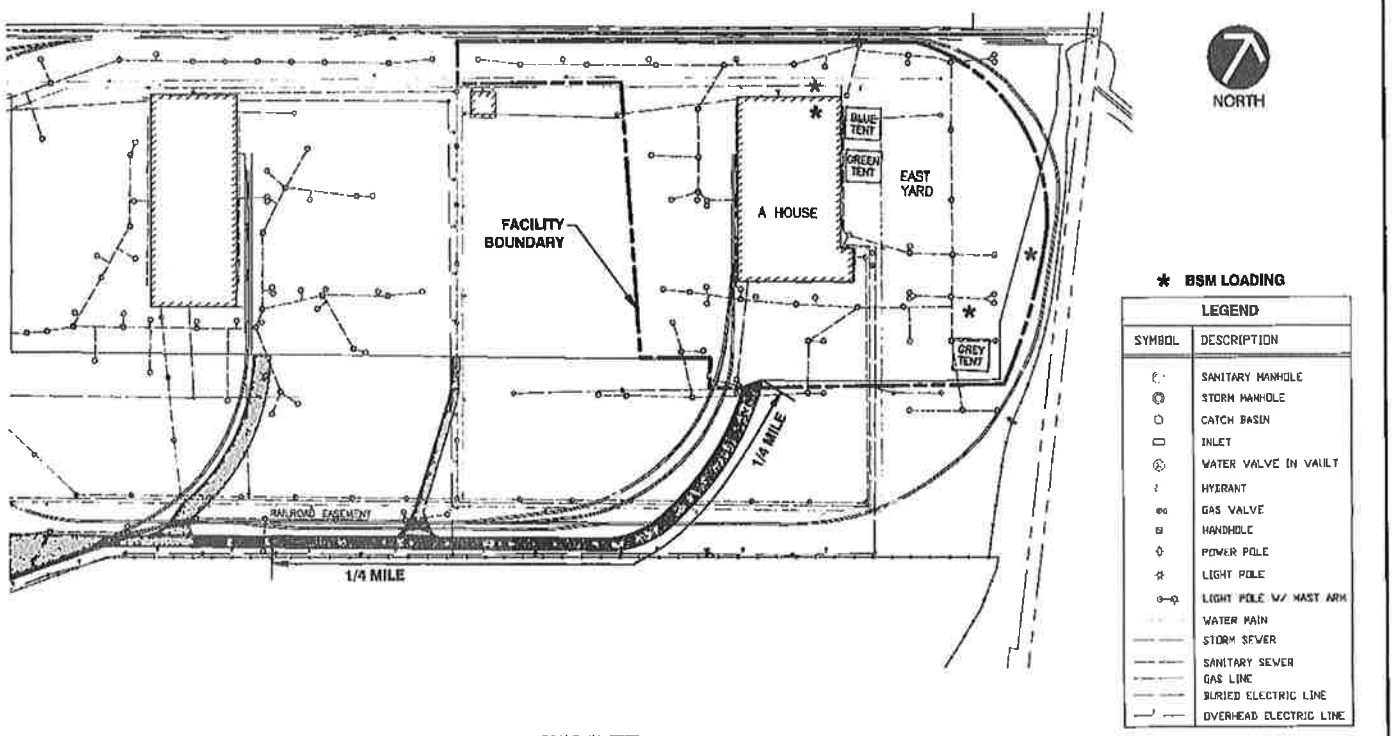
The Facility maintains a BSM Daily Log as follows:

a) Record daily, roadway condition, cleaning and street sweeping.
b) Record loaders and outgoing trucks are visually inspected (i.e. free of loose material).
c) Record BSM removed from dock within 24 hours and placed in enclosure.
d) Record each event of a leak and cleanup measures.
e) Record weather conditions, including temperature and precipitation.
f) All records required to be kept shall be kept and maintained at the Facility and be available for inspection for a minimum of three years from the date the record is created.
g) Normal business records will document for bulk solid materials: delivery, drying, bagging and loading.

8.0 REFERENCES

- ***Manual of Best Management Practices For Port Operations And Model Environmental Management System;*** L.A. Corson, Ph.D. and S.A. Fisher

- ***City of Chicago Department of Public Health Article II - Air Pollution Control Rules and Regulations For Control of Emissions from the Handling and Storage of Bulk Material Piles***, March 13, 2014



* HAND SIGNATURE ON FILE

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NORTH AMERICAN STEVEDORING COMPANY
CHICAGO, ILLINOIS

BULK SOLID MATERIALS FACILITY

DRAWN BY:	WRM	CHECKED BY:	RMP	APPROVED BY:	*WKG	FIGURE NO.:	1
DATE:	5/12/14	DWG SCALE:	1"=200'	PROJECT NO:	141-032		

REFERENCE

1. BASE MAP PROVIDED BY NASCO FROM "MASTER UTILITY PLAN" DATED: 2009.

P:\2014\141-032\-0000\Dwg\141032 Figure 1Bulk Solid Materials Facility.dwg{LAYOUT} LS:(5/12/2014 - [illegible]) - LP: 5/12/2014 4:53 PM

NASCO Daily Log
Bulk Solid Materials - Fugitive Dust Plan

Date	Time	Initials	Deg F	Precip	a Paving	b Trucks	c Dock	d Cleanup	Observations	Action/Date

Instructions: [Refer to Fugitive Dust Plan]

a	Note if roadway free of BSM which can become airborne; note if street sweeping done; if needed, note in Comments & Action taken
b	Confirm BSM loaders and departing trucks are visually inspected and free of loose material
c	Confirm unloaded BSM is moved to enclosure within 24 hours of unloading
d	Record event of leak of BSM from vehicle or equipment and cleanup steps taken
Observations	Describe condition noted such as residue or visible emissions.

Bulk Solid Material Facility
Iroquois Landing, Chicago, IL

ATTACHMENT B

DEMOGRAPHIC PROFILE (ECHO REPORT)

Menu

ECHO
Enforcement and
Compliance History Online

Detailed Facility Report

Facility Summary

NORTH AMERICAN STEVEDORING CO
9301 S KREITER AVE, CHICAGO, IL 60617

Facility Information (FRS)

FRS ID: 110005934249
EPA Region: 05
Latitude: 41.726304
Longitude: -87.537855
Locational Data Source: FRS
Industry:
Indian Country: N

Regulatory Interests

Clean Air Act: Operating Minor (1703105895)
Clean Water Act: No Information
Resource Conservation and Recovery Act: Inactive ( ) Other (ILR000006775)
Safe Drinking Water Act: No Information

Also Reports

Air Emissions Inventory (EIS): No Information
Greenhouse Gas Emissions (eGGRT): No Information
Toxic Releases (TRI): No Information

Enforcement and Compliance Summary

Statute	Insp (5 Years)	Date of Last Inspection	Current Compliance Status	Qtrs in NC (of 12)	Qtrs in Significant Violation	Informal Enforcement Actions (5 years)	Formal Enforcement Actions (5 years)	Penalties from Formal Enforcement Actions (5 years)	EPA Cases (5 years)	Penalties from EPA Cases (5 years)
CAA			**Noncompliance**	2	0	1				
RCRA			**No Violation**	0	0					

Facility/System Characteristics

Facility/System Characteristics

Statute	Identifier	Universe	Status	Areas	Permit Expiration Date	Indian Country	Latitude	Longitude
	110005934249					N	41.726304	-87.537855
CAA	1703105895	Other Minor	Operating	SIP		N		
RCRA	ILR000006775	Other	Inactive ( )			N	41.726708	-87.537375

Facility Address

System	Identifier	Facility Name	Facility Address
FRS	110005934249	NORTH AMERICAN STEVEDORING CO	9301 S KREITER AVE, CHICAGO, IL 60617
AFS	1703105895	NORTH AMERICAN STEVEDORING CO (FORMERLY	9301 S KREITER AVE, CHICAGO, IL 60617
RCR	ILR000006775	CERES TERMINALS INC	9301 S KREITER AVE, CHICAGO, IL 60617

Facility SIC Codes

System	Identifier	SIC Code	SIC Desc
AFS	1703105895	9999	

Facility NAICS Codes

System	Identifier	NAICS Code	NAICS Desc
AFS	1703105895	339999	All Other Miscellaneous Manufacturing

Facility Tribe Information

Tribal Name	EPA Tribal ID	Distance to Tribe (miles)
No data records returned		

Enforcement and Compliance

Compliance Monitoring History (5 years)

Statute	Source ID	System	Inspection Type	Lead Agency	Date	Finding
No data records returned						

Entries in italics are not considered inspections in official counts.

Compliance Summary Data

Statute	Source ID	Current SNC/HPV	Description	Current As Of	Qtrs in NC (of 12)
CAA	1703105895	No		02/15/2015	2
RCRA	ILR000006775	No		02/14/2015	0

Three Year Compliance Status by Quarter

Statute/Program/Pollutant/Violation Type	QTR 1	QTR 2	QTR 3	QTR 4	QTR 5	QTR 6	QTR 7	QTR 8	QTR 9	QTR 10	QTR 11	QTR 12
CAA (Source ID: 1703105895)	10/01-12/31 2011	01/01-03/31 2012	04/01-06/30 2012	07/01-09/30 2012	10/01-12/31 2012	01/01-03/31 2013	04/01-06/30 2013	07/01-09/30 2013	10/01-12/31 2013	01/01-03/31 2014	04/01-06/30 2014	07/01-09/30 2014
Facility-Level Status	No Viol	No Viol	No Viol	No Viol	No Viol	No Viol	No Viol	No Viol	No Viol	No Viol	In Viol	In Viol
HPV History												

Statute	Program/Pollutant/Violation Type	QTR 1	QTR 2	QTR 3	QTR 4	QTR 5	QTR 6	QTR 7	QTR 8	QTR 9	QTR 10	QTR 11	QTR 12
	Program/Pollutant in Current Violation												
CAA	SIP											V-EM&PRO	V-EM&PRO
	FACILITY-WIDE PERMIT REQUIREMENTS												V-EM&PRO

Statute	Program/Pollutant/Violation Type	QTR 1	QTR 2	QTR 3	QTR 4	QTR 5	QTR 6	QTR 7	QTR 8	QTR 9	QTR 10	QTR 11	QTR 12
RCRA (Source ID: ILR000006775)		01/01-03/31 2012	04/01-06/30 2012	07/01-09/30 2012	10/01-12/31 2012	01/01-03/31 2013	04/01-06/30 2013	07/01-09/30 2013	10/01-12/31 2013	01/01-03/31 2014	04/01-06/30 2014	07/01-09/30 2014	10/01-12/31 2014
RCRA Facility-Level Status													

Informal Enforcement Actions (5 Years)

Statute	Source ID	Type of Action	Lead Agency	Date
CAA	1703105895	STATE NOV ISSUED	State	04/22/2014

Formal Enforcement Actions (5 Years)

Statute	Source ID	Type of Action	Lead Agency	Date	Penalty	Penalty Description
No data records returned						

ICIS Case History (5 years)

Primary Law/Section	Case No.	Case Type	Lead Agency	Case Name	Issued/Filed Date	Settlement Date	Federal Penalty	State/Local Penalty	SEP Cost	Comp Action Cost
No data records returned										

Environmental Conditions

Water Quality

Permit ID	Watershed (HUC 8)	Watershed Name (HUC 8)	Watershed (HUC 12)	Watershed Name (HUC 12)	Receiving Waters	Impaired Waters	Combined Sewer System?
110005934249	04040001	LITTLE CALUMET-GALIEN	040400010603	Calumet River-Frontal Lake Michigan		No	

Air Quality

Non-Attainment Area?	Pollutant(s)
Yes	Ozone
No	Lead
Yes	Particulate Matter

Pollutants

TRI History of Reported Chemicals Released in Pounds per Year at Site ①

TRI Facility ID	Year	Total Air Emissions	Surface Water Discharges	Off-Site Transfers to POTWs	Underground Injections	Releases to Land	Total On-site Releases	Total Off-site Releases
No data records returned								

TRI Total Releases and Transfers in Pounds by Chemical and Year

Chemical Name
No data records returned

Demographic Profile

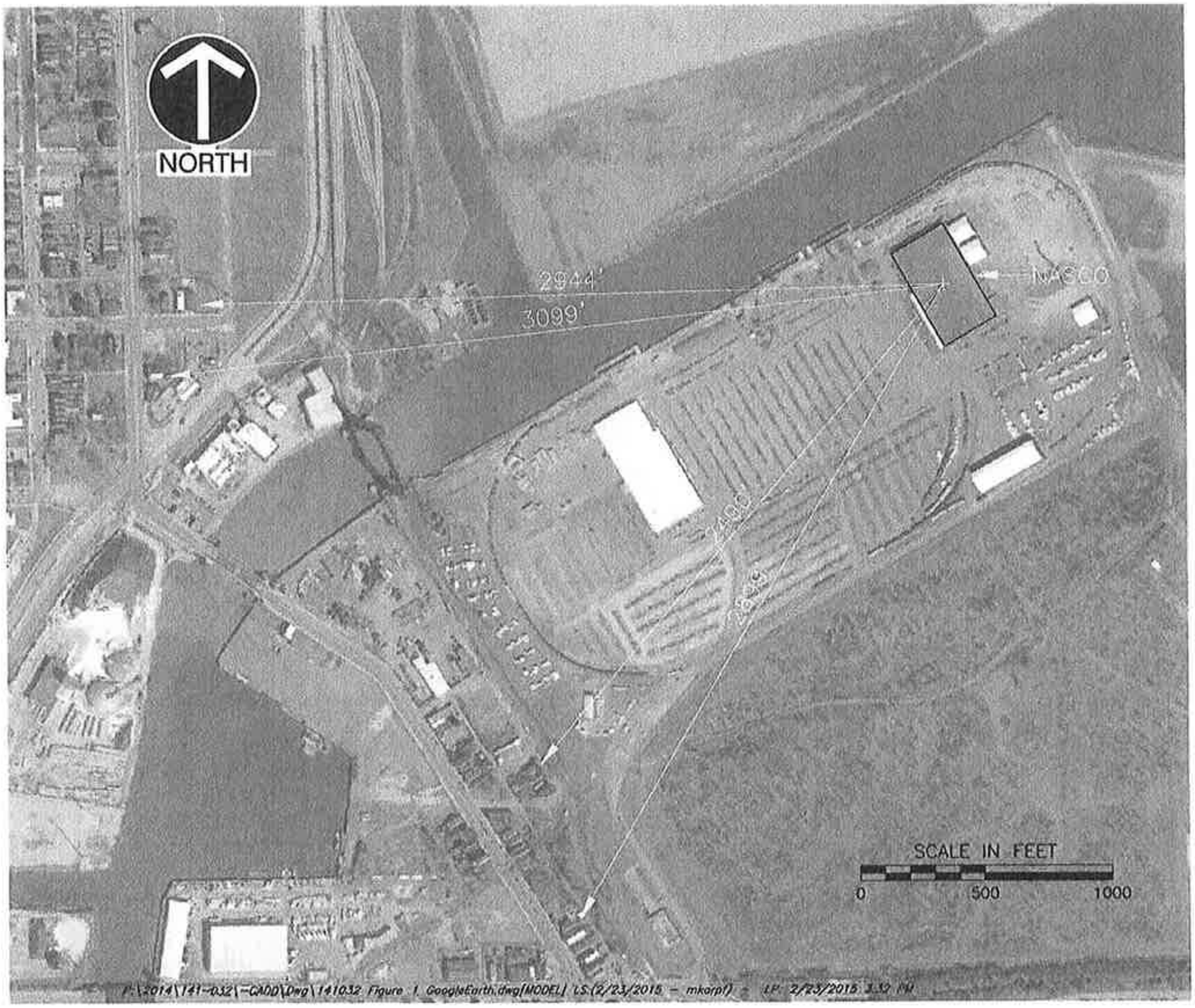
Demographic Profile of Surrounding Area (1 Mile)

This section provides demographic information regarding the community surrounding the facility. ECHO compliance data alone are not sufficient to determine whether violations at a particular facility had negative impacts on public health or the environment. Statistics are based upon the 2010 US Census and American Community Survey data, and are accurate to the extent that the facility latitude and longitude listed below are correct. The latitude and longitude are obtained from the EPA Locational Reference Table (LRT) when available.

Radius of Area:	1	Land Area:	87%	Households in Area:	4,245
Center latitude:	41.726304	Water Area:	13%	Housing Units in Area:	5,257
Center Longitude:	-87.537855	Population Density:	5,266/sq.mi.	Households on Public Assistance:	139
Total Persons:	13,230	Percent Minority:	95%	Persons Below Poverty Level:	9,239

Race Breakdown	Persons (%)	Age Breakdown	Persons (%)
White:	4,046 (30.58%)	Child 5 years and younger:	1,281 (9.68%)
African-American:	4,563 (34.49%)	Minors 17 years and younger:	4,408 (33.32%)
Hispanic-Origin:	7,983 (60.34%)	Adults 18 years and older:	8,822 (66.68%)
Asian/Pacific Islander:	36 (.27%)	Seniors 65 years and older:	1,437 (10.86%)
American Indian:	192 (1.45%)		
Other/Multiracial:	4,393 (33.2%)		

Education Level (Persons 25 & older)	Persons (%)	Income Breakdown	Households (%)
Less than 9th Grade:	1,730 (23.97%)	Less than $15,000:	1,247 (29.49%)
9th through 12th Grade:	1,045 (14.48%)	$15,000 - $25,000:	677 (16.01%)
High School Diploma:	2,336 (32.37%)	$25,000 - $50,000:	1,365 (32.28%)
Some College/2-yr:	1,523 (21.1%)	$50,000 - $75,000:	456 (10.79%)
B.S./B.A. or More:	583 (8.08%)	Greater than $75,000:	483 (11.42%)


NORTH
2944'
3099'
NASCO
2400'
2583'
SCALE IN FEET
0
500
1000
P:\2014\141-032\-CADD\Dwg\141032 Figure 1 GoogleEarth.dwg[MODEL] LS:(2/23/2015 - mkorpf) - LP: 2/23/2015 3:32 PM

ATTACHMENT C

COST ESTIMATE FOR DUST MONITORING (BAM-1020)

Dust Monitoring Budgetary Cost
Annual Operation

Task	**Unit Rate**	**Estimated Days and Units**	**Estimated Cost**
TASK 1 Quality Assurance Project Plan	$6,750.00	Lump Sum	$6,750.00
TASK 2 Project Mobilization			
Labor	$8,500.00	Lump Sum	$8,500.00
Expenses	$2,500	Lump Sum	$2,500.00
10-meter Met Station w/solar	$12,500.00	1	$12,500.00
Met Station Installation	$7,500.00	1	$7,500.00
Battery powered dust monitoring station	$10,000.00	4	$40,000.00
Solar Option for dust monitors	$750.00	4	$3,000.00
Radio Telemetry to Local PC	$9,500.00	1	$9,500.00
TASK 3 Perimeter Monitoring Station Operation			
Labor (Assumes technician 8 hours a week at $75/hr)	$600.00/week	52	$31,200.00
Labor Senior Review (Assumes 2 hours week at $195/hr)	$390.00	52	$20,280.00
Expenses (Monitor parts/supplies)	$5,000.00	1	$5,000.00
TASK 4 Data Management			
Labor (Assumes 8 hrs/week at $105/hr	$840.00	52	$43,680.00
TASK 5			
Annual Summary Report			
Labor (1)	$8,500.00	Lump Sum	$8,500.00
Expenses	$500	Lump Sum	$500.00

Notes:

(1)-Reporting costs based on one year of operation and data collection

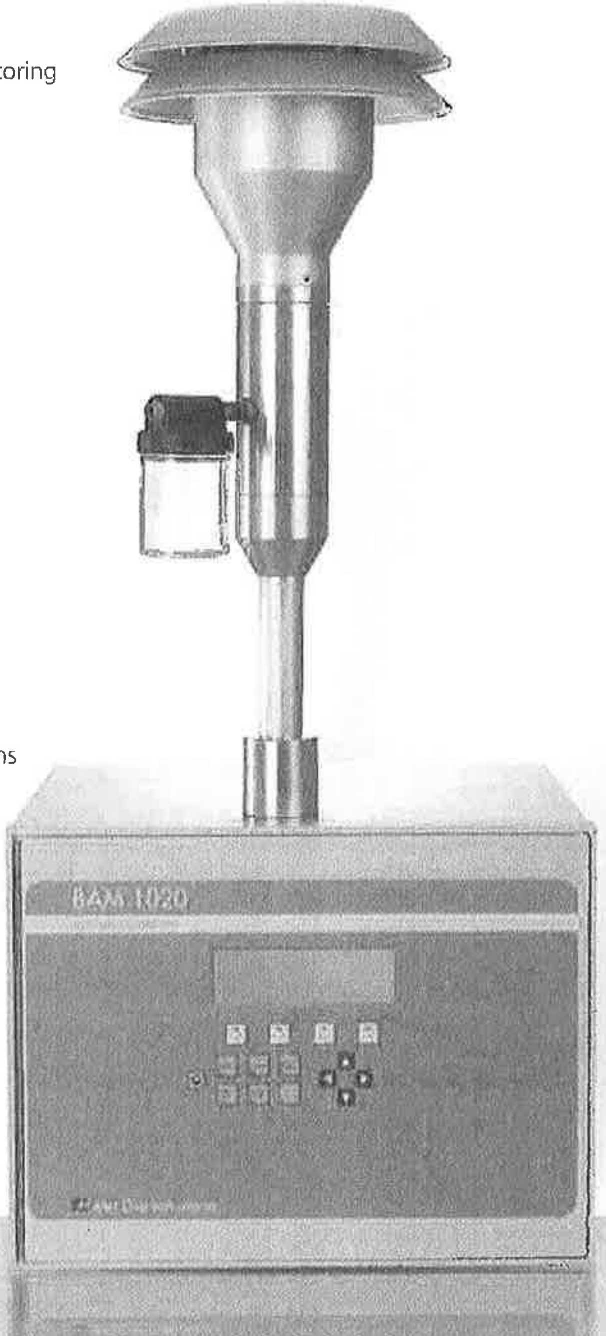
BAM-1020

Continuous Particulate Monitor

Met One Instruments, Inc.

Features

- U.S. EPA Equivalent Method for PM_{10}, $PM_{2.5}$, and $PM_{10-2.5}$ monitoring
- Long term unattended remote operation of up to 60 days between site visits
- Very low operating costs
- Automatic Span Calibration checks
- Fast and easy field audits using common FRM audit tools
- Bench top or equipment rack mounting in mobile or stationary shelters
- Rugged anodized aluminum, stainless steel, and baked enamel construction
- Highly accurate, reliable, and mechanically simple flow system
- Hourly filter advances minimize effects on volatile compounds
- Advanced Smart Heater technology precisely controls sample relative humidity
- Integrated datalogger allows the connection of up to six meteorological sensors
- Data retrieval through RS-232 serial ports using direct PC connections, modems, printers, or digital data collection systems



Designations

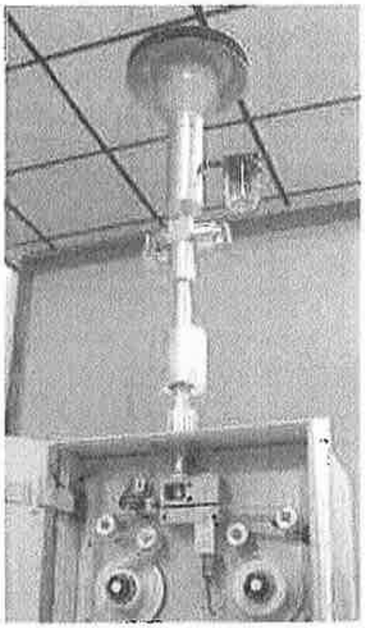
The Met One Instruments Model BAM-1020 was the first instrument to obtain U.S. EPA Federal Equivalent Method (FEM) designation for continuous $PM_{2.5}$ monitoring, in addition to its longstanding EPA designation for PM_{10} monitoring. The BAM-1020 has also obtained the corresponding $PM_{2.5}$ and PM_{10} certifications in the European Union. Two BAM-1020 units can also be operated together as an EPA designated $PM_{10-2.5}$ coarse method. Met One Instruments supplies complete sampling accessory kits for compliance with each designation.

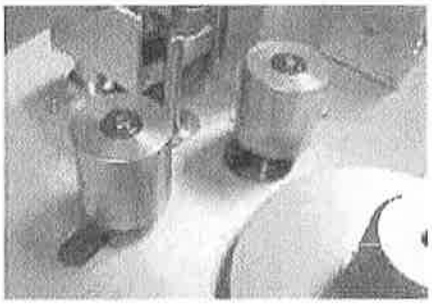
Principle

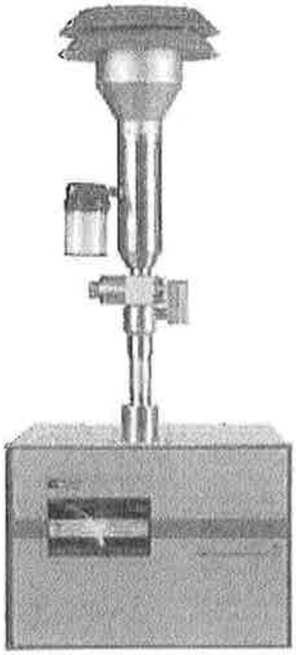
The BAM-1020 automatically measures and records airborne particulate concentration levels (in milligrams or micrograms per cubic meter) using the industry-proven principle of beta ray attenuation Thousands of BAM-1020 units are currently deployed worldwide, making the unit one of the most successful air monitoring platforms in the world

Operation

At the beginning of each sample hour, a small ^{14}C (carbon-14) element emits a constant source of high-energy electrons (known as beta rays) through a spot of clean filter tape. These beta rays are detected and counted by a sensitive scintillation detector to determine a zero reading. The BAM-1020 then advances this spot of tape to the sample nozzle, where a vacuum pump pulls a measured and controlled amount of outside air through the filter tape, loading it with ambient dust. At the end of the sample hour, this dust spot is placed back between the beta source and the detector, thereby causing an attenuation of the beta ray signal which is used to determine the mass of the particulate matter on the filter tape. This mass is used to calculate the volumetric concentration of particulate matter in ambient air.







Data Collection

All data files are accessible via an industry standard two-way RS-232 serial port using common terminal programs or Met One Instruments software such as Air Plus™ and Comet.™ The data is available in a variety of formats including daily reports, last record, all data, and new records since last download. Configuration files, error logs, and flow statistics are also available. Optional Ethernet and USB data collection support is also available.

Error Handling

The BAM-1020 performs continuous user selected evaluation of a variety of criteria for data validation including flow statistics and a comprehensive set of error codes including power failures, flow failures, hardware failures, tape errors, nozzle errors, span check errors, beta count errors, and more.

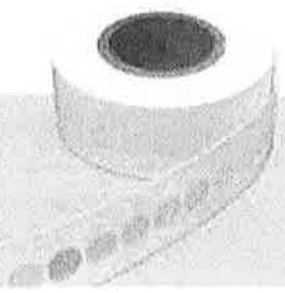
Maintenance

The BAM-1020 is designed to run continuously with only monthly or bi-monthly scheduled maintenance—a single roll of filter tape will last more than 60 days. The BAM-1020 also contains a comprehensive self-test function which allows the unit to preemptively test itself for any mechanical failures in the tape control system.

Specifications BAM-1020

PARAMETER	SPECIFICATION
Operating Principle	Measures ambient particulate concentrations using beta ray attenuation
U.S. EPA Designations	Class III FEM, PM_{10} (EQPM-0798-122) $PM_{2.5}$ (EQPM-0308-170) $PM_{10-2.5}$ (EQPM-0709-185)
EU Certifications	TUV Rheinland, $PM_{2.5}$ (936/21209919/A) PM_{10} (936/21205333/A, 936/21220762/A)
PERFORMANCE	
Accuracy	Exceeds U.S. EPA Class III $PM_{2.5}$ FEM standards for additive and multiplicative bias*
Measurement Resolution	0.24 µg in 1mg range, 2.4 µg in 10mg range, 12 bit resolution
Data Resolution	1 µg/m^3
Data Interval	Hourly concentration values. Met sensor averages from 1 to 60 min
Hourly Detection Limit (2σ)	< 4.8 µg/m^3 (3.6 µg/m^3 typical)
24 Hour Detection Limit	< 1.0 µg/m^3
Range	1 mg (1000 µg) default setting. Settable from 0.1 mg to 10 mg
Measurement Cycle Time	1 hour
Flow Rate	16.7 liters per minute, actual or standard flow conditions
Filter Tape	Glass fiber filter tape, 60 days of operation per roll
Span Check	Automatic 0.8 mg span membrane verification with ±5% deviation alarms
Beta Source	^{14}C (carbon -14), 60 µCi ±15 µCi (< 2.22 x 106 Beq), half-Life 5730 years
Beta Detector Type	Photomultiplier tube with organic plastic scintillator
ENVIRONMENTAL	
Operating Temperature	0° to +50°C (inside shelter)
Ambient Temperature	-40° to +55°C (BX-596 AT sensor) -30 to +50C (BX-592). Extended range sensors available
Ambient Humidity	0 – 90% RH, noncondensing
Sample Humidity Control	Active inlet heater module with internal filter RH and temperature sensors
Enclosure	Weatherproof enclosure or shelter is required
INTERFACE	
User Interface	Standard 8x40 character LCD with dynamic keypad. Optional color touch screen
Analog Output	Isolated 0 –1 VDC output standard. 0 –10 V, 4–20 mA, 0 –16 mA switch-selectable
Serial Interface	RS-232 serial port with USB converter. Ethernet and expanded serial ports with BX-965 option
Printer Output	Output-only serial port for data or diagnostic output to a PC or serial printer
Telemetry Inputs	Clock reset (voltage or contact closure), telemeter fault (contact closure)
Alarm Contact Closures	Data error, tape fault, flow error, power failure, maintenance
Error Reporting	User-configurable available through serial port, display, and relay outputs
Memory	4369 records (182 days at 1 record/hr). Expanded memory with BX-965 option
ELECTRICAL	
Power Supply	Factory configured for 100/120 or 220/240 VAC and 50 or 60 Hz. Dedicated 15A service OK
Power Consumption 110V	262W max with Medo pump and inlet heater running (642W with Gast pump)
Power Consumption 230V	312W max with Medo pump and inlet heater running (717W with Gast pump)
PHYSICAL	
Weight	54 lbs (24.5 kg) without external accessories.
Unit Dimensions	Height = 12.25" (31 cm) Width = 17" (43 cm) Depth = 16" (40 cm).

*Slope and offset bias in linear regression with reference method samplers at low concentrations. See 40 CFR part 53.



Standard Equipment

- Operation Manual and Quick Setup Guide
- Internal Automatic Span Membrane
- Internal Flow Sensor and Flow Controller
- Internal Filter Temperature, Pressure, and RH Sensors
- Six Channel Data Logger for Accessory Sensors
- Serial Data Cable and Modular Power Cable
- Pump Control Cable and Air Tubing
- Rack Mounting Brackets and Hardware
- Comet™ Data Collection Software
- One Roll of 460130 Glass Fiber Filter Tape

Complete Sampling Accessories Kits (Pumps Separate)

- BX-FEM$_{2.5}$ Accessories kit for EPA PM$_{2.5}$ configuration
- BX-2.5EU Accessories kit for EU PM$_{2.5}$ configuration
- BX-2.5 Accessory kit for non-regulatory PM$_{2.5}$
- BX-10 Accessories kit for EPA PM$_{10}$ configuration
- BX-10EU Accessories kit for EU PM$_{10}$ configuration
- BX-COARSE Accessories kit for EPA PM$_{10\text{-}2.5}$ dual-unit configuration

BX-965 Report Processor Option

This upgraded back panel assembly has expanded digital communications support including Ethernet, an autonomous REPORT serial port with expanded memory, and the capability to serially network two BAMs together in the PM-coarse configuration. BX-965 is recommended for all BAMs where data is collected digitally.

BX-970 Touch Screen Display

This upgraded front door assembly consists of a high visibility color touch screen display with simplified menu navigation. The system also allows BAM-1020 data to be transferred to a USB flash drive. All touch screen units also come with a BX-965 Report Processor back panel.

BX-894 Real-Time Module Option

This add-on light scatter module allows the BAM to log real-time particulate trending levels on any unused met sensor input channel, without interfering with the high accuracy beta system measurements in any way.

Rev July 2013

Individual Sampling Accessories and Options

- BX-121 & BX-122 High Capacity Gast Pump
- BX-126 & BX-127 Low Noise Medo Pump
- BX-802 EPA Louvered PM$_{10}$ Inlet
- BX-808 BGI PM$_{2.5}$ VSCC™ Cyclone
- BX-807 BGI PM$_{2.5}$ Sharp Cut Cyclone
- BX-811 BGI PM$_{1}$ Sharp Cut Cyclone
- BX-827 & BX-830 Smart Inlet Heater
- BX-803 TSP Inlet with Debris Screen
- BX-302 Zero Filter Audit Kit with Leak Valve
- BX-305 Leak Check Valve with Hose Barb
- BX-344 Inlet Cleaning Kit
- BX-308 Service Tool Kits
- BX-590 Wind Direction Sensor
- BX-591 Wind Speed Sensor
- BX-592 Ambient Temperature Sensor
- BX-593 Ambient RH sensor
- BX-594 Barometric Pressure Sensor
- BX-595 Solar Radiation Sensor
- BX-596 Ambient Temperature and Pressure Sensor
- BX-902B, BX-903, & BX-906 Weatherproof Mini Shelter Kits
- BX-801 Standard 8' Inlet Tube Kit With Roof Flange
- 8112-X Custom length inlet tubes, up to 8 feet per segment
- Inlet tube extension kits, up to 16 feet total
- Phone, cellular, radio, and satellite modem kits

Met One Instruments, Inc.

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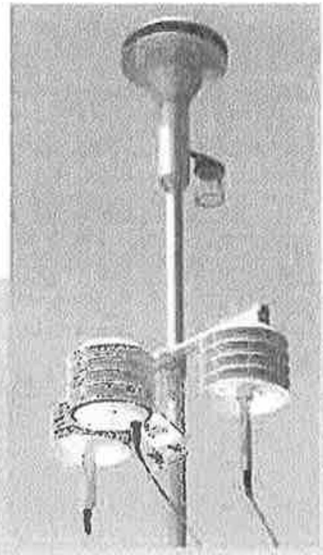
E-mail: sales@metone.com | **www.metone.com**



ATTACHMENT D

SWEEPING LOGS

North America Stevedoring - Sweeping Log

Date	Driver	Area Swept	Signature
10/29/14	DC	B House A House	
		sale ARcA MAnt AREA	
11-3/14		A House / Dock in front of	
		A house Main Road's	
		Maintence ARcA	
11-4-14		A House Dock font of	
		A house Main Rd.	
		Maintacnce ARcA	
11-5-14		Salt ARAE Main sale	
		Main Road's A House	
11-10-14		Main Road's / scale around scale	
		Dock By A House.	
11-11-14		The 42, Main Road's A House	
		Maintance ARea Dock By A House	
11-12-14		Dock Main Road's	
11-14-14	DC	B House CN Road	
		By Nugget Pile front	
		A House.	

North America Stevedoring - Sweeping Log

Date	Driver	Area Swept	Signature
10/6/14	DC	A House front of Maintanee shop B House, C-N [illegible] Tent South Side A House	
10/7/14	DC	A House / B House ' by scale Maintance AREA [illegible] [illegible] [illegible] Main Roads	
10/8/14	DC	swept up salt By scale & front of salt Tent.	
10/10/14	DC	East & South side scale Main Rd Maintenace	
[illegible]			
10-17-14		Dock, East side of scale Main Road's	
10-21-14		42 Road. A House around and on scale. B House CN tent on Road MANT. AREA	
10-22-14		main gate Main Road's By scale A House Mantance AREA	
10-24-14		A House B House Dock scale By the scale mantance Are	

North America Stevedoring - Sweeping Log

Date	Driver	Area Swept [redacted]	Signature
9/9/14	DC	Main Road's Main gate	
		Mant AREA A House	
9/10/14	DC	A House Main Road's	
		sucked up wateR Main gate	
	9-15-14	Tranning on new Machine	
	Throu 9-18-14	swept little Area's	
9-19-14		Crane AREA, Bulk sidE A House	
		B House	
9-30-14	DC	A-House Dock In front of	
		A House Main gate Main Road's	
10-2-14	DC	Dock, In front of A House	
		Inside B. House Inside A house	
		Main Road's Maintance AREA	
10-3-14	DC	Front of A House / Dock AREA	
		Main Roads A House Maintance	
		AREA B House AREA By	
		Scale	
		10-3-14	

North America Stevedoring - Sweeping Log

Date	Driver	Area Swept	Signature
8-18-14	DC	Main gate Main Road's	
		Mant. AREA	
8-20-14	DC	Mant AREA front of A House	
		Main gate Main Road's	
8-21-4		[illegible]	
8-2[illegible]-14	DC	Main gate Main Road's	
8-2[illegible]-14	DC	Main gate Main Road's	
		Mant. AREA	
8-28-14	DC	Mant. AREA Main gate	
		Main Road's scale	
		South side Scale House	
9-2-14		A House bulk side main Rd	
		MANT ARE S. side scale House	
		Main gate	
9-3-14	DC	Dock In front of A House	
		Main Road's	

North America Stevedoring - Sweeping Log

Date	Driver	Area Swept	Signature
7-21-14	DC	Main Road's Main gate	
		Maintance Area	
7-22-14	DC	A House Main gate Main Road's	
		Mantnce ARea	
7-31-14	DC.	Main Road Main gate	
		Mantance AREA.	
8-5-14		Blue Tent - CN tent - CN Road	
		Main Road's Main gate	
8-6-14	DC	Main Road's B House Dock	
		Main gate Mants AReA	
8-12-14	[redacted]	Main Road's coil side - A House	
		Main gate C-N - Road	
8-13-14		LP Damage Area C-N Building	
		Main Road's Mant. AREA	
		C-N Road	
8-14-14		Main Road's CN Building	
		Mant. AREA Pig Iron AREA	
		Main Gate	

North America Stevedoring - Sweeping Log

Date	Driver	Area Swept	Signature
7-14-14	DC.	Main Road's Main gate	
		In front of A House	
		Dock AReA Mant. AReA	
		Inside A House coil side	
[illegible]			
7-15-14	DC.	Dock, Main Road's Maingate	
		Nw corner B House Mant. AREA	
7-16-14		Dock Main Road's	
		Mant. AReA [illegible] gray Tent	
7-17-14		Dock Main Road's	
		Main gate Mant. AReA	

North America Stevedoring - Sweeping Log

Date	Driver	Area Swept	Signature
6-30-14		Main Road'S Main gates	
		Dock' [redacted]' sucked up water	
		swept In side A House By scale	
7-1-14		sucked up water	
7-2-14		Dock by A House	
		Main Road's Maingate	
		Maint. AREA	
7-3-14		mant AREA	
7-7-14		Main Road's Main gate	
		Mant. AREA sucked up	
		water Diesel area Inside A House	
		Coilside	
7-8-14		C.N Building sucked up water	
		Everywhere A House / MANT AREA	
		Main gate Main Road's Dock side	
7-9-14		Maintance AREA main Road's	
		Dock AReA MAin gate	
7-10-14		Maintance AREA Main Road's	
7-11-14		Dock side	

North America Stevedoring - Sweeping Log

6-23-14 — 6-26-14

Date	Driver	Area Swept	Signature
6-23-14		Magt. AReA Main Road's	
	DC	Main gate, Dock AReA	
6-24-14	DC	Main Road's Maingate	
		Dock AReA sucked up	
		water All over And fuel AReA	
6-25-14			
6-26-14	DC	Dock AReA Around A House	
		Main Road's Main Gate	
		Mant. AReA. Inside A House	
6-27-14	DC	Main Road's Main gate	
		Maintance ARea ~~[illegible]~~ E. side	
		BHouse	

26/10

North America Stevedoring - Sweeping Log

Date	Driver 6-16 - 620-14	Area Swept	Signature
6/16/14	DC	Mant. AREA Main Road's	
		Main gate	
6-17-14	DC	Dock side Main Road's	
		Maingate spot's where pig Iron was	
		South side A House.	
6-18-14	DC	Main gat Main Road's Mant AREA	
		Aloond A House sucked up water	
		Diesel areA	
6-[illegible]-14	DC	Main Road's Maingate	
		Mant. AReA Magelina side	
		sucked up water allover	
		Dock side	
[illegible]	[illegible]		
6-20-14	DC	Sucked up water everywhere	
		Dock AReA Main Road's	
		Main gate Mant. AReA	
		CN Building & Road	

North America Stevedoring - Sweeping Log

Date	Driver I. David J Camp	Area Swept	Signature
6/9/14	DC	Main gate, Main Road's Mant. AREA Dock in front of A House fuel AREA sucked up water	David J Camp
6/10/14	DC	Main gate Main Road's South 3 East side of scale East side B house In front of A House sucked up water & swept	
6/11/14	DC	sucked up water A House & In front of A House, fuel AREA swept Mant. AREA Main gate Main Road's	
6/12/14	DC	EAST END of Dock, Main Road's, By the scale Maingate ARound B House	
6-13-14	DC	Main gate Main Road's Mant. AReA By scale House	

North America Stevedoring - Sweeping Log

Date	Driver David Camp	Area Swept	Signature
6-2-14	DC	Main Road's main gate	
		Dock By A House	
		Scale area water In A House	
6-3-14		1/2 Road Main gate Main Road's	
		scale side Around B House	
		Diesel Area front office	
6-4-14		Main Road's Main gate	
		sucked up water Diesel Area	
6.5.14		Main Road's Main gate	
		Diesel Arean CN tent	
		CN Road	
6-6-14		Main Road's Main gate	
		CN Road Diesel Area	

North America Stevedoring - Sweeping Log

Date	Driver David Camp	Area Swept
5-27-14		Cn - Building Maingate
		Main Road AHouse
5-28-14		CN Building Main gate
		Main Roads Mant. area
		sucked up wateR fuel AReA
5-29-14		LP ARound A House
		Main gate Main Road
		Mant AReA
5-30-14		Main gate , Main Road
		Dock In front A House
		scale AReA ARound Cn Bulidi

[redacted]

North America Stevedoring - Sweeping Log

David J Camp

Date	Driver	Area Swept
5-19-14	DC	No Sweeping / Not Here
5-20-14	DC	Main Road's, Lpside, parts of
		The Dock. MAint. AREA
5-21-14	DC	Sucked up water A House &
		fueling AREA "BP" CN Building
		Main Roads Maintance AREA
		washed truck.
5-22-14	DC	Main Road's Mant. AREA
5-22-14	DC	Main Road'S, Main gate
		Dock AREA front of A House
		C-N Road And Building
		Maintance AREA

North America Stevedoring - Sweeping Log

Date	Driver David Camp	Area Swept
5-12-14	D.C	~~[illegible]~~ east side of Dock
		Main gate Main Road'S
		AHouse - sucked up wateR
		fuel satiton sucked up wateR
		AHOUSE
5-13-14	DC	wateR in A House / ~~[illegible]~~
		tanker AREA, MAIn RoadS
		MAin gate C-N-Building & Road
		MAintance ARcA
5-14-14	DC	Dock AREA MAin gate
		Main Road'S Maintance
5-15-14	DC	MAin Road's, AHouse
		MAin Ent. ~~[illegible]~~ sucked up
		water TAnkeR AREA &
		Dock
5-16-14	DC	sucked water upon Dock &
		fuel satition. Main Road's
		Main gates Aroond C-N Building

North America Stevedoring - Sweeping Log

Date	Driver	Area Swept
4-21-14	David CAmp	CN Building Mant. AReA Around A House Main gate
	All	Main Road's Front of office BHouse
4 22-14	David Camp	sucked up water In tanker area
		North East corner "All Main Road Mant ARea
		Main gate Dock AReA
4 23-14	DAvid CAmp	Main sts AHouse south side
		A House Dock side Main gate
4-24-14	" DC "	EAst side BHouse Main gate
		All Mainsts Mant AReA
4-25-14	DC	Dock By Building A, CN Road
		Maingate All main Road's
		Mant. AREA Dock By A Building ②
4-28-14	DC	The 42 All Main Road's
		MAnt. AReA- TAnkeR ARea
4-29-14	[illegible]	The 42 [illegible] Around The CN Building
4-30-14	DC	MAnt. ARea Main Roads Maingate
		Around A Building fuel AREA, LP AREA
5-1-14	DC	CN Building MAin Road's Road 42
		MAnt. AReA.
[illegible] 5-2-14	DC	MAin Road's, 42. Around A Build
		MAnt. AREA.
[illegible]	[illegible]	Part of the Dock AREA
5-8-14	DC	MAin Road's southside A House
		Across from Dock AReA
5-9-14		MAin Road's Dock AREA
		Around A & B house
		MAnt. AReA

ATTACHMENT E

FDP DAILY LOGS

NASCO Daily Log
Bulk Solid Materials - Fugitive Dust Plan

Date	Time	Initials	Deg F	Precip	a Paving	b Trucks	c Dock	d Cleanup	Observations	Action/Date
12/31	13:45	SP	32°	NONE	OK	OK	N/A	NO Sweeping	Conditions OK	
1/2	13:15	SP	37°	Light Rain	OK	OK	N/A	No Sweeping	Conditions OK	
1/5	13:30	SP	12°	None	OK	OK	N/A	No Sweeping	Conditions OK	
1/6	13:30	SP	8°	None	NOT OK	OK	N/A	No Sweeping	Conditions Dirty outside WHSE	1/6 Clean outside WHSE
1/7	13:30	SP	20°	Heavy Snow	OK	OK	N/A	NO Sweeping	Conditions OK	
1/8	13:00	SP	16°	Light Snow	OK	OK	N/A	NO Sweeping	Conditions OK	
1/9	13:30	SP	26°	None	OK	OK	N/A	NO Sweeping	Conditions OK	
1/12	13:30	SP	23°	Light Snow	OK	OK	N/A	No Sweeping	Conditions OK	
1/13	13:15	SP	21°	None	NOT OK	OK	N/A	No Sweeping	Debris outside A-House	1/13 Shovel up Debris
1/14	13:00	SP	36°	None	OK	OK	N/A	No Sweeping	Conditions OK	
1/15	13:30	SP	35°	Fog	OK	OK	N/A	NO Sweeping	Conditions OK	
1/16	13:00	SP	44°	Light Mist	NOT OK	OK	N/A	No Sweeping	Debris outside A-House	1/16 Shovel up Debris
1/19	13:45	SP	40°	Light Rain	OK	OK	N/A	NO Sweeping	Conditions OK	
1/20	13:30	SP	36°	Light Rain	OK	OK	N/A	NO Sweeping	Conditions OK	

Instructions: [Refer to Fugitive Dust Plan]

a	Note if roadway free of BSM which can become airborne; note if street sweeping done; if needed, note in Comments & Action taken
b	Confirm BSM loaders and departing trucks are visually inspected and free of loose material
c	Confirm unloaded BSM is moved to enclosure within 24 hours of unloading
d	Record event of leak of BSM from vehicle or equipment and cleanup steps taken
Observations	Describe condition noted such as residue or visible emissions.

Bulk Solid Material Facility
Iroquois Landing, Chicago, IL

NASC aily Log
Bulk Solid Materials - Fugitive Dust Plan

Date	Time	Initials	Deg F	Precip	a Paving	b Trucks	c Dock	d Cleanup	Observations	Action/Date
1/21	13:00	SP	34°	FOG	ok	ok	ok	NO Sweeping	Conditions ok	
1/22	12:30	SP	34°	Light MIST	OK	ok	ok	NO Sweeping	Conditions ok	
1/23	14:30	SP	45°	NONE	ok	ok	ok	NO Sweeping	Conditions ok	
1/26	14:00	SP	33°	Light Snow	ok	ok	Ok	NO Sweeping	indoor Loading Conditions OK	
1/27	13:00	SP	36°	Light RAIN	OK	OK	OK	NO Sweeping	BSM LOADING INSIDE	
1/28	13:30	SP	39°	MIST	ok	ok	ok	NO Sweep	Conditions ok	
1/29	14:00	SP	32°	Light Snow	ok	OK	ok	NO Sweeping	Conditions ok	
1/30	12:00	SP	32°	NONE	ok	OK	ok	NO Sweeping	conditions ok	
2/2	13:15	SP	30°	SNOW	OK	Ok	ok	NO Sweeping	Low Activity conditions ok	
2/3	14:30	SP	30°	Light SNOW	ok	OK	ok	NO Sweeping	Conditions ok	
2/4	13:30	SP	17°	NONE	ok	OK	ok	NO Sweeping	Conditions ok	
2/5	13:00	SP	32°	NONE	ok	Ok	ok	NO Sweeping	Conditions Ok	
2/6	13:15	SP	44°	NONE	ok	ok	Ok	NO Sweeping	Conditions ok	
2/9	13:30	SP	28°	Light Snow	Ok	ok	N/A	NO Sweeping	Conditions ok	

Instructions: [Refer to Fugitive Dust Plan]

a	Note if roadway free of BSM which can become airborne; note if street sweeping done; if needed, note in Comments & Action taken
b	Confirm BSM loaders and departing trucks are visually inspected and free of loose material
c	Confirm unloaded BSM is moved to enclosure within 24 hours of unloading
d	Record event of leak of BSM from vehicle or equipment and cleanup steps taken
Observations	Describe condition noted such as residue or visible emissions.

Bulk Solid Material Facility
Iroquois Landing, Chicago, IL

NASCO Daily Log
Bulk Solid Materials - Fugitive Dust Plan

Date	Time	Initials	Deg F	Precip	a Paving	b Trucks	c Dock	d Cleanup	Observations	Action/Date
2/10	13:45	GP	29°	NONE	ok	ok	N/A	NO Sweeping	Ground wet Conditions ok	

Instructions: [Refer to Fugitive Dust Plan]

a	Note if roadway free of BSM which can become airborne; note if street sweeping done; if needed, note in Comments & Action taken
b	Confirm BSM loaders and departing trucks are visually inspected and free of loose material
c	Confirm unloaded BSM is moved to enclosure within 24 hours of unloading
d	Record event of leak of BSM from vehicle or equipment and cleanup steps taken
Observations	Describe condition noted such as residue or visible emissions.

Bulk Solid Material Facility
Iroquois Landing, Chicago, IL

ATTACHMENT F

COMPLIANCE COMMITMENT AGREEMENT
VN A-2014-00002

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

IN THE MATTER OF:	)	
	)	
North America Stevedoring Co.	)	
9301 S. Kreiter Avenue	)	
Chicago, Illinois 60617	)	
I.D. 031600GVM	)	
	)	ILLINOIS EPA VN A-2014-00002
	)	BUREAU OF AIR
	)	

COMPLIANCE COMMITMENT AGREEMENT

I. Jurisdiction

1. This Compliance Commitment Agreement ("CCA") is entered into voluntarily by the Illinois Environmental Protection Agency ("Illinois EPA") and North America Stevedoring Co.("Respondent") (collectively, the "Parties") under the authority vested in the Illinois EPA pursuant to Section 31(a)(7)(i) of the Illinois Environmental Protection Act ("Act"), 415 ILCS 5/31(a)(7)(i).

II. Allegations of Violations

2. Respondent operates a landing Marine Loading Terminal located at the mouth of Calumet and Lake Michigan, at 9301 S. Kreiter Ave, Chicago, Illinois 60617.

3. Pursuant to Violation Notice ("VN") A-2014-00002, issued on April 22, the Illinois EPA contends that Respondent has violated the following provisions of the Act, Illinois Pollution Control Board Regulations and permit conditions:

   a. Section 9(b) of the Act and 35 Ill. Adm. Code 201.142: North American Stevedoring Co. failed to obtain a construction permit from the Illinois EPA prior to constructing its barge, rail, and truck transfer terminal.

   b. Section 9(b) of the Act and 35 Ill. Adm. Code 201.143: North American Stevedoring Co. failed to obtain an operating permit from the Illinois EPA prior to operating its barge, rail, and truck transfer terminal.

   c. Section 9.14 of the Act and 35 Ill. Adm. Code 201.175: North American Stevedoring Co. may have failed to register for the Registration of Smaller Sources ("ROSS") program.

   d. Section 9.12 of the Act: North American Stevedoring Co. failed to pay applicable construction permit application fees.

e. Section 9(a) of the Act, 35 Ill. Adm. Code 212.309(a), 212.310, and 212.312: North American Stevedoring Co. failed to develop, implement and submit to the Illinois EPA an operating program designed to significantly reduce fugitive particulate emissions at the source.

f. Section 9.1(d) of the Act and 40 CFR 63.6595, 63.6603, 63.6605, 63.6612, 63.6615, 63.6620, 63.6625, 63.6630, 63.6640, 63.6645, 63.6650, and 63.6655: North American Stevedoring Co. may have failed to comply with the emission limitation standards, the corresponding operation, maintenance, and monitoring plan requirements, the testing and initial compliance requirements, the monitoring requirements, and the notification, reporting, and record keeping requirements of 40 CFR 63, Subpart ZZZZ – National Emission Standards for Hazardous Air Pollutants for Reciprocating Internal Combustion Engines.

III. Compliance Activities

4. On June 5, 2014, the Illinois EPA received Respondent's response to VN A-2014-00002, which included proposed terms for a CCA. The Illinois EPA has reviewed Respondent's proposed CCA terms, as well as considered whether any additional terms and conditions are necessary to attain compliance with the alleged violations cited in the VN.

5. Respondent agrees to undertake and complete the following actions, which the Illinois EPA has determined are necessary to attain compliance with the allegations contained in VN A-2014-00002:

a. Verify through signature of this document, that the facility does not handle or store petroleum based or metallurgical coke.

b. By August 15, 2014, submit to the Illinois EPA, Bureau of Air, Permit Section, a complete, true, ✓ accurate, and acceptable registration for the ROSS program. Additionally, submit a copy of the ✓ registration for the ROSS program to the Illinois EPA, Bureau of Air, Compliance Section.

c. By August 15, 2014, amend and submit to the Illinois EPA, Bureau of Air, Compliance Section, the Fugitive Dust Plan, to address the storage and handling of salt and Section 6.10 to address that spilled material will be cleaned up immediately. Verify through signature of this document, that the Fugitive Dust Plan will be developed in accordance with 35 Ill. Adm. Code 212.309 and 212.312 and be implemented and updated and maintained in accordance with 35 Ill. Adm. Code 212.309, 212.310, and 212.312.

d. Verify through signature of this document, that materials will not be stored outside of buildings, except for the purpose of immediate transfer or loadout.

e. Verify through signature of this document, that the 475 HP Emergency Generator is equipped with digital hour metered, operates in accordance with 40 CFR 63.6640(f).

f. By July 31, 2014, submit to the Illinois EPA, Bureau of Air, Compliance Section, the avoided construction fees in the amount of $1,500.00.

g. By July 31, 2014, submit to the Illinois EPA, Bureau of Air, Compliance Section, the avoided operating fees for the year 2006 through 2011 in the amount of $2,235.00.

IV. Terms and Conditions

6. Respondent shall comply with all provisions of this CCA, including, but not limited to, any appendices to this CCA and all documents incorporated by reference into this CCA. Pursuant to Section 31(a)(10) of the Act, 415 ILCS 5/31(a)(10), if Respondent complies with the terms of this

CCA, the Illinois EPA shall not refer the alleged violations that are the subject of this CCA, as described in Section II above, to the Office of the Illinois Attorney General or the State's Attorney of the county in which the alleged violations occurred. Successful completion of this CCA or an amended CCA shall be a factor to be weighed, in favor of the Respondent, by the Office of the Illinois Attorney General in determining whether to file a complaint on its own motion for the violations cited in VN A-2014-00002.

7. This CCA is solely intended to address the violations alleged in Illinois EPA VN A-2014-00002. The Illinois EPA reserves, and this CCA is without prejudice to, all rights of the Illinois EPA against Respondent with respect to noncompliance with any term of this CCA, as well as to all other matters. Nothing in this CCA is intended as a waiver, discharge, release, or covenant not to sue for any claim or cause of action, administrative or judicial, civil or criminal, past or future, in law or in equity, which the Illinois EPA may have against Respondent, or any other person as defined by Section 3.315 of the Act, 415 ILCS 5/3.315. This CCA in no way affects the responsibilities of Respondent to comply with any other federal, state, or local laws or regulations, including but not limited to the Act, the Board Regulations, and Respondent's Permit.

8. Pursuant to Section 42(k) of the Act, 415 ILCS 5/42(k), in addition to any other remedy or penalty that may apply, whether civil or criminal, Respondent shall be liable for an additional civil penalty of $2,000 for violation of any of the terms or conditions of this CCA.

9. This CCA shall apply to and be binding upon the Illinois EPA, and on Respondent and Respondent's officers, directors, employees, agents, successors, assigns, heirs, trustees, receivers, and upon all persons, including but not limited to contractors and consultants, acting on behalf of Respondent, as well as upon subsequent purchasers of Respondent's source.

10. In any action by the Illinois EPA to enforce the terms of this CCA, Respondent consents to and agrees not to contest the authority or jurisdiction of the Illinois EPA to enter into or enforce this CCA, and agrees not to contest the validity of this CCA or its terms and conditions.

11. This CCA shall only become effective:

    a) If, within 30 days of receipt, Respondent executes this CCA and submits it, via certified mail, to Raymond E. Pilapil, Illinois EPA, Bureau of Air, Compliance Section (MC 40), P.O. Box 19276, Springfield, IL 62794-9276. If Respondent fails to execute and submit this CCA within 30 days of receipt, via certified mail, this CCA shall be deemed rejected by operation of law; and

    b) Upon execution by all Parties.

12. Pursuant to Section 31(a) (7.5) of the Act, 415 ILCS 5/31(a)(7.5), this CCA shall not be amended or modified prior to execution by the Parties. Any amendment or modification to this CCA by Respondent prior to execution by all Parties shall be considered a rejection of the CCA by operation of law. This CCA may only be amended subsequent to its effective date, in writing, and by mutual agreement between the Illinois EPA and Respondent's signatory to this CCA, Respondent's legal representative, or Respondent's agent.

AGREED:

FOR THE ILLINOIS ENVIRONMENTAL PROTECTION AGENCY:

BY: ______________________ DATE: 1-15-15

Eric E. Jones
Manager, Compliance Unit, Bureau of Air

FOR RESPONDENT:

BY: ______________________ DATE: 7-31-14

[Signature of Company Official]

Ian R. Hirt
[Name of Company Official (please print)]

General Manager
[Job Title of Company Official]

REFERENCE 1

AP-42 CHAPTER 13, SECTION 13.2.5, NOVEMBER 2006

13.2.5 Industrial Wind Erosion

13.2.5.1 General[1-3]

Dust emissions may be generated by wind erosion of open aggregate storage piles and exposed areas within an industrial facility. These sources typically are characterized by nonhomogeneous surfaces impregnated with nonerodible elements (particles larger than approximately 1 centimeter [cm] in diameter). Field testing of coal piles and other exposed materials using a portable wind tunnel has shown that (a) threshold wind speeds exceed 5 meters per second (m/s) (11 miles per hour [mph]) at 15 cm above the surface or 10 m/s (22 mph) at 7 m above the surface, and (b) particulate emission rates tend to decay rapidly (half-life of a few minutes) during an erosion event. In other words, these aggregate material surfaces are characterized by finite availability of erodible material (mass/area) referred to as the erosion potential. Any natural crusting of the surface binds the erodible material, thereby reducing the erosion potential.

13.2.5.2 Emissions And Correction Parameters

If typical values for threshold wind speed at 15 cm are corrected to typical wind sensor height (7 - 10 m), the resulting values exceed the upper extremes of hourly mean wind speeds observed in most areas of the country. In other words, mean atmospheric wind speeds are not sufficient to sustain wind erosion from flat surfaces of the type tested. However, wind gusts may quickly deplete a substantial portion of the erosion potential. Because erosion potential has been found to increase rapidly with increasing wind speed, estimated emissions should be related to the gusts of highest magnitude.

The routinely measured meteorological variable that best reflects the magnitude of wind gusts is the fastest mile. This quantity represents the wind speed corresponding to the whole mile of wind movement that has passed by the 1 mile contact anemometer in the least amount of time. Daily measurements of the fastest mile are presented in the monthly Local Climatological Data (LCD) summaries. The duration of the fastest mile, typically about 2 minutes (for a fastest mile of 30 mph), matches well with the half-life of the erosion process, which ranges between 1 and 4 minutes. It should be noted, however, that peak winds can significantly exceed the daily fastest mile.

The wind speed profile in the surface boundary layer is found to follow a logarithmic distribution:

$$u(z) = \frac{u*}{0.4} \ln\frac{z}{z_0} \qquad (z > z_0) \tag{1}$$

where:

u = wind speed, cm/s
u^* = friction velocity, cm/s
z = height above test surface, cm
z_0 = roughness height, cm
0.4 = von Karman's constant, dimensionless

The friction velocity (u^*) is a measure of wind shear stress on the erodible surface, as determined from the slope of the logarithmic velocity profile. The roughness height (z_0) is a measure of the roughness of the exposed surface as determined from the y intercept of the velocity profile, i. e., the height at which the wind speed is zero. These parameters are illustrated in Figure 13.2.5-1 for a roughness height of 0.1 cm.

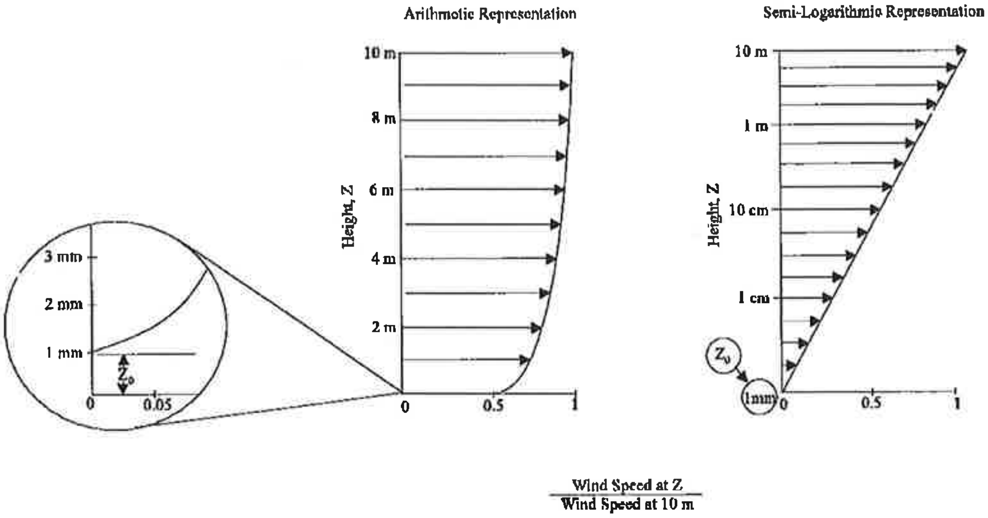


Figure 13.2.5-1. Illustration of logarithmic velocity profile.

Emissions generated by wind erosion are also dependent on the frequency of disturbance of the erodible surface because each time that a surface is disturbed, its erosion potential is restored. A disturbance is defined as an action that results in the exposure of fresh surface material. On a storage pile, this would occur whenever aggregate material is either added to or removed from the old surface. A disturbance of an exposed area may also result from the turning of surface material to a depth exceeding the size of the largest pieces of material present.

13.2.5.3 Predictive Emission Factor Equation[4]

The emission factor for wind-generated particulate emissions from mixtures of erodible and nonerodible surface material subject to disturbance may be expressed in units of grams per square meter (g/m^2) per year as follows:

$$\text{Emission factor} = k \sum_{i=1}^{N} P_i \qquad (2)$$

where:

k = particle size multiplier
N = number of disturbances per year
P_i = erosion potential corresponding to the observed (or probable) fastest mile of wind for the ith period between disturbances, g/m^2

The particle size multiplier (k) for Equation 2 varies with aerodynamic particle size, as follows:

Aerodynamic Particle Size Multipliers For Equation 2			
30 µm	<15 µm	<10 µm	<2.5 µm
1.0	0.6	0.5	0.075[a]

[a] Multiplier for < 2.5 um taken from Reference 11.

This distribution of particle size within the under 30 micrometer (µm) fraction is comparable to the distributions reported for other fugitive dust sources where wind speed is a factor. This is illustrated, for example, in the distributions for batch and continuous drop operations encompassing a number of test aggregate materials (see Section 13.2.4).

In calculating emission factors, each area of an erodible surface that is subject to a different frequency of disturbance should be treated separately. For a surface disturbed daily, N = 365 per year, and for a surface disturbance once every 6 months, N = 2 per year.

The erosion potential function for a dry, exposed surface is:

$$\begin{aligned} P &= 58\,(u^* - u_t^*)^2 + 25\,(u^* - u_t^*) \\ P &= 0 \text{ for } u^* \le u_t^* \end{aligned} \qquad (3)$$

where:

u^* = friction velocity (m/s)
u_t = threshold friction velocity (m/s)

Because of the nonlinear form of the erosion potential function, each erosion event must be treated separately.

Equations 2 and 3 apply only to dry, exposed materials with limited erosion potential. The resulting calculation is valid only for a time period as long or longer than the period between disturbances. Calculated emissions represent intermittent events and should not be input directly into dispersion models that assume steady-state emission rates.

For uncrusted surfaces, the threshold friction velocity is best estimated from the dry aggregate structure of the soil. A simple hand sieving test of surface soil can be used to determine the mode of the surface aggregate size distribution by inspection of relative sieve catch amounts, following the procedure described below.

FIELD PROCEDURE FOR DETERMINATION OF THRESHOLD FRICTION VELOCITY
(from a 1952 laboratory procedure published by W. S. Chepil):

1. Prepare a nest of sieves with the following openings: 4 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm. Place a collector pan below the bottom (0.25 mm) sieve.

2. Collect a sample representing the surface layer of loose particles (approximately 1 cm in depth, for an encrusted surface), removing any rocks larger than about 1 cm in average physical diameter. The area to be sampled should be not less than 30 cm by 30 cm.

3. Pour the sample into the top sieve (4-mm opening), and place a lid on the top.

4. Move the covered sieve/pan unit by hand, using a broad circular arm motion in the horizontal plane. Complete 20 circular movements at a speed just necessary to achieve some relative horizontal motion between the sieve and the particles.

5. Inspect the relative quantities of catch within each sieve, and determine where the mode in the aggregate size distribution lies, i. e., between the opening size of the sieve with the largest catch and the opening size of the next largest sieve.

6. Determine the threshold friction velocity from Table 13.2.5-1.

The results of the sieving can be interpreted using Table 13.2.5-1. Alternatively, the threshold friction velocity for erosion can be determined from the mode of the aggregate size distribution using the graphical relationship described by Gillette.[5-6] If the surface material contains nonerodible elements that are too large to include in the sieving (i. e., greater than about 1 cm in diameter), the effect of the elements must be taken into account by increasing the threshold friction velocity.[10]

Table 13.2.5-1 (Metric Units). FIELD PROCEDURE FOR DETERMINATION OF THRESHOLD FRICTION VELOCITY

Tyler Sieve No.	Opening (mm)	Midpoint (mm)	u_t^* (cm/s)
5	4		
9	2	3	100
16	1	1.5	76
32	0.5	0.75	58
60	0.25	0.375	43

Threshold friction velocities for several surface types have been determined by field measurements with a portable wind tunnel. These values are presented in Table 13.2.5-2.

Table 13.2.5-2 (Metric Units). THRESHOLD FRICTION VELOCITIES

Material	Threshold Friction Velocity (m/s)	Roughness Height (cm)	Threshold Wind Velocity At 10 m (m/s)	
			z_o = Act	z_o = 0.5 cm
Overburden[a]	1.02	0.3	21	19
Scoria (roadbed material)[a]	1.33	0.3	27	25
Ground coal (surrounding coal pile)[a]	0.55	0.01	16	10
Uncrusted coal pile[a]	1.12	0.3	23	21
Scraper tracks on coal pile[a,b]	0.62	0.06	15	12
Fine coal dust on concrete pad[c]	0.54	0.2	11	10

[a] Western surface coal mine. Reference 2.
[b] Lightly crusted.
[c] Eastern power plant. Reference 3.

The fastest mile of wind for the periods between disturbances may be obtained from the monthly LCD summaries for the nearest reporting weather station that is representative of the site in question.[7] These summaries report actual fastest mile values for each day of a given month. Because the erosion potential is a highly nonlinear function of the fastest mile, mean values of the fastest mile are inappropriate. The anemometer heights of reporting weather stations are found in Reference 8, and should be corrected to a 10-m reference height using Equation 1.

To convert the fastest mile of wind (u^+) from a reference anemometer height of 10 m to the equivalent friction velocity (u^*), the logarithmic wind speed profile may be used to yield the following equation:

$$u^* = 0.053\ u_{10}^+ \qquad (4)$$

where:

u^* = friction velocity (m/s)

u_{10}^+ = fastest mile of reference anemometer for period between disturbances (m/s)

This assumes a typical roughness height of 0.5 cm for open terrain. Equation 4 is restricted to large relatively flat piles or exposed areas with little penetration into the surface wind layer.

If the pile significantly penetrates the surface wind layer (i. e., with a height-to-base ratio exceeding 0.2), it is necessary to divide the pile area into subareas representing different degrees of exposure to wind. The results of physical modeling show that the frontal face of an elevated pile is exposed to wind speeds of the same order as the approach wind speed at the top of the pile.

For 2 representative pile shapes (conical and oval with flattop, 37-degree side slope), the ratios of surface wind speed (u_s) to approach wind speed (u_r) have been derived from wind tunnel studies.[9] The results are shown in Figure 13.2.5-2 corresponding to an actual pile height of 11 m, a reference (upwind) anemometer height of 10 m, and a pile surface roughness height (z_0) of 0.5 cm. The measured surface winds correspond to a height of 25 cm above the surface. The area fraction within each contour pair is specified in Table 13.2.5-3.

Table 13.2.5-3. SUBAREA DISTRIBUTION FOR REGIMES OF u_s/u_r[a]

Pile Subarea	Percent Of Pile Surface Area			
	Pile A	Pile B1	Pile B2	Pile B3
0.2a	5	5	3	3
0.2b	35	2	28	25
0.2c	NA	29	NA	NA
0.6a	48	26	29	28
0.6b	NA	24	22	26
0.9	12	14	15	14
1.1	NA	NA	3	4

[a] NA = not applicable.

The profiles of u_s/u_r in Figure 13.2.5-2 can be used to estimate the surface friction velocity distribution around similarly shaped piles, using the following procedure:

1. Correct the fastest mile value (u^+) for the period of interest from the anemometer height (z) to a reference height of 10 m u^+_{10} using a variation of Equation 1:

$$u^+_{10} = u^+ \frac{\ln (10/0.005)}{\ln (z/0.005)} \tag{5}$$

   where a typical roughness height of 0.5 cm (0.005 m) has been assumed. If a site-specific roughness height is available, it should be used.

2. Use the appropriate part of Figure 13.2.5-2 based on the pile shape and orientation to the fastest mile of wind, to obtain the corresponding surface wind speed distribution (u^+_s)

$$u^+_s = \frac{(u_s)}{u_r} u^+_{10} \tag{6}$$

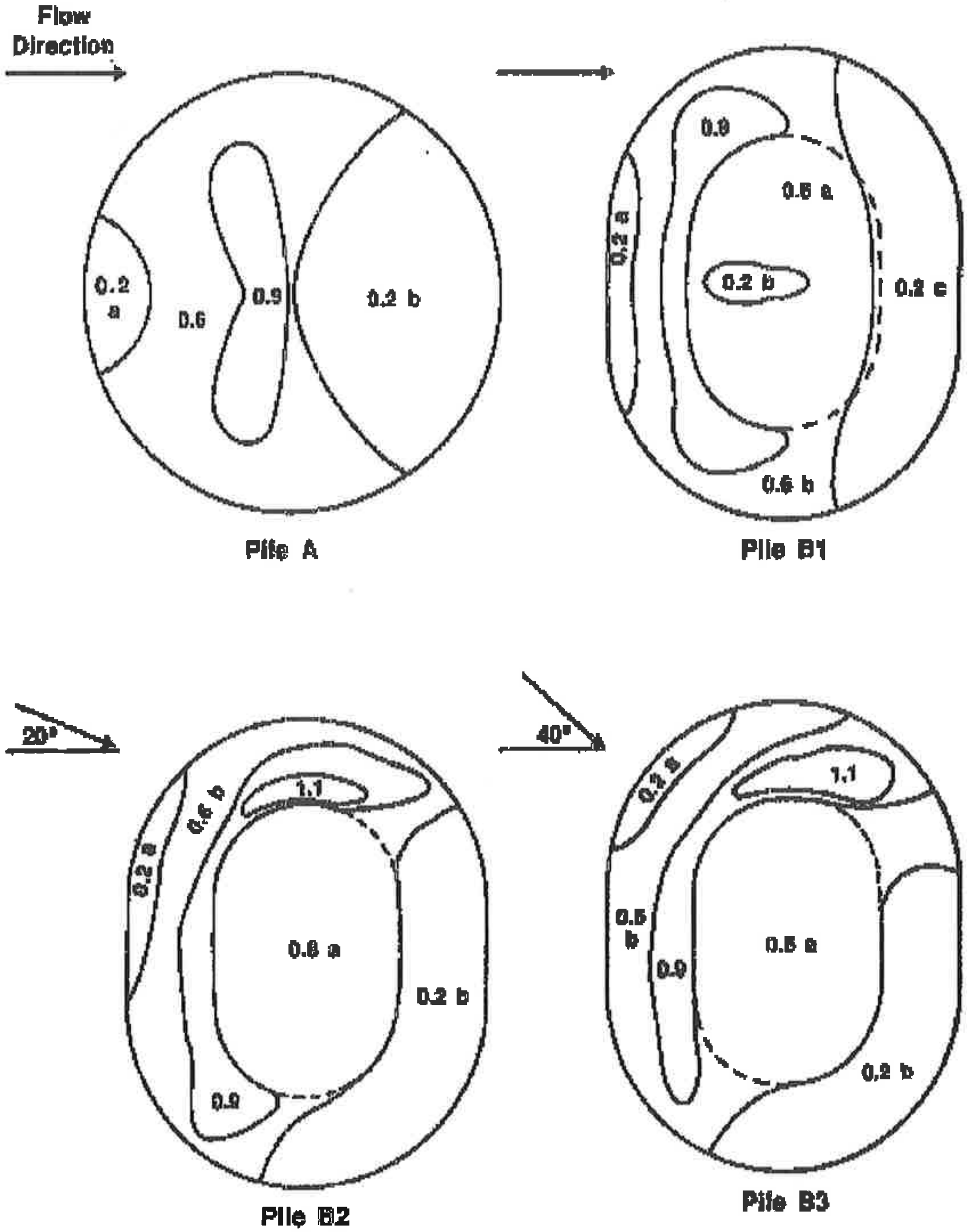


Figure 13.2.5-2. Contours of normalized surface windspeeds, u_s/u_r.

3. For any subarea of the pile surface having a narrow range of surface wind speed, use a variation of Equation 1 to calculate the equivalent friction velocity (u^*):

$$u^* = \frac{0.4u_s^+}{\frac{25}{\ln 0.5}} = 0.10u_s^+ \qquad (7)$$

From this point on, the procedure is identical to that used for a flat pile, as described above.

Implementation of the above procedure is carried out in the following steps:

1. Determine threshold friction velocity for erodible material of interest (see Table 13.2.5-2 or determine from mode of aggregate size distribution).

2. Divide the exposed surface area into subareas of constant frequency of disturbance (N).

3. Tabulate fastest mile values (u^+) for each frequency of disturbance and correct them to 10 m (u^+_{10}) using Equation 5.5

4. Convert fastest mile values (u_{10}) to equivalent friction velocities (u^*), taking into account (a) the uniform wind exposure of nonelevated surfaces, using Equation 4, or (b) the nonuniform wind exposure of elevated surfaces (piles), using Equations 6 and 7.

5. For elevated surfaces (piles), subdivide areas of constant N into subareas of constant u^* (i. e., within the isopleth values of u_s/u_r in Figure 13.2.5-2 and Table 13.2.5-3) and determine the size of each subarea.

6. Treating each subarea (of constant N and u^*) as a separate source, calculate the erosion potential (P_i) for each period between disturbances using Equation 3 and the emission factor using Equation 2.

7. Multiply the resulting emission factor for each subarea by the size of the subarea, and add the emission contributions of all subareas. Note that the highest 24-hour (hr) emissions would be expected to occur on the windiest day of the year. Maximum emissions are calculated assuming a single event with the highest fastest mile value for the annual period.

The recommended emission factor equation presented above assumes that all of the erosion potential corresponding to the fastest mile of wind is lost during the period between disturbances. Because the fastest mile event typically lasts only about 2 minutes, which corresponds roughly to the half-life for the decay of actual erosion potential, it could be argued that the emission factor overestimates particulate emissions. However, there are other aspects of the wind erosion process that offset this apparent conservatism:

1. The fastest mile event contains peak winds that substantially exceed the mean value for the event.

2. Whenever the fastest mile event occurs, there are usually a number of periods of

slightly lower mean wind speed that contain peak gusts of the same order as the fastest mile wind speed.

Of greater concern is the likelihood of overprediction of wind erosion emissions in the case of surfaces disturbed infrequently in comparison to the rate of crust formation.

13.2.5.4 Example 1: Calculation for wind erosion emissions from conically shaped coal pile

A coal burning facility maintains a conically shaped surge pile 11 m in height and 29.2 m in base diameter, containing about 2000 megagrams (Mg) of coal, with a bulk density of 800 kilograms per cubic meter (kg/m$^{3)}$ (50 pounds per cubic feet [lb/ft^3]). The total exposed surface area of the pile is calculated as follows:

Coal is added to the pile by means of a fixed stacker and reclaimed by front-end loaders operating

$$\begin{aligned} S &= \pi r \sqrt{r^2 + h^2} \\ &= 3.14(14.6)\sqrt{(14.6)^2 + (11.0)^2} \\ &= 838\ m^2 \end{aligned}$$

at the base of the pile on the downwind side. In addition, every 3 days 250 Mg (12.5 percent of the stored capacity of coal) is added back to the pile by a topping off operation, thereby restoring the full capacity of the pile. It is assumed that (a) the reclaiming operation disturbs only a limited portion of the surface area where the daily activity is occurring, such that the remainder of the pile surface remains intact, and (b) the topping off operation creates a fresh surface on the entire pile while restoring its original shape in the area depleted by daily reclaiming activity.

Because of the high frequency of disturbance of the pile, a large number of calculations must be made to determine each contribution to the total annual wind erosion emissions. This illustration will use a single month as an example.

Step 1: In the absence of field data for estimating the threshold friction velocity, a value of 1.12 m/s is obtained from Table 13.2.5-2.

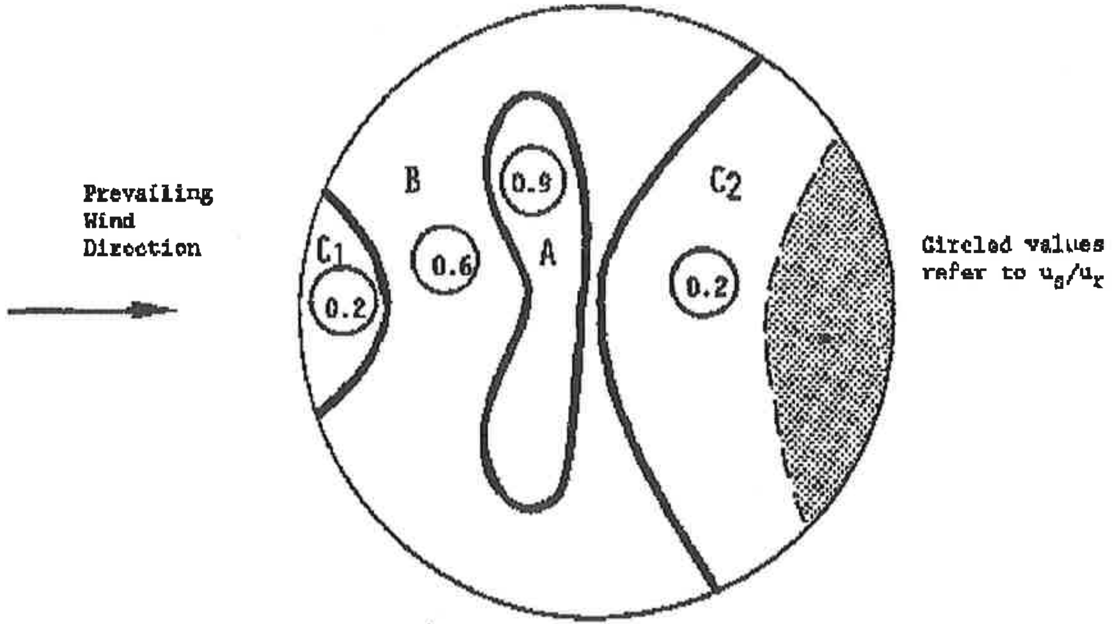
Step 2: Except for a small area near the base of the pile (see Figure 13.2.5-3), the entire pile surface is disturbed every 3 days, corresponding to a value of N = 120 per year. It will be shown that the contribution of the area where daily activity occurs is negligible so that it does not need to be treated separately in the calculations.

Step 3: The calculation procedure involves determination of the fastest mile for each period of disturbance. Figure 13.2.5-4 shows a representative set of values (for a 1-month period) that are assumed to be applicable to the geographic area of the pile location. The values have been separated into 3-day periods, and the highest value in each period is indicated. In this example, the anemometer height is 7 m, so that a height correction to 10 m is needed for the fastest mile values. From Equation 5,

$$u_{10}^{+} = u_7^{+} \left(\frac{\ln(10/0.005)}{\ln(7/0.005)} \right)$$

$$u_{10}^{+} = 1.05\ u_7^{+}$$

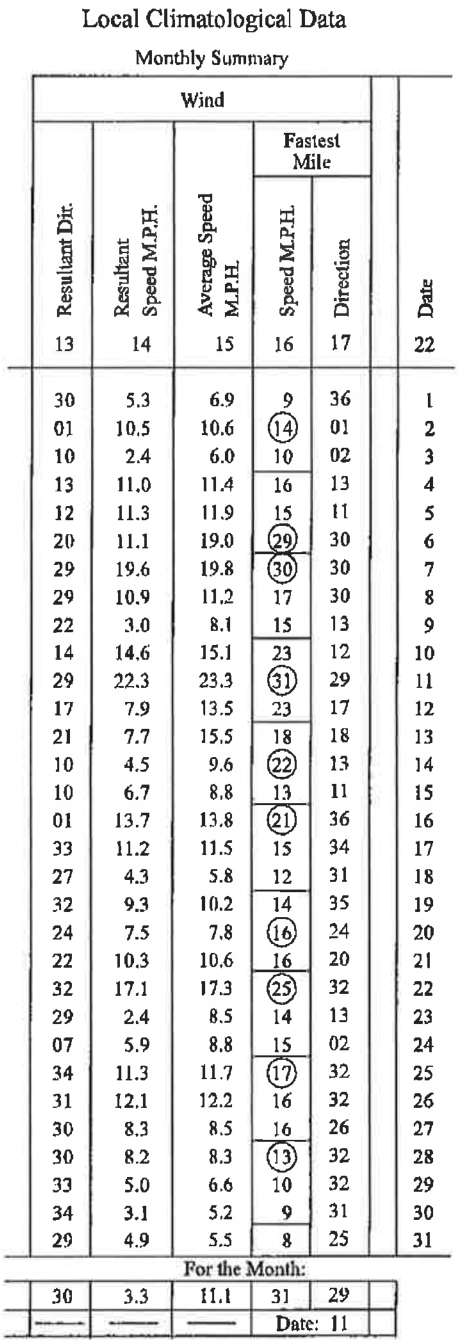
Step 4: The next step is to convert the fastest mile value for each 3-day period into



* A portion of C_2 is disturbed daily by reclaiming activities.

Area ID	$\frac{u_s}{u_r}$	Pile Surface %	Pile Surface Area (m^2)
A	0.9	12	101
B	0.6	48	402
$C_1 + C_2$	0.2	40	335
		Total	838

Figure 13.2.5-3. Example 1: Pile surface areas within each wind speed regime.



DEPARTMENT OF COMMERCE · UNITED STATES OF AMERICA

Local Climatological Data

Monthly Summary

Wind					
			Fastest Mile		
Resultant Dir. 13	Resultant Speed M.P.H. 14	Average Speed M.P.H. 15	Speed M.P.H. 16	Direction 17	Date 22
30	5.3	6.9	9	36	1
01	10.5	10.6	⑭	01	2
10	2.4	6.0	10	02	3
13	11.0	11.4	16	13	4
12	11.3	11.9	15	11	5
20	11.1	19.0	㉙	30	6
29	19.6	19.8	㉚	30	7
29	10.9	11.2	17	30	8
22	3.0	8.1	15	13	9
14	14.6	15.1	23	12	10
29	22.3	23.3	㉛	29	11
17	7.9	13.5	23	17	12
21	7.7	15.5	18	18	13
10	4.5	9.6	㉒	13	14
10	6.7	8.8	13	11	15
01	13.7	13.8	㉑	36	16
33	11.2	11.5	15	34	17
27	4.3	5.8	12	31	18
32	9.3	10.2	14	35	19
24	7.5	7.8	⑯	24	20
22	10.3	10.6	16	20	21
32	17.1	17.3	㉕	32	22
29	2.4	8.5	14	13	23
07	5.9	8.8	15	02	24
34	11.3	11.7	⑰	32	25
31	12.1	12.2	16	32	26
30	8.3	8.5	16	26	27
30	8.2	8.3	⑬	32	28
33	5.0	6.6	10	32	29
34	3.1	5.2	9	31	30
29	4.9	5.5	8	25	31
For the Month:					
30	3.3	11.1	31	29	
——	——	——	Date: 11		

Figure 13.2.5-4. Example daily fastest miles wind for periods of interest.

equivalent friction velocities for each surface wind regime (i. e., u_s/u_r ratio) of the pile, using Equations 6 and 7. Figure 13.2.5-3 shows the surface wind speed pattern (expressed as a fraction of the approach wind speed at a height of 10 m). The surface areas lying within each wind speed regime are tabulated below the figure.

The calculated friction velocities are presented in Table 13.2.5-4. As indicated, only 3 of the periods contain a friction velocity which exceeds the threshold value of 1.12 m/s for an uncrusted coal pile. These 3 values all occur within the $u_s/u_r = 0.9$ regime of the pile surface.

Table 13.2.5-4 (Metric And English Units). EXAMPLE 1:
CALCULATION OF FRICTION VELOCITIES

	u_7^+		u_{10}^+		$u^* = 0.1u^+$ (m/s) s		
3-Day Period	mph	m/s	mph	m/s	u_s/u_r: 0.2	u_s/u_r: 0.6	u_s/u_r: 0.9
1	14	6.3	15	6.6	0.13	0.40	0.59
2	29	13.0	31	13.7	0.27	0.82	1.23
3	30	13.4	32	14.1	0.28	0.84	1.27
4	31	13.9	33	14.6	0.29	0.88	1.31
5	22	9.8	23	10.3	0.21	0.62	0.93
6	21	9.4	22	9.9	0.20	0.59	0.89
7	16	7.2	17	7.6	0.15	0.46	0.68
8	25	11.2	26	11.8	0.24	0.71	1.06
9	17	7.6	18	8.0	0.16	0.48	0.72
10	13	5.8	14	6.1	0.12	0.37	0.55

Step 5: This step is not necessary because there is only 1 frequency of disturbance used in the calculations. It is clear that the small area of daily disturbance (which lies entirely within the u_s/u_r = 0.2 regime) is never subject to wind speeds exceeding the threshold value.

Steps 6 and 7: The final set of calculations (shown in Table 13.2.5-5) involves the tabulation and summation of emissions for each disturbance period and for the affected subarea. The erosion potential (P) is calculated from Equation 3.

For example, the calculation for the second 3-day period is:

$$P = 58(u^* - u_t^*)^2 + 25(u^* - u_t^*)$$

$$P_2 = 58(1.23 - 1.12)^2 + 25(1.23 - 1.12)$$

$$= 0.70 + 2.75 = 3.45 \text{ g/m}^2$$

Table 13.2.5-5 (Metric Units). EXAMPLE 1: CALCULATION OF PM-10 EMISSIONS[a]

3-Day Period	u^* (m/s)	$u^* - u_t^*$ (m/s)	P (g/m^2)	ID	Pile Surface Area (m^2)	kPA (g)
2	1.23	0.11	3.45	A	101	170
3	1.27	0.15	5.06	A	101	260
4	1.31	0.19	6.84	A	101	350
TOTAL						780

[a] Where $u_t^* = 1.12$ m/s for uncrusted coal and k = 0.5 for PM-10.

The emissions of particulate matter greater than 10 µm (PM-10) generated by each event are found as the product of the PM-10 multiplier (k = 0.5), the erosion potential (P), and the affected area of the pile (A).

As shown in Table 13.2.5-5, the results of these calculations indicate a monthly PM-10 emission total of 780 g.

13.2.5.5 Example 2: Calculation for wind erosion from flat area covered with coal dust

A flat circular area 29.2 m in diameter is covered with coal dust left over from the total reclaiming of a conical coal pile described in the example above. The total exposed surface area is calculated as follows:

$$s = \frac{\pi}{4} d^2 = 0.785\ (29.2)^2 = 670\ m^2$$

This area will remain exposed for a period of 1 month when a new pile will be formed.

<u>Step 1</u>: In the absence of field data for estimating the threshold friction velocity, a value of 0.54 m/s is obtained from Table 13.2.5-2.

<u>Step 2</u>: The entire surface area is exposed for a period of 1 month after removal of a pile and N = 1/yr.

<u>Step 3</u>: From Figure 13.2.5-4, the highest value of fastest mile for the 30-day period (31 mph) occurs on the 11th day of the period. In this example, the reference anemometer height is 7 m, so that a height correction is needed for the fastest mile value. From Step 3 of the previous example, $u^+_{10} = 1.05\ u^+_7$, so that $u^+_{10} = 33$ mph.

<u>Step 4</u>: Equation 4 is used to convert the fastest mile value of 14.6 m/s (33 mph) to an equivalent friction velocity of 0.77 m/s. This value exceeds the threshold friction velocity from Step 1 so that erosion does occur.

<u>Step 5</u>: This step is not necessary, because there is only 1 frequency of disturbance for the entire source area.

Steps 6 and 7: The PM-10 emissions generated by the erosion event are calculated as the product of the PM-10 multiplier (k = 0.5), the erosion potential (P) and the source area (A). The erosion potential is calculated from Equation 3 as follows:

$$P = 58(u^* - u_t^*)^2 + 25(u^* - u_t^*)$$

$$\begin{aligned} P &= 58(0.77 - 0.54)^2 + 25(0.77 - 0.54) \\ &= 3.07 + 5.75 \\ &= 8.82 \text{ g/m}^2 \end{aligned}$$

Thus the PM-10 emissions for the 1-month period are found to be:

$$\begin{aligned} E &= (0.5)(8.82 \text{ g/m}^2)(670 \text{ m}^2) \\ &= 3.0 \text{ kg} \end{aligned}$$

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REFERENCE 2

A SIMPLE EXPRESSION FOR WIND EROSION THRESHOLD FRICTION VELOCITY by YAPING SHAO

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A simple expression for wind erosion threshold friction velocity

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Abstract. Threshold friction velocity u_{*t} is the friction velocity at which wind erosion is initiated. While u_{*t} is affected by a range of surface and soil properties, it is a function of particle size only for idealized soils. In this paper we present a simple expression for u_{*t} for spherical particles loosely spread over a dry and bare surface. In this expression we consider the balance between the driving forces (aerodynamic drag and lift) and the retarding forces (cohesion and gravity) and assume that the cohesive force is proportional to particle size. It is found that u_{*t} can be expressed as $\sqrt{Y_1 d + Y_2 \frac{1}{d}}$, with Y_1 and Y_2 being empirical constants. The new expression is both simple and effective.

1. Introduction

Threshold friction velocity u_{*t} represents the capacity of an aeolian surface to resist wind erosion. Soil particles resting on the surface under the influence of an airstream experience several forces, including the aerodynamic drag F_d, the aerodynamic lift F_l, the gravity force F_g, and the interparticle cohesive force F_i. The driving forces for the liftoff of sand-sized particles are F_d and F_l, which are related to the wind shear near the surface and hence are functions of the surface friction velocity u_*. Threshold friction velocity is the minimum friction velocity required for wind erosion to occur. At $u_* = u_{*t}$ the aerodynamic forces just overcome the retarding forces (F_g and F_i) and initialize the movement of soil particles.

In reality, u_{*t} is affected by a range of factors such as soil texture, soil moisture, soil salt content, surface crust, the distribution of vegetation, and roughness elements. Under ideal conditions, u_{*t} can be expressed as a function of only particle size. The $u_{*t}(d)$ relationship for idealized conditions is important, as it defines the lower limit of u_{*t} for a given soil type. Several theories for $u_{*t}(d)$ exist, derived for soils with uniform and spherical particles spread loosely over a dry and bare surface [*Bagnold*, 1941; *Greeley and Iversen*, 1985; *Phillips*, 1980].

Bagnold [1941] derived a simple expression for $u_{*t}(d)$ by considering the balance between the aerodynamic drag and the gravity force and found that $u_{*t} \propto d^{1/2}$. The Bagnold expression describes well the behavior of u_{*t} for particles larger than approximately 100 μm but fails to predict the existence of the minimum of u_{*t} at around $d = 75$ μm and the subsequent increase of u_{*t} with decreasing particle size. *Greeley and Iversen* [1985] have taken into account the cohesive force and aerodynamic lift in addition to the aerodynamic drag and gravity force considered by Bagnold and found that u_{*t} is of the form

$$u_{*t} = A_1 \sqrt{\sigma_p g d} F(Re_{*t}) G(d) \tag{1}$$

where F is a function of particle Reynolds number at threshold friction velocity, Re_{*t}, G is a function of particle diameter, σ_p is particle to air density ratio, and g is acceleration due to gravity. A_1, F, and G are estimated from wind tunnel measurements [*Greeley and Iversen*, 1985]. This expression overcomes the shortcomings of the Bagnold expression and is effective in describing the behavior of u_{*t} for the entire particle size range. However, the two empirical functions, $G(d)$ and $F(Re_{*t})$, have complex and irrational expressions that are possibly due to a misfit of $G(d)$.

In this paper we describe a new expression for u_{*t} that has a much simpler expression than the Greeley and Iversen one. The new expression also has more rational physical interpretations. When compared with the wind tunnel data, the new expression is equally effective as that of Greeley and Iversen.

2. Review of the Bagnold Expression and the Greeley-Iversen Expression

For a particle of size d, $u_{*t}(d)$ is determined by the balance of F_d, F_l, F_g, and F_i, as shown in Figure 1. At the instant of particle motion the combined retarding

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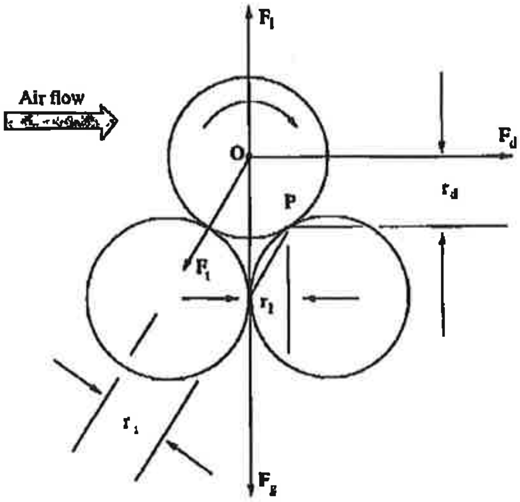

Figure 1. Forces acting on a particle resting on the surface under the influence of an airstream, including the aerodynamic drag F_d, the aerodynamic lift F_l, the gravity force F_g, the moment F_m, and the cohesive force F_i; r_d, r_l, r_m, and r_i are moment arm lengths associated with F_d, F_l and F_g, F_m, and F_i, respectively. O is the center of gravity of the particle, and P is the pivot point for particle entrainment.

effect of F_g and F_i will be overcome by the combined lifting effect of F_d and F_l. The particle will tend to pivot about point P in a downstream direction. The balance of forces at the instant of entrainment can be obtained by the summation of moments about the pivot point P,

$$r_d F_d + r_l(F_l - F_g) + r_m F_m - r_i F_i = 0, \qquad (2)$$

where r_d, r_l, r_m, and r_i are moment arm lengths. In general, the moment arm lengths depend on the arrangements of particles and are difficult to determine. However, it is plausible to assume that they are all linearly proportional to the particle size and can be expressed as $r_d = a_d d$, $r_l = a_l d$, $r_m = a_m d$, and $r_i = a_i d$. It follows that

$$a_d F_d + a_l(F_l - F_g) + a_m F_m - a_i F_i = 0. \qquad (3)$$

Bagnold [1941] derived a simple theory for $u_{*t}(d)$ by considering the balance between F_d and F_g:

$$a_d F_d - a_l F_g = 0. \qquad (4)$$

The drag force on a particle protruding into the airflow can be written as

$$F_d = \frac{1}{2} C_{d,s} \rho A U, \qquad (5)$$

where $C_{d,s}$ is the aerodynamic drag coefficient for the particle attached to the surface, ρ is air density, A is the particle cross section perpendicular to the flow, and U is the flow speed at a reference point, say, at the height comparable to the particle diameter. There are difficulties in implementing (5) because $C_{d,s}$ is not well understood and U is not well defined in a flow with a strong shear. A pragmatic approach is to relate F_d to u_* as

$$F_d = K_d \rho d^2 u_*^2, \qquad (6)$$

where K_d is a function of the particle friction Reynolds number, defined as

$$Re_* = u_* d/\nu. \qquad (7)$$

Assuming $a_d = a_l$ in (4), we obtain

$$u_{*t} = A_B(Re_{*t})\sqrt{\sigma_p g d}, \qquad (8)$$

where A_B is a coefficient depending on Re_{*t}, the particle friction Reynolds number at the threshold friction velocity. A_B is called the dimensionless threshold friction velocity, as it can be expressed as

$$A_B = \frac{u_{*t}}{\sqrt{\sigma_p g d}}. \qquad (9)$$

A_B has been found to be a constant between 0.1 and 0.2 for $Re_{*t} > 3.5$. Equation (8) implies that $u_{*t}(d)$ is proportional to $d^{1/2}$ for sufficiently large particle Reynolds numbers. Bagnold's prediction is illustrated in Figure 2. For grains larger than approximately 100 μm, the proportionality between u_{*t} and $d^{1/2}$ has been confirmed by experimental data. However, observations have also shown that a minimum u_{*t} exists around 75-100 μm, and for smaller particles, u_{*t} increases rapidly with decreasing d. The early interpretation of this phenomenon is that for $Re_{*t} < 3.5$, the particles lie below the viscous sublayer and are increasingly less susceptible to aerodynamic drag. In this case, the coefficient A_B is no longer a constant but increases rapidly with decreasing particle size, and therefore u_{*t} can no longer be considered to be proportional to $d^{1/2}$.

Iversen et al. [1976] pointed out that the rapid increase of threshold friction velocity with decreasing particle size is due to the interparticle cohesion, rather than the Reynolds number effect. *Iversen et al.* [1976], *Iversen and White* [1982] and *Greeley and Iversen* [1985] considered inter-particle cohesion and aerodynamic lift in addition to aerodynamic drag and gravity force considered by *Bagnold* [1941]. The aerodynamic drag, lift, and moment forces are all expressed as

$$F_d = K_d \rho u_*^2 d^2 \qquad (10)$$

$$F_l = K_l \rho u_*^2 d^2 \qquad (11)$$

$$F_m = K_m \rho u_*^2 d^2, \qquad (12)$$

where K_d, K_l, and K_m, with magnitudes of around 4, 2, and 1, are dimensionless empirical coefficients associated with the aerodynamic drag, aerodynamic lift, and moment, respectively. It follows that

$$a_d F_d + a_l F_l + a_m F_m = (a_d K_d + a_l K_l + a_m K_m)\rho u_*^2 d^2. \qquad (13)$$

Table 1. The Functional form of $F(Re_{*t})$ in the Greeley-Iversen Expression

Re_{*t}	A_1	$F(Re_{*t})$
$0.03 \le Re_{*t} \le 0.3$	0.20	$(1+2.5Re_{*t})^{-1/2}$
$0.3 \le Re_{*t} \le 10$	0.13	$(1.928Re_{*t}^{0.092}-1)^{-1/2}$
$Re_{*t} \ge 10$	0.12	$1-0.0858\exp[-0.0617(Re_{*t}-10)]$

As detailed information for the coefficients, such as a_d and K_d, is difficult to obtain, it is sensible to simply denote

$$a_t K_t = a_d K_d + a_l K_l + a_m K_m. \qquad (14)$$

Substituting (13) and (14) into (2) and using (9)-(14), we obtain

$$A_B^2 = \frac{a_l \pi}{6}[1 + \frac{6a_t}{\pi a_l}\frac{F_i}{\rho_p d^3 g}]/a_t K_t. \qquad (15)$$

Greeley and Iversen [1985] hypothesized that A_B is of the form

$$A_B = A_1 F(Re_{*t}) G(d), \qquad (16)$$

where F is a function accounting for the Reynolds number dependence of the aerodynamic drag, and G is a function of particle diameter, accounting for the effects of interparticle cohesive forces. The constant A_1 as well as the functions F and G are determined by fitting (15) to observed data. Measurements obtained in a series of wind tunnel experiments with a range of particle sizes, particle densities, and wind tunnel pressures have been used for the fitting [*Greeley and Iversen*, 1985]. It is found that

$$G(d) = (1 + 0.006/\rho_a g d^{2.5})^{1/2} \qquad (17)$$

and that $F(Re_{*t})$ is as shown in Table 1.

The behavior of (16) is depicted in Figure 2. The minimum of $u_{*t}(d)$ occurs at $d = 75$ μm; for particles larger than this, u_{*t} increases with increasing d (eventually with $d^{1/2}$) due to the increasing dominance of the gravity force. This result is in agreement with the expression of *Bagnold* [1941], as given in (8). For smaller particles, $u_{*t}(d)$ increases rapidly with decreasing d due to interparticle cohesive forces.

Iversen et al. [1987] studied the effect of particle-to-fluid density ratio on u_{*t}. In their study, dimensionless threshold friction velocity A_B was fitted as a function of particle-to-fluid density ratio for particle diameter

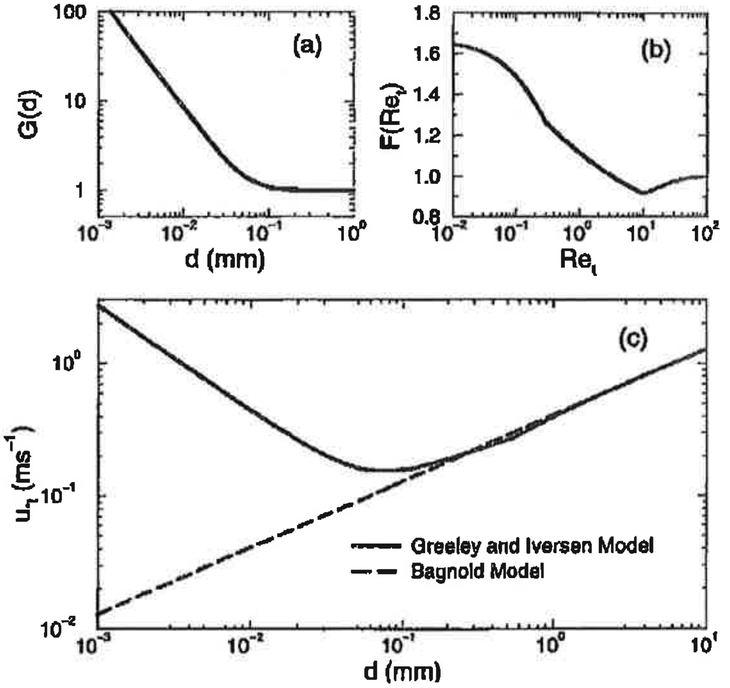

Figure 2. The Bagnold and Greeley-Iversen expressions for the prediction of threshold friction velocity for individual particles.

$d > 200$ μm (or $Re_{*t} > 10$), in which the interparticle force becomes negligible compared with the other forces on the particle at threshold. Using broader data sources including measurements of u_{*t} in liquid, they found that A_B decreases by a factor of 2.5 as Re_{*t} increases from 0.05 to 10 and A_B is almost constant for $Re_{*t} > 10$. The decrease of A_B with increasing Re_{*t} may be a result of the relative decrease of the cohesion forces when compared with the particle weight.

3. The New Expression

While the expression of Greeley and Iversen well describes the wind tunnel observations reported by *Iversen and White* [1982], the two empirical functions in (16), $G(d)$ and $F(Re_{*t})$, have rather complex expressions. A simpler expression for u_{*t} with rational physical interpretations can be derived through an explicit treatment of the cohesive force.

Interparticle cohesion is a combined effect of the van der Waals force, liquid and chemical force, and electrostatic force, all of which are sensitive to soil properties, such as particle shape, particle surface texture, soil mineralogy, packing arrangement, and the presence or absence of bonding agents such as soil moisture and soluble salts. For spherical particles free of the influence of moisture and chemical binding, the cohesion can be attributed mainly to the van der Waals force and the electrostatic force. While an accurate estimate of these cohesive forces is difficult, it is useful to consider their general behavior in theory.

3.1. The van der Waals Forces

The attraction between uncharged micron-sized particles is due to the van der Waals forces. The van der Waals forces are types of a short-range force with the domain of importance under a diameter of a dust particle. Theories originated from colloidal sciences exist for the calculation of the van der Waals forces for idealized situations, notably the Hamaker theory and the Liftshitz theory [*Langbein*, 1974; *Mahanty and Ninham*, 1976]. For a small spherical particle of diameter d with a separation δ from a same sized particle, one approximation for the van der Waals attraction forces between the two particles in vacuum is

$$F_{i,v} = \frac{h_w}{32\pi\delta^2} d, \tag{18}$$

where h_w varies between 10^{-18} and 10^{-21} J, depending on the material. The minimum value of δ is conventionally considered to be 0.4 nm. For regions with separation smaller than 0.4 nm, the interactions between the particles are further complicated, as Verwey and Overbeek repulsion [*Theodoor and Overbeek*, 1985] takes place. The above relationship is considered to be valid for $\delta/d \ll 1$. For $\delta/d > 0.2$ the van der Waals attraction becomes negligible beyond this range, being of the order of thermal (Brownian) forces. If particles are surrounded by air, the van der Waals attraction between the two particles may increase due to the interactions between the gas molecules adsorbed on the particles. In room temperature, van der Waals forces between particles can be increased up to 2 orders of magnitude with increasing pressure [*Xie*, 1997].

3.2. Electrostatic Force

The electrostatic force applicable for dust emission is the electrical double layer force, also called the nonconductor force. For smooth and ideally spherical particles, it can be written as

$$F_{i,e} = \frac{\pi E U^2 d}{2\delta}, \tag{19}$$

where U is the contact potential difference that generally ranges from 0 to about 0.5 V, δ is the separation between the two adhering particles, and E is the permittivity of free space.

The above discussions indicate that despite large uncertainties in the magnitude of the cohesive force, it appears to be linearly proportional to particle size. In the idealized situation that contiguous particles have smooth and clean surfaces, so that electrical charges and capillary forces can be eliminated, the interparticle force is proportional to the particle diameter, namely,

$$F_i = \beta d, \tag{20}$$

where β is a dimensional parameter. For a range of powder particles, *Phillips* [1980] suggested that the order of magnitude of β is approximately 10^{-5} Nm^{-1}. Equation (3) can now be rewritten as

$$a_t K_t \rho u_{*t}^2 d^3 = a_l \frac{\pi}{6} \rho_p g d^4 + a_s \beta d^2, \tag{21}$$

where K_t should be a function of Re_{*t}. It follows that

$$u_{*t}^2 = f(Re_{*t})(\sigma_p g d + \frac{\gamma}{\rho d}), \tag{22}$$

where

$$f(Re_{*t}) = \frac{\pi}{6} \frac{a_l}{a_t} \frac{1}{K_t}$$

$$\gamma = \frac{6}{\pi} \frac{a_s}{a_l} \beta.$$

The function f is inversely proportional to K_t, which in essence is a drag coefficient depending on Re_{*t} and needs to be determined empirically. We assume that $f(Re_{*t})$ can be approximated with a polynomial of Re_{*t} and fit (22) to the experimental data of *Iversen and White* [1982] for the particle size range between 50 and 1800 μm, within which the experimental data are most reliable. It turns out that an excellent fit of the observed data can be achieved using $f(Re_{*t}) = 0.0123$ with values of γ ranging between 1.65×10^{-4} and 5×10^{-4} kg s^{-2}. The new expression for u_{*t} is thus very simple.

Figure 3 shows a comparison of (22) and (16), together with observed data of *Cleaver and Yates* [1973],

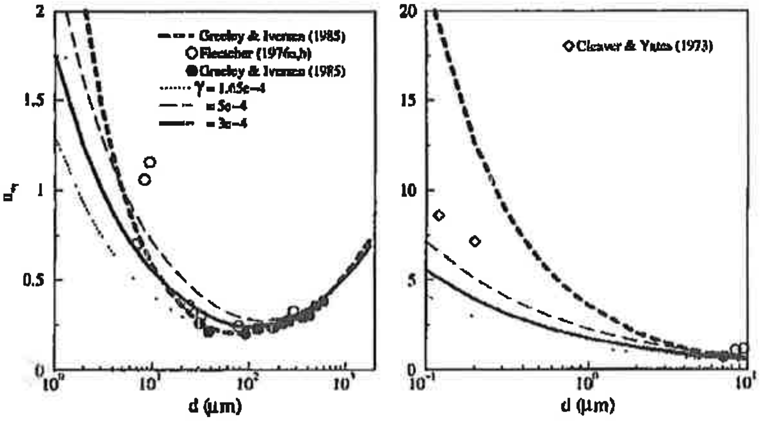

Figure 3. Comparison of the new expression, equation (22) with three different γ values, with the Greeley-Iversen expression, equation (16), together with the observed data of *Fletcher* [1976a, 1976b], *Greeley and Iversen* [1985], and *Cleaver and Yates* [1973].

Fletcher [1976a, 1976b], and *Greeley and Iversen* [1985]. For the particle size range $50 \leq d \leq 1800$ μm, the predictions using (22) and (16) are in good agreement but differ somewhat for the particle size range $1 \leq d \leq 50$ μm. For the latter particle size range, there is no reliable experimental data for validation, and therefore it is difficult to judge which one of the two expressions performs better. An obvious advantage of (22) is that it has a much simpler functional form than (16) and the physical interpretation of (22) is tidy.

A further comparison has been made by applying (22) and (16) to different planetary conditions. The six cases considered by *Iversen and White* [1982] are listed in Table 2. The predictions obtained by using (22) and (16) for the cases of Mars and Venus are shown in Figure 4. For all cases, (22) agrees well with (16) for particle sizes larger than 10 μm.

The new expression has several interesting features that deserve further discussion. Equation (22) suggests a new dimensionless threshold friction velocity of the form

$$A_N = \sqrt{f(Re_{*t})} = \frac{u_{*t}}{\sqrt{(\sigma_p g d + \frac{\gamma}{\rho d})}}. \qquad (23)$$

The conventional form of A_B contains effects from both the particle Reynolds number and the interparticle cohesion. *Iversen and White* [1982] and *Iversen et al.* [1987] have determined the specific form of A_B by attempting to isolate one effect from the other. The functional form of A_B in the expression of *Greeley and Iversen* [1985] implies that the cohesive force F_i is proportional to $d^{1/2}$ rather than proportional to d. This leads to a possible underestimation of F_i and an unnecessarily complicated expression, namely, (16). In contrast, A_N explicitly accounts for the effect of interparticle cohesion in the $\gamma/\rho d$ term. Equation (23) implies that if interparticle cohesion is considered, u_{*t} is in general proportional to $\sqrt{Y_1 d + Y_2 \frac{1}{d}}$ rather than to $\sqrt{d}$ as the previous expressions suggest. Hence A_N can be determined by assuming it is only a function of particle Reynolds number $f(Re_{*t})$.

A_N shows a weak dependence upon Re_{*t} and this is certainly the case for the particle size range between 30 and 1300 μm, for which most u_{*t} measurements have been made. From the wind tunnel measurements for the Venus case, *Iversen et al.* [1987] have found (see their Figure 4) that A_B is almost constant for the particle size range between 32 and 311 μm with increased

Table 2. Planetary Conditions Used by *Iversen and White* [1982]

		P, Pa	T, K	ρ, kgm^{-3}	$10^4\nu$, m^{2}s^{-1}	g, ms^{-2}	ρ_p/ρ
Mars	Case 1	500	240	0.011	11.2	3.75	240,000
	Case 2	500	150	0.0177	5.3	3.75	150,000
	Case 3	1,000	240	0.0221	5.6	3.75	120,000
	Case 4	1,000	150	0.0353	2.64	3.75	75,000
Earth		10^5	300	1.227	0.146	9.81	2.160
Venus		-	-	64.6	0.00443	8.77	41

Here P is surface pressure, T is temperature, and ρ_p is set to be 2650 kg m^{-3} for all cases.

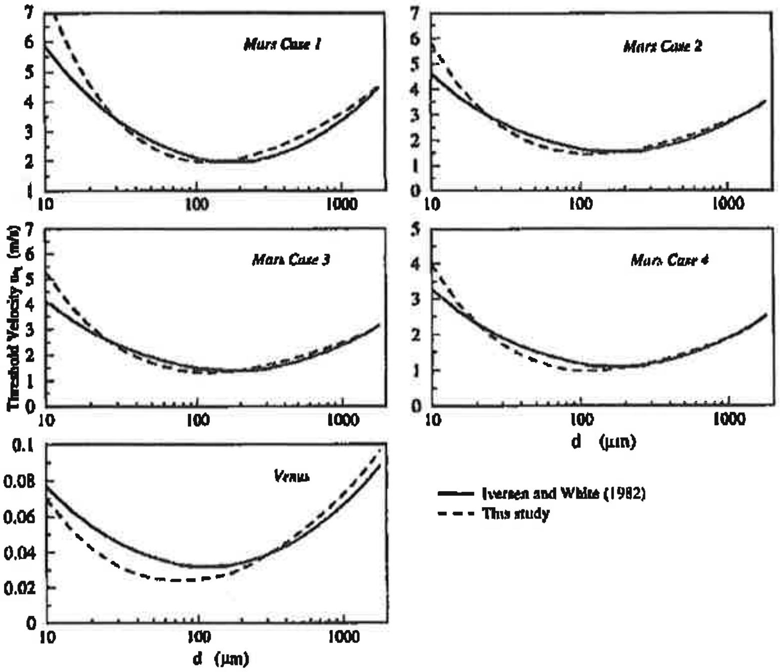

Figure 4. Comparison of equation (22) and (16) for planetary conditions of Mars and Venus listed in Table 2.

Re_{*t}. The wind tunnel data of *Iversen and White* [1982] suggest that for a given particle diameter, A_B decreases by a factor of 1.3 as Re_{*t} increases from 0.05 to 1. We have found that the value of $f(Re_{*t})$ does not vary over a wide range but lies between 0.011 and 0.013, which is consistent with the observations of *Iversen and White* [1982]. For large particles ($d > 200$ µm), equation (22) shows that the asymptotic behavior of the $u_{*t}(d)$ relationship is $u_{*t} \propto d^{1/2}$ and $A_N = A_B \simeq 0.11 - 0.12$. For small particles, the term Y_2/d dominates $Y_1 d$, and thus u_{*t} is determined by the balance between the aerodynamic and cohesive forces. The rapid increase of u_{*t} with decreasing d shows the strong effect of the cohesive force and the diminishing influence of the gravity force. For $d < 50$ µm, the cohesive force is at least 100 times larger than the gravity force. The asymptotic behavior of the $u_{*t}(d)$ relationship for small particles is $u_{*t} \propto d^{-1/2}$ as $d \to 0$.

The values of γ range between 1.65×10^{-4} and 5×10^{-4} kg s^{-2} and imply that the coefficient of interparticle force β is around 10^{-4} with the assumption of $6a_s/\pi a_l$ being of order of 1. This value of β is 1 order smaller than the measured values of 0.0012 (for quartz particles) and 0.0017 (for Pyrex particles) [*Corn*, 1961].

4. Conclusions

In this paper we have derived a new expression for calculating the wind erosion threshold friction velocity u_{*t} for spherical particles loosely spread over a dry and bare surface. This expression takes into account the effect of interparticle cohesion on u_{*t} but retains a simple functional form, namely, (22). The key argument embedded in the new expression is that the interparticle cohesive force should be, in general, proportional to d^{-1}. The new expression compares well with the Greeley-Iversen one for the conditions of Earth, Venus, and Mars. We note that the Greeley-Iversen expression is derived through fitting it to experimental data. We have found that although u_{*t} is a function of Re_{*t}, the dependence of the former on the latter is a weak one. For wind erosion studies on Earth, this dependency can be neglected. On the basis of the wind tunnel measurements presented by *Greeley and Iverson* [1985], the expression we recommend for calculating u_{*t} is

$$u_{*t} = \sqrt{A_N(\sigma_p g d + \frac{\gamma}{\rho d})}, \qquad (24)$$

with A_N being around 0.0123 and γ being around 3×10^{-4} kg s^{-2}.

In this paper, as in many others, we have assumed that the particles under consideration are spherical. Of course, real particles are not ideally spherical, smooth, and nondeformable. Small particles often have the shape of a platelet with considerable surface roughness and often show large deformation in the contact region. Therefore the theoretical predictions (23) and (19) are rarely applicable to yielding accurate estimates for the van der Waals and electrostatic forces. There are other types of interparticle forces, such as the capillary and Coulomb forces, which depend strongly on the moisture and chemical agents between the particles. It virtually impossible to accurately determine the magnitude of the cohesive force acting on small particles. As a consequence, the uncertainty in the prediction of u_{*t} becomes larger as the particle become smaller.

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