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THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Particulate Emission Factors for Blasting Operations and Other Potential Sources

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

in cooperation with

National Steel and Shipbuilding Company
San Diego, California

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DISCLAIMER

Final Report

PARTICULATE EMISSION FACTORS FOR BLASTING OPERATIONS AND OTHER POTENTIAL SOURCES

Project No. N1-97-04

And

DETERMINATION OF MASS FRACTION SIZE DISTRIBUTION OF PARTICULATE MATTER FROM HEMATITE DURING OPEN AIR ABRASIVE BLASTING

Project No. 1-98-1 Subtask 40

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NATIONAL SHIPBUILDING RESEARCH PROGRAM

FACILITIES AND ENVIRONMENTAL EFFECTS PANEL

SP-1

September 1999

Particulate Emission Factors for Blasting Operations and Other Potential Sources
Project No. N1-97-04

Executive Summary and Introduction

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Executive Summary

This project examined the potential sources of particulate matter in various size ranges that are potentially generated from common shipyard processes and operations. An investigation was conducted to determine which shipyard sources would most likely generate particulate matter in both the course (10 microns in diameter) and fine (2.5 microns in diameter) size range. Based upon this investigation, a matrix was developed indicating whether a process was a known, possible, or unlikely primary (directly emitted into the air) or secondary (formed from chemical reactions and condensation) source of particulates. The results of this matrix indicated that dry abrasive blasting was the most likely source of the majority of particulate emissions from shipyards.

A literature study was conducted to determine previously derived emission factors for dry abrasive blasting. Additionally, a survey of federal and state environmental agencies was conducted in order to determine if the agency had adopted emission factors for abrasive blasting for use in estimating particulate emissions. Finally, a survey of abrasive media manufacturers and/or distributors was conducted to determine if relevant product tests had been performed. The results of these studies and surveys revealed that there was only a small amount of data from work performed previous to this project from which emissions could be derived. The available data was shown to be limited, with information available on only testing of a few types of abrasive, under limited number of production variables.

In order to determine which type of abrasives, (and under what production variables) should be selected for emission testing, a national survey of shipyards was done to determine which abrasives were most commonly used. Additionally, the survey requested data on production variables, such as nozzle and pot pressures, hose diameter and length, and nozzle types and diameters. The results of the survey indicated that four abrasives (a five type of abrasive was added later in the project) should be tested to determine emissions factors at two nozzle pressures (80 and 122 psi).

A testing protocol was developed based on work previously conducted by Southwest Research Institute to develop emissions for coal slag.

Field tests of the selected media were conducted at a shipyard located in Louisiana. The results of the field test were used to develop emission factors for particulates in both the course and fine size range. The emission factors developed from these tests were, in all instances, lower than those emission factors in use by federal and state environmental agencies. Coal slag and sand were determined to have relatively higher emissions that other abrasive in all size ranges. Copper slag, garnet and hematite were shown to have the lowest emission factors.

The study, while providing a significant amount of new information regarding particulate matter generation from dry abrasive blasting operations, illustrated the fact that there remains a significant amount of necessary information required to derive predictive equations regarding production factors (abrasive cleaning and use rates), environmental factors (particulate emissions and waste volumes) and cost factors (purchase, clean-up and disposal). Consequently, a considerable amount of research must to be done in order to produce the data required for a comprehensive understanding of these important issues.

Introduction

This report is organized into sections based upon the results of seven[1] individual project tasks. These sections are as follows:

- Task 1: Shipyard Sources of Particulate Matter
- Task 2: Abrasive Blasting Emission Factors
- Task 3: Survey of U.S. Shipbuilding and Repair Industry Dry Abrasive Blast Media and Equipment Usage
- Task 4: Shipyard Abrasive Blasting Particulate Emission Factor Development Test Plan
- Task 5: Analysis of Field Samples
- Task 7: Development of Emission Factors
- Task 8: Project Summary and Guidance Document

Each task report section presents the results, interpretation and conclusions resulting from the respective individual task. Task 8 provides a project summary and guidance document designed to show how to use the emissions factors developed as a result of this project. Additionally, an Excel spreadsheet was developed that allows the shipyard to input required production factors from which an estimate of particulate emissions in various size ranges is derived.

[1] The project consisted of eight tasks, of which seven tasks required written reports. Therefore there is no Task 6 report.

Particulate Emission Factors for Blasting Operations and Other Potential Sources
Project No. N1-97-04

Task 1: Shipyard Sources of Particulate Matter

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Task 1: Shipyard Sources of Particulate Matter

Introduction

Particulate Matter ("PM") represents a broad class of chemically and physically diverse substances. It can be principally characterized as discrete particles that exist in the condensed (liquid or solid) phase spanning several orders of magnitude in size. For regulatory purposes, fine particles can be generally defined as those particles with an aerodynamic diameter of 2.5 microns (10^{-6} meters) or less, while coarse fraction particles are those particles with an aerodynamic diameter greater than 2.5 microns, but equal to or less than a nominal 10 μm. The health and environmental effects of particulate matter are strongly related to the size of the particles.

How is particulate matter formed?

Airborne particulate matter can be anthropogenic or natural in origin. Both anthropogenic and natural particulate material can occur from either primary or secondary processes. Anthropogenic refers to particulate matter, which is directly emitted, or formed from precursors that are emitted as a result of human activity. Primary anthropogenic sources include fossil fuel combustion, fireplace emissions, and road dust. Secondary anthropogenic particulate material can be generated photo-chemically from anthropogenic SO_2, NO_X, or organic gases. Primary natural sources include wind blown dust from soil undisturbed by man, sea-salt, natural forest fires and biogenic sources such as pollen, mold spores, leaf waxes and fragments from plants. In addition, plants emit gaseous species such as terpenes. Terpenes are photo-chemically reactive. In the presence of ozone or hydroxyl radicals, they react to form secondary organic particles.

Primary particles are composed of material emitted directly into the atmosphere. This includes material emitted in particulate form such as wind-blown dust, sea salt, road dust, mechanically generated particles and combustion-generated particles such as fly ash and soot. It also includes particles formed from the condensation of high temperature vapors such as those formed during combustion. The concentration of primary particles depends on their emission rate, transport and dispersion, and removal rate from the atmosphere.

Secondary particles form from condensable vapors formed by chemical reaction involving gas-phase precursors or by other processes involving chemical reactions of free, adsorbed, or dissolved gases. Secondary formation processes can result in either the formation of new particles or the addition of particulate material to preexisting. Most atmospheric sulfate particles are formed from atmospheric oxidation of sulfur dioxide. Atmospheric nitrate is also essentially secondary. Oxides of nitrogen react in the atmosphere to form nitric acid vapor that in turn may react with ammonia gas to form particulate ammonium nitrate. Nitric acid may also react with particles containing sodium chloride or calcium carbonate, releasing hydrochloric acid or carbon dioxide, and forming sodium nitrate or calcium nitrate, which remains in the particle. A portion of the organic aerosol is also attributed to secondary processes. Secondary aerosol formation can depend on concentrations of other gaseous reactive species such as ozone, hydroxyl radical, or hydrogen peroxide; atmospheric conditions including solar radiation and relative humidity; and the interactions of precursors and preexisting particles within cloud or fog droplets.

The emission sources, formation processes, chemical composition, atmospheric residence times, transport distances and other parameters of fine and coarse particles are distinct. Fine particles are generally formed secondarily from gaseous precursors such as sulfur dioxide (SO_2), nitrogen oxides (NO_X), or organic compounds and are composed of sulfate, nitrate, and ammonium compounds; elemental carbon; and metals. Fine particles can also be directly emitted. Combustion of coal, oil, diesel, gasoline, and wood, as well as high temperature process sources such as smelters and steel mills, produce emissions that contribute to fine particle formation. In contrast, coarse particles are typically mechanically generated by crushing or grinding and are often dominated by resuspended dusts and crustal material from paved or unpaved roads or from construction, farming, and mining activities. Fine particles can remain in the atmosphere for days to weeks and travel through the atmosphere hundreds to thousands of kilometers, while coarse particles deposit to the earth within minutes to hours and within tens of kilometers from the emission source.

Table 1.1 summarizes the key differences between fine and coarse particles.

Table 1-1. Comparison Of Ambient Fine And Coarse Mode Particles

	Fine Mode	**Coarse Mode**
Formed from:	Gases	Large solids/droplets
Formed by:	Chemical reaction; Nucleation; Condensation; Coagulation; Evaporation of fog and cloud droplets in which gases have dissolved and reacted.	Mechanical disruption (e.g., crushing, grinding, abrasion of surfaces); Evaporation of sprays; Suspension of dusts.
Composed of:	Sulfate, $SO_4^{=}$; Nitrate, NO_3^-; Ammonium, $NH_4^{+;}$ Hydrogen ion, H^+; Elemental carbon Organic compounds (e.g., PAHs, PNAs);	Resuspended dusts (e.g., soil dust, street dust); Coal and oil fly ash; Metal oxides of crustal elements (Si, Al, Ti, Fe); $CaCO_3$, NaCl, sea salt; Pollen, mold spores; Plant/animal fragments;

	Metals (e.g., Pb, Cd, V, Ni, Cu, Zn, Mn, Fe); Particle-bound water.	Tire wear debris.
Solubility:	Largely soluble, hygroscopic and deliquescent.	Largely insoluble and non-hygroscopic.
Sources:	Combustion of coal, oil, gasoline, diesel, wood; Atmospheric transformation Products of NO, SO, and organic compounds including biogenic species (e.g., terpenes); High temperature processes, smelters, steel mills, etc.	Resuspension of industrial dust and soil tracked onto roads; Suspension from disturbed soil (e.g., farming, mining, unpaved roads); Biological sources; Construction and demolition; Coal and oil combustion; Ocean spray.
Lifetimes:	Days to weeks	Minutes to hours
Travel Distance:	100s to 1000s of kilometers	< 1 to 10s of kilometers

Shipyard sources of particulate matter

To determine which shipyard operations and processes that may be sources of particulate matter, we first developed a detailed list of shipyard operations and processes, secondly investigated which types of pollutants may be derived from each operation or process, and finally, compared the list of derived pollutants to our understanding of the formation of both coarse and fine particulate matter. In many cases, common shipyard operations or processes, such as hydroblasting and tank cleaning, were eliminated as potential sources of particulate matter as their was no indication of primary or secondary generation of particulates from the processes.

Following the selection of shipyard operations or processes that may result in the generation of particulate matter, a literature search was conducted to locate established emission factors, or other relevant documentation, for the selected process or operation. If referenced emission factors could be located for a particulate process, or applicable portion of the process, it was accepted that the process was an established source of particulate matter. If a referenced emission factor could not be located for a particulate process but the process supported a known or accepted mode of particulate matter generation, the process was identified as a possible source of particulates. If a reference emission factor could not be located and the process could not be directly related to source particulate matter formation, the process was identified as unlikely to be a source of particulates.

The Table 1.2 below summarizes those shipyard processes and operations that were evaluated as potential sources of coarse or fine particulate matter.

Table 1-2. Summary of Shipyard Operations and Processes and Potential Sources of Particulate Matter

Operation	Process	Source of Pollutants	Pollutants of Concerns	Primary Source (Directly Emitted in the Air)		Secondary Source (Formed from chemical reactions and condensation)	
				Coarse	Fine	Coarse	Fine
Surface Preparation	Solvent Cleaning	VOC containing solvents	VOC	Unlikely	Unlikely	Possibly[2]	Possibly[1]
	Dry Abrasive Blasting	Break down of abrasive media	particulates	Yes	Yes[3]	Unlikely	Unlikely
	Steel Pickling	Emission of sulfuric acid from dip bath	SO_X	Unlikely	Unlikely	Possibly[4]	Possibly[3]
	Copper/Copper-Nickel Pickling	Emission of nitric acid from dip bath	NO_X	Unlikely	Unlikely	Possibly[3]	Possibly[3]
Marine Coating Operations	Coating Application	VOC containing coatings	VOC	Possibly[1]	Possibly[1]	Possibly[1]	Possibly[1]
	Spray Painting	Overspray	Particulates	Possibly[5]	Possibly[4]	Unlikely	Unlikely

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2 Organic compounds can participate in condensation reactions resulting in particulate formation.

3 AP - 42 Chapter 13.2.6 has been updated to include emission factors for $PM_{2.5}$

4 SO_2 and NO_X can participate in condensation reactions resulting in particulate formation.

5 Size distribution of overspray is not well characterized. Unknown if coarse or fine particles could be generated via this process.

Metal Processing, Fabrication and Machining	Pre-construction priming	VOC containing primer	VOC	Possibly[1]	Possibly[1]	Possibly[1]	Possibly[1]
		Overspray	Particulates	Possibly[4]	Possibly[4]	Unlikely	Unlikely
	Metal shaping	Torch cutting	metal fumes	Possible[6]	Possibly[5]	Possibly[5]	Possibly[5]
		Mechanical cutting	particulates	Yes	Unlikely	Unlikely	Unlikely
	Metal joining	Welding	metal fumes	Yes	Possibly[7]	Possibly[6]	Possibly[6]
		Heat treating	external combustion	Yes	Possibly[3]	Possibly[3]	Possibly[3]
		Casting	external combustion	Yes	Possibly[3]	Possibly[3]	Possibly[3]
	Metal finishing	Grinding	particulates	Yes	Unlikely	Unlikely	Unlikely
	Metal finishing	Sanding	particulates	Yes	Unlikely	Unlikely	Unlikely

[6] Metal fumes are generated from torch burning. Unknown size distribution of particulates.

[7] Most particulate matter produced by welding is submicron in size and therefore all PM_{10} or less in size. Amount of, if any, PM2.5 or less is unknown.

Transportation	Material, Personnel and Equipment Movement	Tire wear	particulates	Yes	Unlikely	Unlikely	Unlikely
		Dust Resuspension	particulates	Yes	Possibly	Unlikely	Unlikely
	Trucks and other self propelled vehicles	Internal Combustion engines	particulates	Yes	Possible	Possibly	Possibly
			NO_X, SO_2	Yes	Possibly[3]	Possibly[3]	Possibly[3]
Yard Services	Steam boilers	Diesel fuel combustion	NO_x, SO_2	Yes	Possibly[3]	Possibly	Possibly
			particulates	Yes	Possibly	Unlikely	Unlikely
		Natural gas combustion	NO_X,	Yes	Possibly[3]	Possibly	Possibly
			VOC	Unlikely	Unlikely	Possibly[1]	Possibly[1]
			particulates	Yes	Yes	Unlikely	Unlikely
	Compressed air	Diesel fuel combustion	NO_x, SO_2	Yes	Possibly[3]	Possibly[3]	Possibly[3]
			particulates	Yes	Possibly	Unlikely	Unlikely
	Power generation	Diesel fuel combustion	NO_x, SO_2	Yes	Possibly[3]	Possibly[3]	Possibly[3]
			particulates	Yes	Possibly	Unlikely	Unlikely

Material Movement	Cranes	Diesel fuel combustion	NO_X, SO_2	Yes	Possibly[3]	Possibly[3]	Possible[3]
			Particulates	Yes	Possibly	Unlikely	Unlikely
Electrical Services	Plating	Nitric acid plating solution	NO_X	Unlikely	Unlikely	Possibly	Possibly
	Lacquer coating	VOC containing lacquers and varnishes	VOC	Possibly[1]	Possibly[1]	Possibly[1]	Possibly[1]
Carpentry	Cutting	Saw dust	Particulates	Unlikely	Unlikely	Unlikely	Unlikely
	Sanding	Saw dust	Particulates	Unlikely	Unlikely	Unlikely	Unlikely
	Sealing, Painting	VOC containing sealers and/or paints	VOC	Unlikely	Unlikely	Possibly[1]	Possibly[1]
Fiberglass Lay-up and Repair	Fiberglass resin and solvents	VOC containing materials	VOC	Unlikely	Unlikely	Possibly[1]	Possibly[1]
	Cutting, Grinding, Sanding	fiberglass dust	particulates	Possibly	Possibly	Unlikely	Unlikely

Table 1-2. Notation

Notation	Explanation
Yes	Reference emission factor(s) or other document literature reference.
Possibly	No referenced emission factor, but current understanding of particle formation/generation process is applicable to operation or process.
Unlikely	No reference emissions, and particle formation/generation process is not applicable to operation or process.

Summary of Results

Many shipyard operations and processes were determined to be potential sources of both primary and/or secondary generation of both coarse and fine particulate matter. While many of the shipyard operations and processes may be sources of particulate matter, most of these are likely to be insignificant due to the fact that either 1) while the particulate emission factor may be relatively high, the material throughput is small or 2) the throughput may be relatively large, the emission factor is small.

Based on the Table 1-2 above, some general observations can be drawn concerning what shipyard operations and processes could be of concern as significant sources of particulate matter. These observations are bulleted below:

- Material Movement, Metal Processing, Fabrication and Machining, Surface Preparation, Transportation and Yard Services were identified as shipyard operations that included specific processes that were known primary sources of coarse particulate matter. Significant sources of coarse particulate matter appear to be confined to dry abrasive blasting. Marine coating operations conducted with paint spray equipment could also release a significant amount of coarse particulates, however no data regarding the particle size distribution of coating overspray was located during the research phase of this Task. Therefore no reliable conclusion regarding coarse particulate matter generation from marine coating operations could be drawn.

- Yard Services and Surface Preparation were identified as shipyard operations that included specific processes that were known primary sources of fine particulate matter. Possible significant sources of fine particulate matter appear to be confined to dry abrasive blasting. Marine coating operations conducted with paint spray equipment could also release a significant amount of fine particulates, however no data regarding the particle size distribution of coating overspray was located during the research phase of this Task. Therefore no reliable conclusion regarding fine particulate matter generation from marine coating operations could be drawn.

- No shipyard operations or processes were positively identified as secondary sources of particulate. However, several shipyard operations included processes that were possible sources of chemical precursors to secondary sources of both coarse and fine particulate matter.

Conclusions

Dry abrasive blasting is most likely the major significant primary source of both coarse and fine particulate matter generation derived from shipyard operations. Other secondary sources of coarse and fine particulate matter may also be derived from shipyard operations. The level of significance of these sources cannot be estimated at this time due to the lack of reliable data regarding emissions factors, condensation rates, and particulate formation processes.

Bibliography of Sources for Task One

Source	Author	Use
Regulatory Impact Analysis for Proposed Particulate Matter National Ambient Air Quality Standard	Innovative Strategies and Economics Group, Office of Air Quality Planning and Standards, U.S. EPA, December 1996	Sources of fine and course particulate matter.
Profile of the Shipbuilding and Repair Industry	Office of Compliance, Office of Enforcement and Compliance Assurance, U.S. EPA, November 1997	Identification of shipbuilding and repair processes and operations.
Air Quality Criteria for Particulate Matter Chapter 3. Physics and Chemistry of Particulate Matter		Sources of fine and course particulate matter.
Baseline Characterization of Emissions from Fiberglass Boat Manufacturing for National Marine Manufacturers Association	Stelling Engineering, Air-Tech Environmental LLC, and Radian International. August 1997	Emissions from fiberglass operations.
AP - 42, Chapter 1.4 Natural Gas Combustion	Technical Support Division, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC	Emission factors
AP - 42 Chapter 3.3 Gasoline and Diesel Industrial Engines	Technical Support Division, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC	Emission factors

AP -42 Chapter 13.2.6 Abrasive Blasting	Technical Support Division, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC	Emission factors
AP - 42 Chapter 13.2.2 Unpaved Roads	Technical Support Division, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC	Emission factors
AP - 42 Chapter 13.2.1 Paved Roads	Technical Support Division, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC	Emission factors
AP - 42 Chapter 12.19 Electric Arc Welding	Technical Support Division, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC	Emission factors
AP - 42 Chapter 1.3 Fuel Oil Combustion	Technical Support Division, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC	Emission factors

Particulate Emission Factors for Blasting Operations and Other Potential Sources Project No. N1-97-04

Task 2: Abrasive Blasting Emission Factors

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Task 2 - Abrasive Blasting Emissions Factors

Introduction

A research survey was performed to determine what emission factors have been developed for the generation of particulate matter derived from abrasive blasting. The following specific potential sources of emission factor data were researched:

- Federal Environmental Protection Agency;
- Air Quality Agencies of Selected States;
- Studies conducted by the National Shipbuilding Research Program; and
- Manufacturers and/or distributors of abrasive blast media commonly used in shipyards.

The research effort focused on obtaining information regarding the following three specific emission factor categories of particulate matter: (1) Total Particulate Matter/Total Suspended Particulates ("TPM"), (2) Particulate Matter 10 microns in diameter and smaller ("PM_{10}") and (3) Particulate Matter 2.5 microns in diameter and smaller ("$PM_{2.5}$").

This research was conducted using mailed questionnaires[8], telephone contacts, review of published literature, electronic abstract searches and on-line searches of the World Wide Web. When emission factor citations were identified, documentation was obtained and reviewed for relevant data. A bibliography of pertinent documentation is attached as Appendix 1 of this Task report

Research Results

Emission factors were identified for TPM, PM_{10}, and $PM_{2.5}$ for one or more types of abrasive media. No emission factors were located for mineral (such as garnet) or mineral slag (such as copper slag) abrasives. In general, only a few emission factors for abrasive blasting media were located. For emission factors that were located, the data values for the same type of abrasives varied by a factor of from 3 to 30.

Federal And State Air Quality Agencies

Twenty-six (26) state agencies and the federal Environmental Protection Agency ("EPA") were contacted by telephone to determine if they had established emission factors for any abrasive media commonly used in shipyards. Additionally, the web sites of several state environmental agencies and the EPA were searched for relevant information or data. This survey resulted in the identification of five sets of one or more agency established emission factors from the State of California, the State of Texas and the EPA. However, only four of the five sets of established emission factors were independently derived as the Bay Area Air Quality Management District

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[8] See Appendix 2 for copy of survey questionnaire.

in California merely adopted the emission factors used by the South Coast Air Quality Management District.

The attached summary table displays the agency emission factor data.

Abrasive Blast Media Manufacturers and Distributors

A survey letter was sent to forty-six (46) manufacturers and distributors of abrasive blast media commonly used in the United States. Of the forty-six manufacturers/distributors contacted, ten companies responded to the inquiry. No responding company had emission factors for their abrasive product. Several companies were able to provide sieve data and/or opacity data, used to obtain a California Air Resources Board Certification for abrasive media used for unconfined abrasive blasting. While this data can be indicative of relative "dustiness" of an abrasive media, emission factors could not be derived from this data.

A summary table is attached which indicates the abrasive media manufacturers /distributors contacted and any subsequent responses.

National Shipbuilding Research Program Studies

The catalog of abstracts of the National Shipbuilding Research Program ("NSRP") was searched both from its electronic library on disk and from the NSRP document web site. Several studies relevant to particulate emissions from abrasive blasting in shipyards were located. No study was found that actually determined or derived emission factors for any abrasive media. The most appropriate reference[9] located was a study conducted by Norfolk Shipbuilding & Drydock Corporation ("Norshipco") that reported on the size distribution of particulates derived from abrasive blasting using coal slag during actual ship's hull blasting operations in the floating drydock. This study, while not deriving emission factors for coal slag blasting operations, did determine that PM_{10} was generated from coal slag under normal shipyard blasting operations.

Emission Factor Research Results

The results of the emission factor survey and research for various types of abrasive media is provided below.

Sand

TPM and PM_{10} emission factors for "sand" were obtained from the two states of California and Texas. Texas is using emission factors of 0.0043 and 0.0014 (in units of lbs of emissions/lbs of abrasive used) for TPM and PM_{10} respectively. California is reporting emission factors of 0.0125 and 0.041 0014 (in units of lbs of emissions/lbs of abrasive used) for TPM and PM_{10}, respectively. No $PM_{2.5}$ emission factors for sand were reported by either state.

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9 NSRP Task No. N1-89-2, Subtask 4 - Final Report: Determination of Particulate & Dust Concentration During Shipyard Drydock Sandblasting Operations. Sept. 1992.

Coal Slag

The State of Texas reported emission factors for "coal slag" being 0.0023 and 0.0006 0014 (in units of lbs of emissions/lbs of abrasive used) for TPM and PM_{10} respectively. No $PM_{2.5}$ emission factors for coal slag were identified by any state or federal air quality agency.

Mineral Abrasives

The County of San Diego Air Pollution Control District was the only agency reporting an emission factor for a mineral abrasive. This agency uses a TPM emission factor of 0.0125 (in units of lbs of emissions/lbs of abrasive used) for garnet abrasive.

Mineral Slags

The County of San Diego Air Pollution Control District was the only agency reporting an emission factor for a mineral slag abrasive. This agency uses a TPM emission factor of 0.0125 (in units of lbs of emissions/lbs of abrasive used) for mineral slag abrasive.

Metallic Grit

Two Air Quality Districts in the State of California reported emission factors for "metallic grit" (such as iron or steel grit) The Bay Area and South Coast Air Quality Management Districts reported an emission factor of 0.01 (in units of lbs of emissions/lbs of abrasive used) for PM_{10}. The County of San Diego report an emission for TPM of 0.0038 01 (in units of lbs of emissions/lbs of abrasive used).

Metallic Shot

The State of California reported emission factors for "metallic shot" (such as iron or steel shot) being 0.004 0014 (in units of lbs of emissions/lbs of abrasive used) for PM_{10}. No TPM or $PM_{2.5}$ emission factors for metallic shot were identified by any other state or federal air quality agency.

General Abrasive Media

The federal EPA reported emissions factors for TPM, PM_{10} and $PM_{2.5}$ derived from studies conducted on various media. This data was combined to produce emission factors for abrasive blasting without specifying the type of media used. The emission factors reported are 0.027, 0.013 and 0.0013 0014 (in units of lbs of emissions/lbs of abrasive used) for TPM, PM_{10} and $PM_{2.5}$ respectively.

Additionally the County of San Diego Air Pollution Control District uses a “general media” emission factor for TPM of 0.0075 (in units of lbs of emissions/lbs of abrasive used).

Summary and Conclusions

The results of this task indicate that there is limited established and accepted emission factors for the generation of particulate matter derived from abrasive blasting operations. Two very common types of media used in shipyards, mineral and mineral slag, had no accepted emission factors at all. Other emission factors for different types of abrasive media ranged over a factor of 100. The lack of data regarding emissions of $PM_{2.5}$ was especially evident from the survey. This NSRP project to determine emission factors for various commonly used abrasive will be useful in filling in the significant data gaps that currently exist in the area of shipyard emission inventories.

Table of Research Results

Table 1 - State and Federal Air Quality Agency Emission Factors

	Type of Abrasive								
Agency	**Sand**			**Coal Slag**			**Mineral**		
	TPM/TSP	PM_{10}	$PM_{2.5}$	TPM/TSP	PM_{10}	$PM_{2.5}$	TPM/TSP	PM_{10}	$PM_{2.5}$
Alabama									
Alaska									
Arizona									
California ARB									
CA - Bay Area		**0.041**							
CA - South		**0.041**							
CA - San	**0.0125**						**0.004**		
Connecticut									
Delaware									
Florida									
Georgia									
Hawaii									
Indiana									
Louisiana									
Maine									
Maryland									
Minnesota									
Mississippi									
New									
New Mexico									
New York									
North Carolina									
Ohio									
Oregon									
Pennsylvania									
Texas	**0.043**	**0.0014**		**0.0023**	**0.0006**				
Federal EPA									

Emission Factors are given in units of lbs particulate/lbs of abrasive used

	Type of Abrasive								
Agency	**Mineral Slag**			**Metallic Grit or Shot**			**General Media**		
	TPM/TSP	PM_{10}	$PM_{2.5}$	TPM/TSP	PM_{10}	$PM_{2.5}$	TPM/TSP	PM_{10}	$PM_{2.5}$
Alabama									
Alaska									
Arizona									
California ARB									
CA - Bay Area					**0.01**				
CA - South					**0.01**				
CA - San	**0.005**			**0.0038**			**0.0075**		
Connecticut									
Delaware									
Florida									
Georgia									
Hawaii									
Indiana									
Louisiana									
Maine									
Maryland									
Minnesota									
Mississippi									
New									
New Mexico									
New York									
North Carolina									
Ohio									
Oregon									
Pennsylvania									
Texas									
Federal EPA							**0.027**	**0.013**	**0.0013**

Emission Factors are given in units of lbs particulate/lbs of abrasive used

Table 2 - Summary of Responses from Abrasive Manufacturers

Abrasive Manufacturer	Responded to	Emission Factors?
Abrasives, Inc.	No	N/A
Abrasives Technologies, Inc.	No	N/A
Alpheus Cleaning Technologies Corp.	**Yes**	No
Barnes Environmental, Inc.	**Yes**	No
Barton Mines Corporation	**Yes**	No
Cominco American, Inc., Ruby Garnet	No	N/A
Corona Industrial Sand Company	No	N/A
Conversion Technologies International,	**Yes**	No
Don Kelland Materials, Inc.	No	N/A
E.I. Du Pont De Menours & Company,	No	N/A
EcoSource Garnet, Inc.	No	N/A
Eurogrit BV	No	N/A
Fairmount Abrasives, Inc.	No	N/A
Foster-Dixiana Corporation	No	N/A
Glass Recycling, Inc.	**Yes**	No
GMA Garnet Pty Ltd.	**Yes**	No
Gordon Sand Company	No	N/A
Green Diamond Abrasives	No	N/A
Industrial Mineral Fillers Company	No	N/A
International Garnet	No	N/A
Kleen Blast Abrasives	No	N/A
Minerals Research and Recovery, Inc.	No	N/A
Mobile Abrasives	No	N/A
Nevada Slag, Inc.	No	N/A
North American Abrasives, Inc.	No	N/A
Oglebay Norton Industrial Sand, Inc.	No	N/A
P.W. Gillibrand	No	N/A
Parker Bros. Co., Inc.	No	N/A
Patterson Materials Corporation	No	N/A
Pontchartrain Materials Corporation	No	N/A
RDM Multi-Enterprises, Inc.	No	N/A
RMC Lonestar	No	N/A
Redland Genstar, Inc.	No	N/A
Reed Minerals, A Divison of Harsco	No	N/A
Silica Resources, Inc.	**Yes**	No
Staker Asphalt Paving & Construction	No	N/A
Stan-Blast Abrasive Company, Inc.	No	N/A
Strategic Materials, Inc.	No	N/A
Sweetwater Garnet, Inc.	No	N/A

Virginia Materials & Supplies, Inc.	**Yes**	No
Western Garnet International	No	N/A
Western Minerals	No	N/A
TriVitro Corporation	**Yes**	No
Unimin Corporation	No	N/A
Universal Ground Cullet, Inc.	**Yes**	No
US Technology Corporation	No	N/A

Appendix 1 - Document Bibliography

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2. Compilation of Air Pollution Control Factors, Chapter 13.2.6 Abrasive Blasting. U.S. Environmental Protection Agency. September 1997.
3. Technical Guidance Package for Coating Sources, Abrasive Blast Cleaning. Texas Natural Resource Conservation Commission. January 1995.
4. Particle Size Distribution and Generation Rate of Spent Coal Slag Abrasive Used to Remove Paint From Steel Surfaces. Final Report SwRI Project 01-5526. Prepared by Southwest Research Institute for Bethship - Sabine Yard Port Arthur, Texas. May 1993.
5. South Coast Air Quality Management District Permit Processing Handbook, Section 2, Unconfined Abrasive Blasting. August 1989.
6. Bay Area Air Quality Management District Permit Handbook, Abrasive Blasting (Confined). May 1998
7. Personal Communication, Abrasive Blasting Emission Factors, Ms. Trudy Wood, Air Resources Specialist, San Diego County Air Pollution Control District. August 1998.

Appendix 2 - Vendor Survey Letter

August 16, 2001

First Name Last Name
Title
Company
Address
State, City Zip

Re: National Shipbuilding Research Program Request for Particulate Emission Factor Information

Dear Last Name:

The National Shipbuilding Research Program's ("NSRP") Facilities and Environmental Effects Panel ("SP-1") has contracted with Atlantic Marine, Inc. ("AMI"), located in Jacksonville, Florida to conduct research into abrasive blasting emission factors. This research will involve both the evaluation of existing emission factor data and the testing of various abrasive blasting media commonly used in the U.S. shipbuilding and repair industry for the surface preparation of superstructures, decks, and underwater hulls. The results of this research and testing will be published by the NSRP and provided to U.S. shipyards to be used a guide in selecting abrasive blasting media. Additionally the data may be used by federal and/or state environmental agencies to establish abrasive blasting emission factors for the purpose of evaluating shipyard abrasive blasting permit applications, conducting annual emission inventories or determining appropriateness of dust control procedures.

AMI has contracted with Austin Environmental, Inc. ("AEI"), located in San Diego, California, to conduct research into existing abrasive blasting emission factor data. As a part of this research AEI will determine what data may be available from the manufacturers and distributors of this material.

This letter is to determine if your company has any relevant data on particulate matter emission factors derived from the testing of the abrasive blasting media(s) your company manufacturers or distributes. Specifically, data concerning the following areas is requested:

1. Total Particulate Matter ("TPM") emissions per unit of abrasive used (i.e. lbs of TMP per ton of abrasive used);
2. Particulate Matter 10 microns in diameter or less (PM_{10}) emissions per unit of abrasive used (i.e. lbs of PM_{10} per ton of abrasive used); and
3. Particulate Matter 2.5 microns in diameter or less ($PM_{2.5}$) emissions per unit of abrasive used (i.e. lbs of $PM_{2.5}$ per ton of abrasive used).

Any emission factor data that you are be able to provide us will be used to develop an abrasive media selection database and assist AMI in selecting types of media on which additional testing will be conducted.

Any available data reports that are responsive to this request can be sent directly the offices of AEI in San Diego.

Thank you in advance for any assistance you can provide us in conducting this important research. If you have any questions or require additional information regarding this request, please contact me directly at telephone number 619-523-9621.

Very truly yours,

AUSTIN ENVIRONMETNAL, INC.

Dana M. Austin

cc: NSRP Particulate Emission Factor Project file

Particulate Emission Factors for Blasting Operations and Other Potential Sources
Project No. N1-97-04

Task 3 - Survey of U.S. Shipbuilding and Repair Industry Dry Abrasive Blast Media and Equipment Usage

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Task 3 - Survey of U.S. Shipbuilding and Repair Industry Dry Abrasive Blast Media and Equipment Usage

Introduction

Austin Environmental Inc. ("AEI") conducted a national survey of survey of the U.S. Shipbuilding and Repair industry in order to determine the abrasive blast media and methods that are currently in use. This Task discusses the methodology and results of this survey and provides the basis for the prioritization of abrasive media, equipment and blasting pressures for determination of particulate matter emission factors.

Survey Methodology and Results

A one page "fax-back" survey form requesting data on abrasive media usage for unconfined blasting operations and blasting equipment was prepared based upon information derived from previous NSRP surveys, the research conducted for Tasks 1 and 2 of this project, and AEI's knowledge of dry abrasive blasting operations in the shipbuilding and repair industry (survey form and information sheet are attached as Appendix 1). The survey was specifically designed to require a few moments of completion time by the shipyard's most knowledgeable person regarding abrasive blasting. This was done in an attempt to minimize the effort required by the shipyard to complete the form and maximize the survey return rate.

The survey form, and a one-page information page, was faxed to two hundred and twenty four (224) shipbuilding and repair companies in the United States, using the most current shipyard database complied by AEI. This survey is believed to be a much larger (and more representative of the overall U.S. industry) than other NSRP surveys in that it includes a greater number of shipyards who have not previously participated in NSRP activities.

Table 1 below provides a summary of information on the location and number of shipyards that received the survey and the number of responses received.

Table 1 - Summary of Abrasive Blast Survey Data

Region	Number of Surveys Sent	Number of Responses	Percent Response by Region of Surveys Sent	Percent Response of Total Received
New England States	25	3	1.3	7
Mid-Atlantic & Southeast States	32	8	3.6	19
Gulf Coast States	95	15	6.7	36
California	20	6	2.7	14

Pacific Northwest	34	9	4.0	21
Great Lakes States	9	0	0	0
Other	9	1	0.4	2
Totals	224	42		99

An overall response rate of 18.75 % was achieved via the "fax-back" survey. The response rate varied by region from 0 to 6.7 percent, with the Gulf Coast region having the highest, and the Great Lakes region have the lowest percent response.

Abrasive Blasting Media Results

The forty-two (42) shipyards that responded to the survey indicated an average annual usage of abrasive media of approximately 98 thousand tons. Projected annual usage for the entire U.S. industry, based upon the percent response rate of 18.75%, equals 524,105 tons.

Table 2 - Abrasive Blast Media Usage, Unconfined Abrasive Blasting

Type of Abrasive	Reported Annual Usage (tons)	Percent of Total Usage	Projected Usage in United States (tons)
Coal Slag	39,065	39.75	208,331
Copper Slag	24,309	24.74	129,663
Sand	12,358	12.58	65,932
Steel Shot	10,236	10.42	54,611
Nickel Slag	4,692	4.77	24,999
Garnet	3,459	3.52	18,448
Other	1,864	1.90	9,957
Steel Grit	1,556	1.58	8,280
Glass	151	0.52	2,725
Other Minerals	168	0.17	891
Iron Grit	40	0.04	209
Iron Grit	6	0.01	52
Totals	**97,904**	**100**	**524,098**

Of this reported abrasive usage, over 95 percent was limited to coal slag (39.75%), copper slag (24.74%), sand (12.58%), steel shot (10.42%) and nickel slag (4.77%) and garnet (3.52%).

The usage survey generally confirms the relative popularity of abrasive media used in U.S. shipyards as determined by previous surveys, except for the relatively higher value obtained for sand. Previous NSRP projects that surveyed abrasive blast media usage indicated sand usage of less than 4% of the U.S. total. While it is unknown if this result indicates a actual change in abrasive media usage patterns or was a result of survey bias (or a combination of both), it is clear that with a reported annual usage of over 12 thousand tons, and a projected usage of 65,932 tons, the use of sand as an abrasive media in the U.S. shipbuilding and repair industry remains high. This was unexpected as it had been believed (based on prior NSRP reports) that sand was being phased, out as an abrasive media, due to the potential health risks to shipyard workers.

Abrasive Blasting Equipment Results

The survey requested information regarding abrasive blasting equipment and air pressures that could bear on the amount of particulate emissions derived from the blasting processes. These included air pressure at the pot and nozzle, types of nozzles used and the length and diameter of hoses. The percentage results of this portion of the survey are given in Table 3 below.

Table 3 - Abrasive Blasting Equipment

Air Pressure to Conduct Blasting Operations

PSI at the Pot	**75-100 psi**	**100-125 psi**	**125-160 psi**	
Reported Percentages	18.18 %	68.18 %	13.64 %	
PSI at the Nozzle	**65-85 psi**	**85-100 psi**	**100-120 psi**	**>120 psi**
Reported Percentages	17.02 %	53.19 %	23.40 %	6.38 %

Diameter and Length of Hoses used During Blasting Operations

Diameter (inches)	**1**	**1 ¼**	**1 ½**	**2**	**>2**
Reported Percentages	10.53 %	29.82 %	22.0 %	11.0 %	1 %
Length (feet)	**50-100**	**100-200**	**200-400**	**>400**	
Reported Percentages	48 %	38 %	10.0 %	2.0 %	

Type of Nozzles used for Abrasive Blasting Operations

Type of Nozzle	**Reported Percentages, for nozzle sizes # 6, 7 and 8**
Straight Bore	35.71 %
Conventional Long Venturi	50.0 %

Laminar Long Venturi	1.43 %
Double Venturi	2.86 %
High Pressure Venturi	10.0 %

The results of the abrasive blasting equipment survey indicate that most shipyards are using moderate to high air pressure at both the abrasive blasting pot (81.82 % at 100-160 psi) and nozzle (76.59 % at 85-120 psi). Most shipyards are using small to medium diameter hoses (62.35 % at 1-1 ½ inches) of short to moderate length (86 % at 50 to 200 feet). Nozzle usage is predominately straight bore (35.71 %) and conventional long venturi (50.0 %). A lesser, but significant percentage of shipyards are using high-pressure venturi nozzles (10.0 %).

Prioritization Of Abrasive Media And Equipment for Determination of Emission Factors

The purpose of Task 3 was to acquire information regarding the current usage of abrasive blast media and equipment. In other words, when the actual testing of media under different equipment scenarios is conducted during Task 5 of this project, the results were intended to be reflective of the actual operating conditions in the majority of shipyards. Based upon the survey results, we believe the following media and testing parameters would be most representative of the current abrasive blasting usage and practices in effect today.

Abrasive Media

The types of abrasive media selected for additional testing are coal slag, copper slag, sand and garnet. The total percentage usage of these medium combined equal 80.59 %. Two other types of media that had percentage usages higher than garnet, and were not selected, were steel shot and nickel slag. Steel shot was not selected because it is believed that its use in the U.S. shipbuilding and repair industry remains primarily in enclosed spaces and tanks. Blasting operations conducted under these conditions are typically conducted with air pollution control devices and, as such, the particulate emissions are greatly reduced. Nickel slag was not selected because it had a relatively low percentage usage (4.77 %), and there was another mineral slag (copper slag) with a much higher percent usage selected for testing. Garnet was selected for additional testing even though its percentage use was relative low (3.52 %), because it was the only mineral abrasive that is used in any significant amount by the shipyards. Additionally, garnet has significantly different physical and chemical properties than the other selected types of abrasive media, (hardness, friability and consistent chemical composition) which may be useful in interpreting differences in the emission factor results between the various types of abrasives.

Abrasive Blasting Equipment

Based on the survey results, it was decided to conduct emission factor determinations for each selected abrasive media at both moderate (100 psi) and high (155 psi) nozzle pressures. This was done because of the belief that nozzle pressure (and therefore abrasive particle velocity) would have a significant effect on generation rate of particulate matter for most abrasives.

Having emission factor data for different nozzle pressures will allow us to conduct a linear interpolation between the data sets and infer emission rates for nozzle pressures between the test parameters. Additionally it was determined that the type of nozzle selected for use in conjunction with the testing should be both representative of current usage and the appropriate match for the intended pressure. Therefore, for those tests using moderate nozzle pressure, a conventional long venturi nozzle will be used. For high nozzle pressure tests, a high-pressure nozzle will be used. The testing protocol will be established in Task 4 of this project and the actual testing will be conducted during Task 5.

Summary of Proposed Test Parameters

Each selected media will be tested at two nozzle pressures to determine particulate emission rates for three parameters, total particulate matter, particulate matter < 10 microns and particulate matter < 2.5 microns. This matrix of tests will result in conducting eight tests and determining twenty-four particulate emission factor values.

Table 4 below provides a summary of proposed test parameters.

Table 4 - Summary of Proposed Test Parameters

Test Parameters	**Test Pressures And Nozzle Type**	
Media Type	**100 psi nozzle pressure using conventional long venturi nozzle**	**155 psi nozzle pressure using high pressure nozzle**
Coal Slag	Total Particulate Matter Particulate Matter < 10 microns Particulate Matter < 2.5 microns	Total Particulate Matter Particulate Matter < 10 microns Particulate Matter < 2.5 microns
Copper Slag	Total Particulate Matter Particulate Matter < 10 microns Particulate Matter < 2.5 microns	Total Particulate Matter Particulate Matter < 10 microns Particulate Matter < 2.5 microns
Sand	Total Particulate Matter Particulate Matter < 10 microns Particulate Matter < 2.5 microns	Total Particulate Matter Particulate Matter < 10 microns Particulate Matter < 2.5 microns
Garnet	Total Particulate Matter Particulate Matter < 10 microns Particulate Matter < 2.5 microns	Total Particulate Matter Particulate Matter < 10 microns Particulate Matter < 2.5 microns

Appendix 1 - Abrasive Survey Form

National Shipbuilding Research Program Survey

This letter is to request information regarding the type and amount of abrasive blast media and abrasive blasting equipment used at your shipyard.

This information will be used to select and prioritize abrasive media commonly used in the U.S. shipbuilding and repair industry for determination of particulate matter emission factors for abrasive blasting operations at shipyards. This research project is being conducted under contract to the National Shipbuilding Research Program ("NSRP").

This survey, which is being sent to over 200 shipyards in the U.S., can be completed in less than 10 minutes by the person most knowledgeable about dry abrasive blasting in your facility. Any information your facility provides will be kept confidential and only the results of the complied data received from all shipyards will be reported in the final NSRP report.

Please forward this request and the attached "fax-back" survey form to the appropriate personnel at your facility who has knowledge regarding the type(s) and amounts of abrasive media and abrasive blasting equipment used at your facility. When the survey form is completed, please fax it back to Austin Environmental, Inc. ("AEI"), the company that is compiling the data regarding abrasive blast media and equipment usage for this project.

You received this survey because your company is listed in the most recent listing of shipyards operating in the United States. If this information is incorrect and your facility is not a shipyard, please write "NOT SHIPYARD" on the survey form and fax it back. Your company will be removed from the shipyard database to prevent it from receiving information requests, like this, in the future.

Thank you for your assistance in this important research project. If you would like additional information regarding this survey or this project, please contact Mr. Dana M. Austin, Austin Environmental, Inc., at telephone number 619-523-9621 in San Diego, California.

NSRP Dry Abrasive Blasting Particulate Emission Factors Project

"Fax-Back" Survey - Please Fax Back by August 21, 1998

1. Facility Information

Company Name:	
State:	

2. Estimate of Annual Abrasive Usage for Open Blasting

Type of Abrasive	Abrasive Sub-category	Average Annual Usage in Tons/Year
Metallic	Steel Shot	
	Steel Grit	
	Iron Shot	
	Iron Grit	
Mineral Slag	Copper Slag	
	Nickel Slag	
Mineral	Garnet	
	Other:________________	
Furnace Slag	Coal Slag	
Sand	Sand	
Other	Glass	
	Other:________________	

3. Dry Abrasive Blast Equipment

Air Pressure	**At Pot (psi)**			**At Nozzle (psi)**	
Circle all that apply	75-100 100-125 125-160			65-85 85-100 100-120 >120	
Hoses	**Inside Diameter (inches)**			**Length (feet)**	
Circle all that apply	1 1 ¼ 1 ½ 2 >2			50-100 100-200 200-400 >400	
Nozzles	**Straight Bore**	**Conventional Long Venturi**	**Laminar Long Venturi**	**Double Venturi**	**High Pressure Venturi**
Circle all that apply	#6 #7 #8	#6 #7 #8	#6 #7 #8	#6 #7 #8	#6 #7 #8

4. Fax Back - Fax to Austin Environment, Inc. at 619-523-9973. Thank you!

Particulate Emission Factors for Blasting Operations and Other Potential Sources
Project No. N1-97-04

Task 4- Shipyard Abrasive Blasting Particulate Emission Factor Development Test Plan

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Task 4- Shipyard Abrasive Blasting Particulate Emission Factor Development Test Plan

Introduction

LFR Levine Fricke ("LFR"), along with Atlantic Marine, Inc. ("AMI"), and Dana M. Austin Environmental Consulting ("AECI") will be conducting a series of tests to develop emission factors for shipyard abrasive blasting operations. Tests will be conducted in a controlled environment where steel plate will be blasted to simulate ship blasting conditions.

Testing will take place in a test enclosure and spent blast media will be collected, sampled, and subject to a particle size analyses to establish worst case emission rates and particle characteristics. A mass balance will be conducted to document accuracy of spent blast media collection methods. Based on the results of the shipyard survey conducted by DMAEC (see Task 3 Report), tests will be conducted with four different blast media at two different blast pressures for each media.

This test plan identifies the methodologies to be utilized to collect data that will be used to establish particulate emission factors, which is the ultimate goal of the project. This submittal covers the requirements of Task 4 in the proposal submitted by AMI.

Test Plate Preparation

Steel test plates will be obtained from a local shipyard, mechanical contractor, or by other means. The test plates will be approximately 8 feet by 10 feet by ½ inch thick. The actual blast area will be smaller to avoid overspray from the blasting operation that may damage the test enclosure. Prior to the actual blasting program, the test plates will be blasted to a near-white finish and then repainted using a known volume of a typical marine coating.

Since a mass balance approach will be used, the mass measurements of the media will also include the paint removed from the steel plates. Therefore, estimations of the mass attributable to the coating will be required. This estimation will be derived using paint solids information included on the coatings Material Safety Data Sheets and the known volume of coating applied to the steel plate. This estimate may also be verified by scraping a set amount of paint off a measured piece of steel and weighing it to estimate the weight of coating per square inch of test plate.

Abrasive Blasting Procedures

Abrasive blasting will be performed using experienced shipyard blasting personnel to simulate actual working conditions. Appropriate blasting personnel will be selected based on their ability to provide consistent results under the various test conditions. The blasting personnel will be advised to keep the blasting nozzle approximately 12 inches from the test plate, to the best of their ability, and simulate actual ship blasting techniques. The blast angle will be approximately 90 degrees to simulate worst case conditions, since at this angle, maximum media impact is expected that would result in smaller particles being generated. Blasting will be conducted with various media as described in Section 5.0. Conventional long venturi nozzles will be used for blasting at 100-psi nozzle pressure and high-pressure nozzles will be used for blasting at 155 psi.

Blasting will be conducted to the SP 10 near white metal standard as determined by the blaster. The optimal media feed rate and work rate at each test condition will be pre-determined based on the media manufacturers' recommendations and the blaster's experience. This will ensure that consistent blast results will be obtained for each combination of media and blasting pressure.

Test Facility

The test facility will be a simple wood frame structure covered with a double layer of 4-mil polyethylene sheets. The structure will include a plywood floor. The approximate dimensions of the enclosure will be 15 feet by 20 feet by 8 feet tall. The overall volume will be approximately 2,400 cubic feet. An 8-inch-diameter flexible duct will be positioned in a corner of the ceiling behind the blasting worker. The amount of exhaust air will be approximately 800 standard cubic feet per minute (scfm). It is anticipated that the blasting air will constitute approximately 375 scfm. The remaining 425 scfm will be drawn through natural draft openings strategically placed to ensure appropriate ventilation within the enclosure. The natural draft openings will be installed to allow fresh air into the enclosure and will be designed in accordance with U.S. EPA Method 204. Compliance with Method 204 documents that 100 percent capture efficiency can be assumed. In addition, exhausting approximately 425 cfm will yield an air change rate of 10 per hour based on the overall volume of the enclosure. A 10 air change per hour is a typical design that should maintain a safe working atmosphere for people in the enclosure. Test enclosure exhaust rates may be adjusted to account for field conditions.

Prior to testing, the polyethylene sheets will be sprayed with an antistatic compound to minimize particle deposition. In addition, the blaster will don a new Tyvek suit prior to each test. The blaster's Tyvek suit will also be sprayed with an antistatic compound.

The flexible duct will be connected to a filter containing a new polyester filter bag. The filter bag will collect spent media entrained in the exhaust air stream. The interior of the filter bag will have an acrylic coating to facilitate retrieval of the collected particles. A high-pressure direct drive blower will be used to exhaust the air. The blower will be sized accordingly to handle the static pressure caused by the filter and collected particles.

Test Conditions

As indicated in the Task 3 shipyard survey report, testing will be conducted with four different blast media at two different nozzle pressures. The four types of blasting media will include coal slag, garnet, copper slag, and sand. The two blasting pressures will be 100 and 155 psi. Three runs at each test condition will be conducted.

As indicated in Section 3, the work rate for each test condition will be pre-determined to ensure that consistent blast results are obtained throughout the testing program. The abrasive feed rate for each combination of media and pressure will be determined based on the blaster's experience as well as the media manufacturers' recommendations. After the appropriate feed rates have been set, the necessary work rate to achieve the near white finish will be determined.

Spent Media Collection

Collection and sampling methods will be utilized that minimize the possibility of spent media fragmentation. This will ensure that samples will be representative of spent media in actual blasting operations. Great care will be taken to ensure sample integrity.

The plywood floor of the enclosure will be covered with 6-mil polyethylene sheeting. Prior to each test, a layer of removable 4-mil polyethylene sheeting will be placed on the floor. Cardboard boxes will be placed in the general blasting area to serve as primary spent media collectors. The 4-mil polyethylene sheeting will collect spent media that is not contained by the boxes. As previously stated, all polyethylene sheeting will be sprayed with an antistatic compound.

The blasting personnel will be carefully cleaned of all media using a brush (or compressed air) prior to exiting the enclosure. The floor, walls, and ceiling of the enclosure will also be cleaned of all media with a brush after each test. This collected blast media, as well as that collected in the cardboard boxes, will be stored in a fiberboard drum with a polyethylene liner.

Since dust will be generated when the spent media is placed in the storage drum(s) and the interior surfaces are cleaned, all transfer operations will take place within the enclosure. The exhaust ventilation will remain in operation until all transfer activities and cleanup have been completed. Upon completion of spent media collection, a sample collection bag will be fitted over the open end of the filter bag. The filter bag will be manually shaken to collect the dust in the bag. This dust will be carefully transferred to the collection drum, minimizing fugitive emissions that may go uncollected.

Mass Balance Measurements

Prior to each test, tare weights on the blast machine (including blast media), filter bag, and the storage drum(s) used for the spent media will be obtained. After each test, final weights of the blast machine, collected blast media (including the fiberboard drum), and filter bag will be obtained and the amount of paint removed will be calculated. These data will be used in the mass balance to ensure that a representative sample is collected. In addition, moisture analyses will be conducted on the spent abrasive to account for moisture that may be collected on the media. This will help close the mass balance.

Bulk sample collection

A bulk sample of virgin blast media will be collected from each bag or container prior to filling the sandblast machine. These bulk samples will be composited to form a single cumulative bulk sample for that particular test. A total sample size of approximately one pound of virgin blast material is expected for each run. These composite samples will be subject to particle size analyses.

The final sample size of the spent media will be approximately one pound. ASTM Standard C702, Method C will be used to ensure that the bulk sample of spent media will be representative of the mass inside the drum. To mix the collected media, the fiberboard drum(s) will be turned on its side and rolled to thoroughly mix the material. The drum will be placed upright and the inner polyethylene bag will be removed by forklift or crane. The bag will be lowered until the bottom is within a couple of inches above a sheet of polyethylene that will be laid on top of a Styrofoam board. A small hole will then be cut to allow the media to pour onto the sheet in a conical pile. The bag will be raised as necessary to allow the conical pile to increase in height.

After the bag has been emptied, the conical pile will be flattened as much as possible by pressing down the apex using a sheet of cardboard. Five core samples will be taken from the flattened media. There will be one sample taken from the center of each quarter and one sample taken from the overall center of the pile. Samples will be taken using a 1-inch-diameter metal pipe or equivalent by pressing through the sample, polyethylene sheet, and Styrofoam board. The Styrofoam will act as a plug as the pipe is extracted from each section. These five samples will then be used to form one composite bulk sample. Duplicate bulk samples will be collected from each drum and subject to particle size analysis.

The drummed spent media and filter will be weighed to obtain the final weight to complete the mass balance and the sampled spent media will be analyzed as stated below.

Particle Size Analyses

The initial particle-sizing test will be a sieve analysis using ASTM Standards D 422, E 11, and E 276. Material that passes the Number 200 sieve, particles less than 75 microns, will be subject to sedimentation analyses to determine smaller particle size distribution down to 2.5 microns.

Calculations

Mass balance calculations will be made based on virgin blast media utilized and paint removed from the steel plate versus the amount of spent media (and paint) collected. These data will be used to verify that a representative portion of the spent media has been collected.

Based on the particle size analytical data, a particle size distribution of spent media will be calculated for each run. These distributions will summarize the weight percent of a full range of particle sizes from 2,000 to 2.5 microns. Particular emphasis will be placed on the total spent particle mass as well as particles less than 10 (PM10) and 2.5 (PM2.5) microns to address regulatory requirements for particulate matter emissions.

The calculated data will be utilized for emission factor development (Task 7 of the project).

Quality Assurance/quality control procedures

To validate the precision of sampling techniques and ensure valid data are collected several quality assurance and quality control (QA/QC) techniques will be implemented. Such techniques will include conducting tests at each condition in triplicate. In addition duplicate samples will be collected for each test run and subject to particle size analysis. ASTM methods and associated QA/QC procedures will be followed for bulk sampling and analysis of the spent media.

As indicated in Section 7.0, a mass balance will be completed for each test run to ensure that a significant portion of spent media is collected. Closure (or near closure) of the mass balance will indicate representative sample collection.

Other QA/QC measures will include only the use of experienced blasters to complete the test blasting. Their experience will be drawn upon to help pre-determine optimal abrasive feed rates and work rates for each test condition to ensure that consistent results are obtained throughout the program. In addition, calibration data for all scales used in the test program will be maintained and all calculations will be subject to a two-tiered peer review.

Test schedule

It is anticipated that one test condition per day will be completed. With eight total conditions to be tested, it is anticipated that the test program will last approximately two weeks, including setup and breakdown time. Pending approval of the test program, testing will likely take place from early to late February 1999.

Test limitations

It is expected that reasonable and accurate data will be collected from this test program. However, there are certain limitations on this type of approach. The primary limitation will be the ability to collect all spent media to close the mass balance. Although the proposed methods will likely result in collection of a vast majority of spent blast media, some may be difficult to collect, such as that collected in the exhaust system filter or entrained on the blast equipment operator and other areas of the enclosure. In addition, some finer particulate may pass through the exhaust system filter. With careful sample collection and handling procedures, the effects of these potential limitations should be minimized.

Particulate Emission Factors for Blasting Operations and Other Potential Sources
Project No. N1-97-04

Task 5: Analysis of Field Samples

Task 5 – Analysis of Field Samples

Introduction

Field tests of five different abrasives, at two nozzles pressures, were conducted using the methodology developed and described in Task 4: *Shipyard Abrasive Blasting Particulate Emission Factor Development Test Plan*. Samples taken during the field tests were taken for analysis to Analysis Laboratories, Inc.[10] for particule size analysis. A total of 32 samples were analyized using aproved ASTM methodologies. Additionally, each sample was analyized using both the Hydrometer and Pepette methods. This was done to enusre accuracy of the measurements at the very fine particule size range, where Pipette anaylsis is more sensitive.

Analysis Results

The results of the particle size analysis for both the Hydrometer and Pipette tests are provided in Appendix 1 of this Task report.

As a quality check on the analytical results, the data for each set of abrasive samples were plotted on log-normal graph paper to determine if the results conformed to the normal "S" shaped curve found in grain size distributions. No significant deviations from the expected distribution were identified. Copies of the log-normal plots are provided in Appendix 2 of this Task report.

Mass-Size Fraction Distributions of Particles

Using the particle size analysis results the mass-size fraction distribution of particles for four (4) size ranges were determined. The particle size ranges were:

1. 10 microns and less;
2. 4.0 microns and less;
3. 2.5 microns and less; and,
4. 1.0 microns and less.

It is important to note that the mass-size fraction of particles is not the equivalent to an emission factor for the same particle size fraction. The test results described here are representative of the total mass in each size fraction generated by the test conditions. There is no consideration in these data as to whether or not the particles became airborne (i.e. resulted in an emission).

Table 1 on the following page summarizes the mass-size fraction distribution for each particle size range for each test nozzle pressure. Table 1: Mass-Size Fraction Distribution Results.

[10] Analysis Laboratories, Inc., 2932 Lime Street, Metairie, LA (504)-889-0710.

Abrasive/Test Pressure	1.0 Micron Mass %				2.5 Micron Mass %			
	Run 1	Run 2	Run 3	**Avg.**	Run 1	Run 2	Run 3	**Avg.**
Sand/80 psi	0.100	0.110	0.120	**0.110**	0.170	0.180	0.210	**0.187**
Sand/122 psi	0.130	0.130	0.120	**0.127**	0.200	0.190	0.170	**0.187**
Coal Slag/80 psi	0.100	0.070	0.080	**0.083**	0.140	0.130	0.160	**0.143**
Coal Slag122 psi	0.090	0.090	0.070	**0.083**	0.140	0.160	0.130	**0.143**
Copper Slag/80 psi	0.040	0.030	0.030	**0.033**	0.080	0.040	0.100	**0.073**
Copper Slag/122 psi	0.030	0.030	0.220	**0.093**	0.090	0.100	0.270	**0.153**
Garnet/80 psi	0.230	0.060	0.080	**0.123**	0.300	0.150	0.120	**0.190**
Garnet/122 psi	0.000	0.040	0.040	**0.027**	0.030	0.140	0.120	**0.097**
Hematite/80 psi	0.030	0.020	0.050	**0.033**	0.130	0.130	0.140	**0.133**
Hematite/122 psi	0.050	0.030	0.030	**0.037**	0.150	0.110	0.110	**0.123**

Abrasive/Test Pressure	4.0 Micron Mass %				10 Micron Mass %			
	Run 1	Run 2	Run 3	**Avg.**	Run 1	Run 2	Run 3	**Avg.**
Sand/80 psi	0.230	0.220	0.230	**0.227**	0.670	0.690	0.900	**0.753**
Sand/122 psi	0.260	0.280	0.310	**0.283**	0.850	0.830	0.850	**0.843**
Coal Slag/80 psi	0.270	0.170	0.240	**0.227**	0.970	0.650	0.950	**0.857**
Coal Slag122 psi	0.230	0.240	0.190	**0.220**	0.910	0.910	0.620	**0.813**

Copper Slag/ 80 psi	0.120	0.100	0.140	**0.120**	0.310	0.130	0.170	**0.203**
Copper Slag/122 psi	0.140	0.130	0.310	**0.193**	0.170	0.160	0.340	**0.223**
Garnet/80 psi	0.300	0.200	0.190	**0.230**	0.300	0.370	0.490	**0.387**
Garnet/122 psi	0.180	0.170	0.150	**0.167**	0.410	0.470	0.430	**0.437**
Hematite/80 psi	0.150	0.130	0.140	**0.140**	0.420	0.470	0.390	**0.427**
Hematite/122 psi	0.190	0.110	0.130	**0.143**	0.510	0.380	0.460	**0.450**

Conclusions

The mass-size fraction analyses for the test abrasives and pressures have been completed. The test results for the particle size fractions that are important to this study have been quantified. These results will be used to derive emission factors for the specific abrasives and nozzle pressures tested in this study.

Appendix 1: Hydrometer and Pipette Analysis

Hydrometer and Pipette Analysis forms are on file. This was done to reduce the size of the document and make its distribution easier. If you require this information please contact the report author and copies will be provided to you.

Appendix 2: Log-Normal Plots of Sample Grain Size Distribution

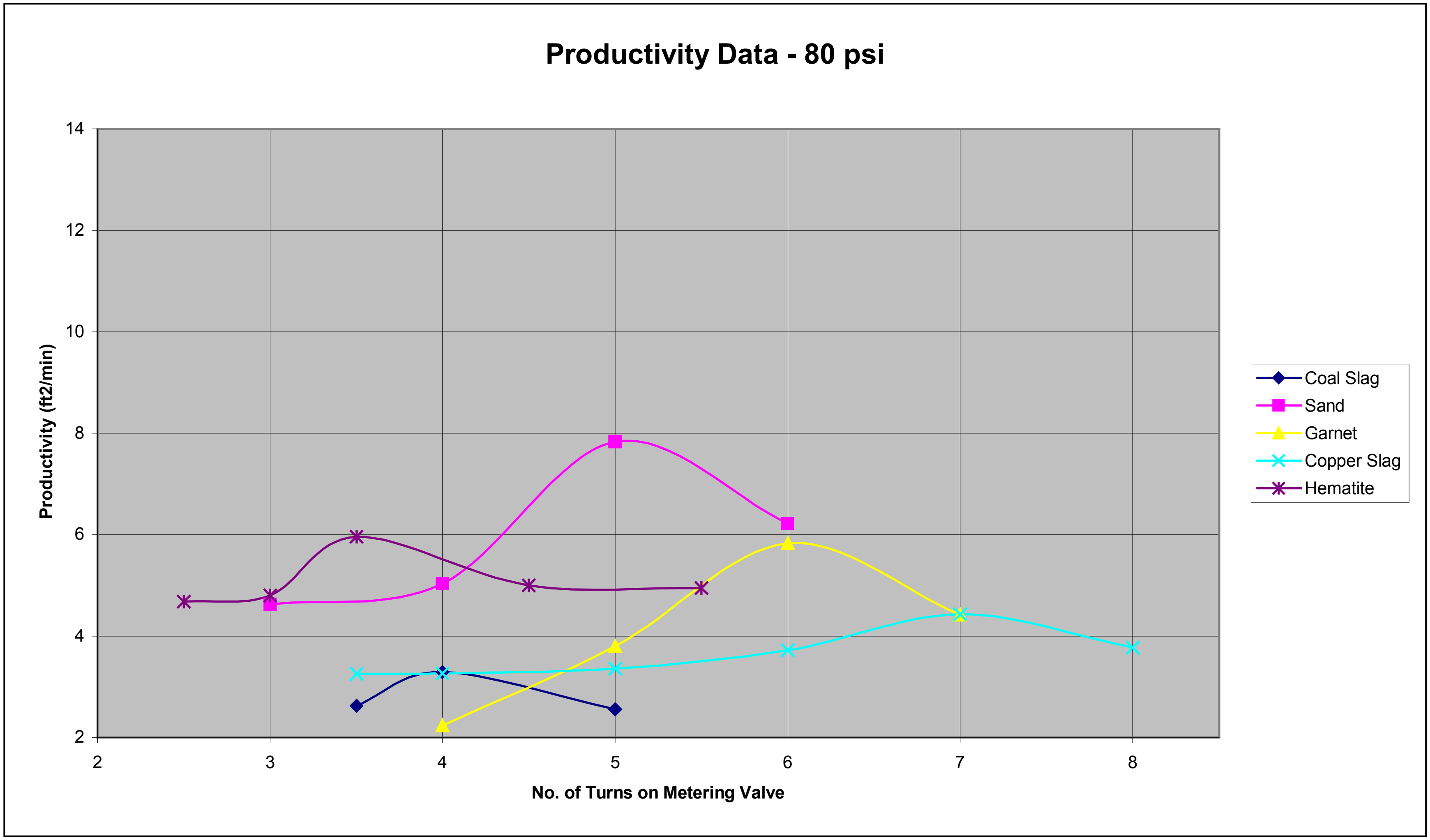
The Log-Normal Plots of Sample Grain Size Distribution are on file. This was done to reduce the size of the document and make its distribution easier. If you require this information please contact the report author and copies will be provided to you.

Appendix 3 Field Results Tables and Charts

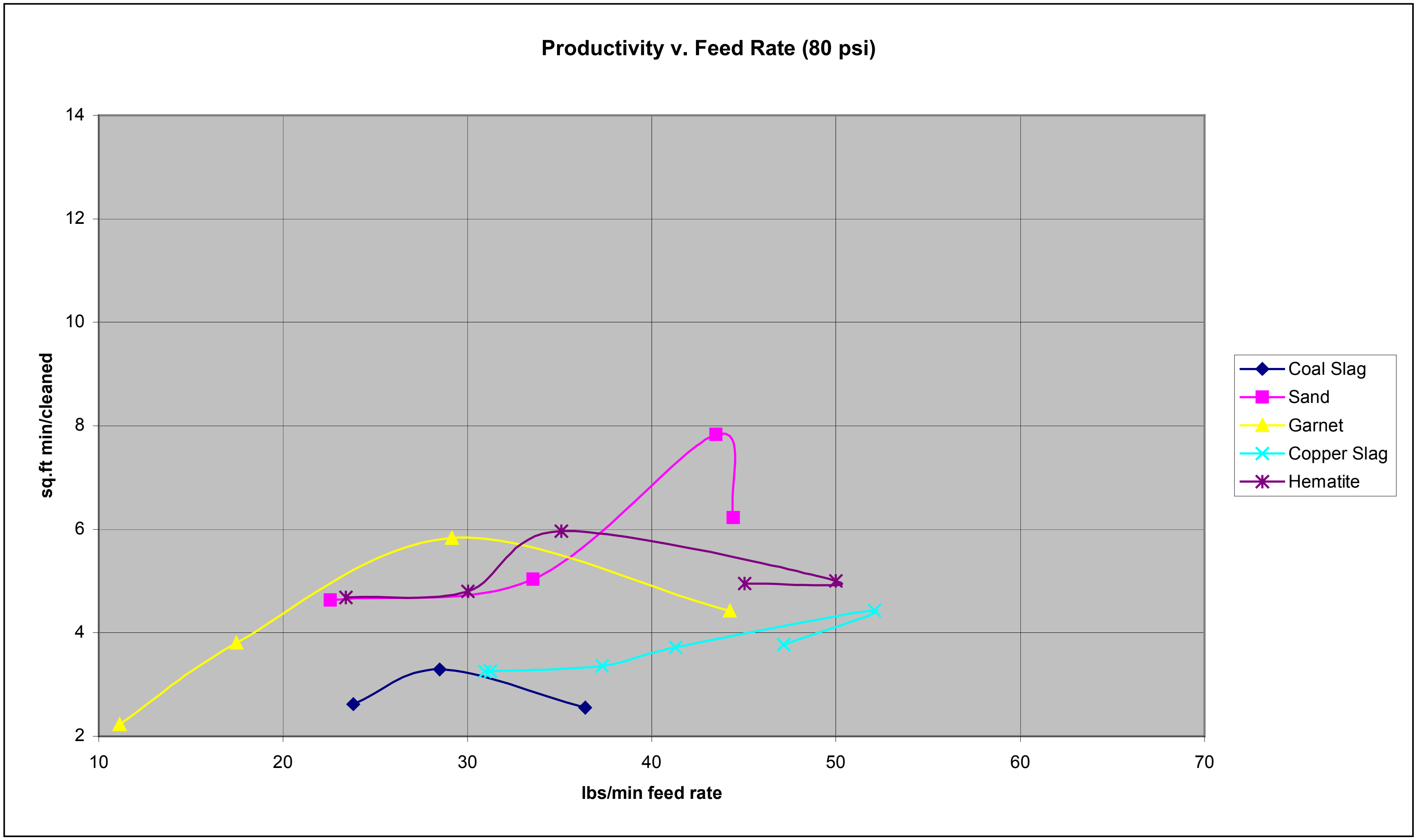
Blast Rate Optimization Summary
Abrasive Blasting Emission Factor Development Project

Nozzle Pressure (psi): 80 **Nozzle Type:** double venturi #6

Abrasive Type	Metering Valve Setting (No. of Turns)	Abrasive Feed Rate (lb/min)	Abrasive Use Rate (lb/ft2)	Productivity (ft2/min)	Optimum Abrasive Rate
Coal Slag	3.5	23.80	9.09	2.62	
	4	28.50	8.70	3.29	X
	5	36.40	14.30	2.55	
Sand	3	22.57	4.87	4.63	
	4	33.56	6.67	5.03	
	5	43.48	5.56	7.83	X
	6	44.44	7.14	6.22	
Garnet	4	11.14	5.00	2.23	
	5	17.48	4.60	3.80	
	6	29.15	5.00	5.83	X
	7	44.25	10.00	4.42	
Copper Slag	3.5	30.96	9.52	3.25	
	4	31.25	9.52	3.26	
	5	37.31	11.11	3.36	
	6	41.30	11.11	3.72	
	7	52.08	11.76	4.43	X
	8	47.17	12.50	3.77	
Hematite	2.5	23.42	5.00	4.68	
	3	30.03	6.25	4.80	
	3.5	35.09	5.88	5.96	X
	4.5	50.00	10.00	5.00	
	5.5	45.05	9.09	4.95	



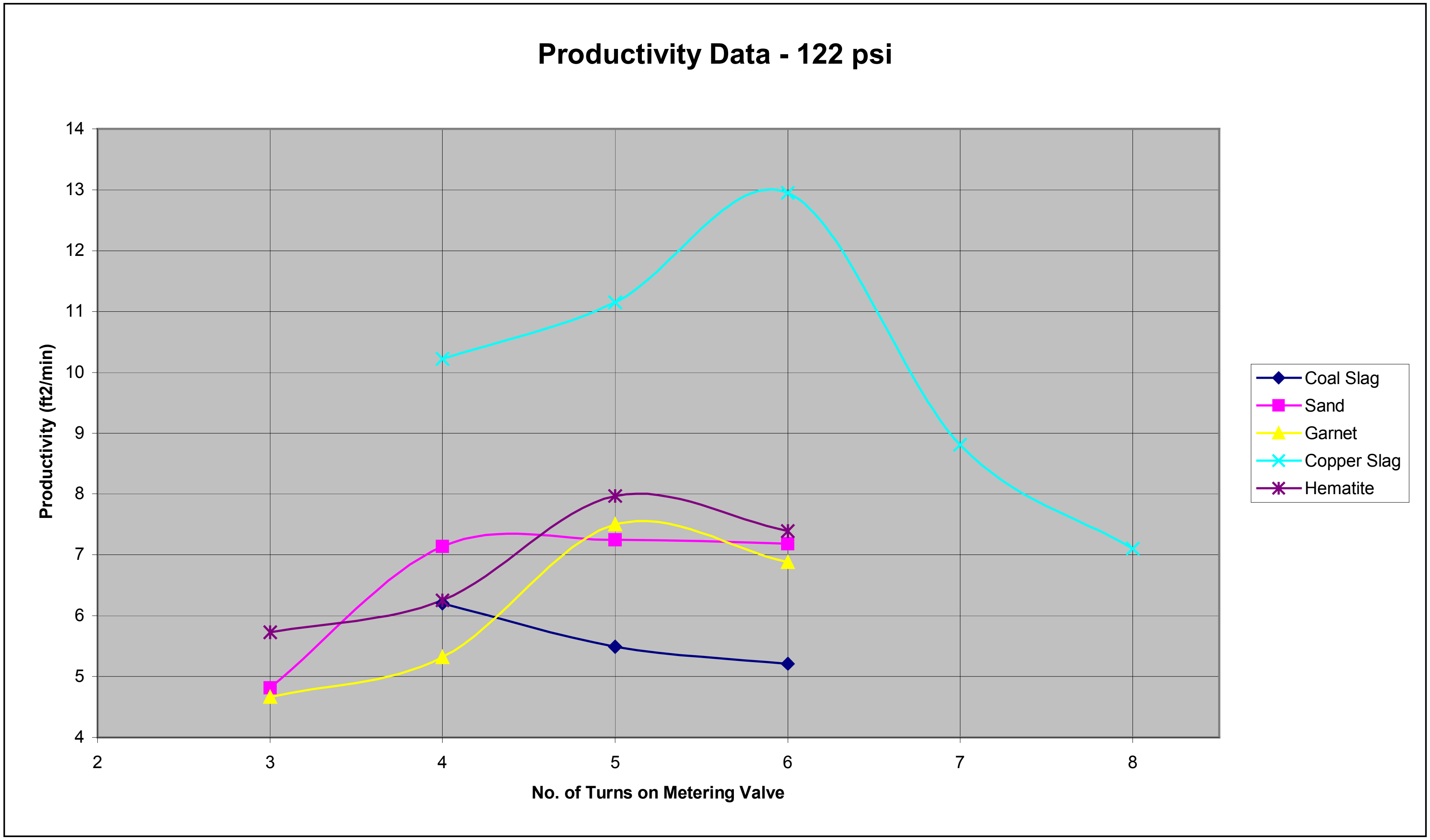
Productivity Data - 80 psi
Productivity (ft2/min)
No. of Turns on Metering Valve
14
12
10
8
6
4
2
2
3
4
5
6
7
8
Coal Slag
Sand
Garnet
Copper Slag
Hematite

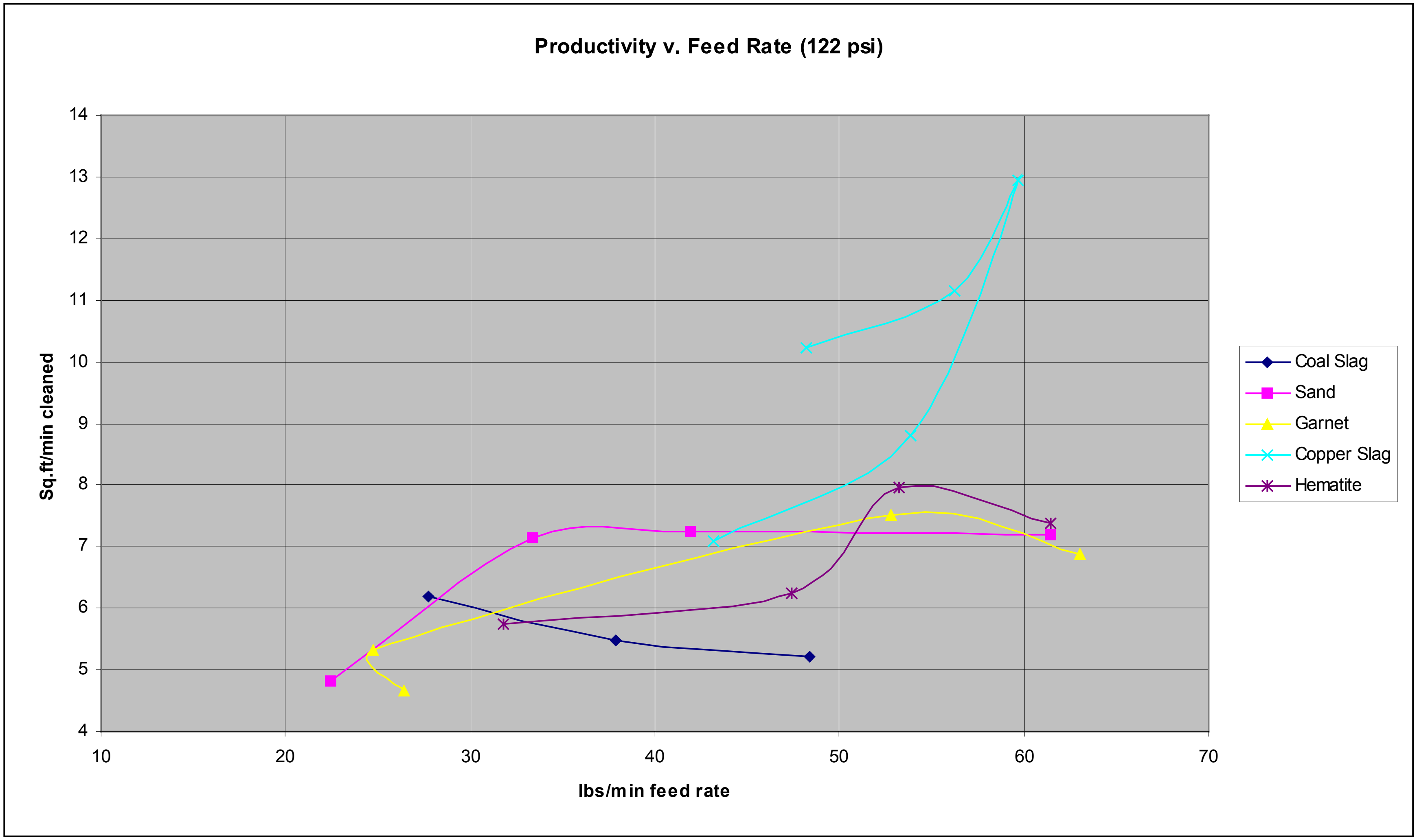

Productivity v. Feed Rate (80 psi)
sq.ft min/cleaned
lbs/min feed rate
14
12
10
8
6
4
2
10
20
30
40
50
60
70
Coal Slag
Sand
Garnet
Copper Slag
Hematite

Blast Rate Optimization Summary
Abrasive Blasting Emission Factor Development Project

Nozzle Pressure (psi): 122 **Nozzle Type:** bozzuka #6

Abrasive Type	Metering Valve Setting (No. of Turns)	Abrasive Feed Rate (lb/min)	Abrasive Use Rate (lb/ft2)	Productivity (ft2/min)	Optimum Abrasive Rate
Coal Slag	4	27.76	4.47	6.20	X
	5	37.86	6.89	5.49	
	6	48.37	9.28	5.21	
Sand	3	22.43	4.66	4.81	
	4	33.40	4.68	7.14	
	5	41.98	5.79	7.25	X
	6	61.44	8.56	7.18	
Garnet	3	26.42	5.67	4.66	
	4	24.77	4.65	5.32	
	5	52.75	7.03	7.50	X
	6	63.01	9.16	6.88	
Copper Slag	4	48.16	4.71	10.22	
	5	56.25	5.05	11.15	
	6	59.68	4.61	12.95	X
	7	53.89	6.12	8.81	
	8	43.17	6.08	7.10	
Hematite	3	31.77	5.55	5.73	
	4	47.40	7.58	6.25	
	5	53.26	6.68	7.97	X
	6	61.44	8.32	7.39	


Productivity Data - 122 psi
Productivity (ft2/min)
14
13
12
11
10
9
8
7
6
5
4
2
3
4
5
6
7
8
No. of Turns on Metering Valve
Coal Slag
Sand
Garnet
Copper Slag
Hematite


Productivity v. Feed Rate (122 psi)
Sq.ft/min cleaned
lbs/min feed rate
14
13
12
11
10
9
8
7
6
5
4
10
20
30
40
50
60
70
Coal Slag
Sand
Garnet
Copper Slag
Hematite

Particulate Emission Factors for Blasting Operations and Other Potential Sources
Project No. N1-97-04

Task 7: Development of Emission Factors

Task 7 – Development of Emission Factors

Introduction

An emission factor is a tool that is used to estimate air pollutant emissions to the atmosphere. It relates the quantity of pollutants released from a source to some activity associated with those emissions. Emission factors are usually expressed as the weight of pollutant emitted, divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g. pounds of particulate matter emitted per ton of coal burned). Emission factors are used to estimate a source's emissions by the general equation:

$$E = A \times EF \times \left[1 - \left(ER/100\right)\right]$$

where:

E = emissions

A = activity rate

EF = uncontrolled emission factor, and

ER = overall emission reduction efficiency, %

(ER is the product of the control device destruction or removal efficiency and the capture efficiency of the control system. When estimating emissions for a long time period (e.g. 1-year), both the device and capture efficiency terms should account for upset periods as well as routine operations).

In the case of emission factors for abrasive blasting operations, A is generally expressed as the mass of abrasive used (usually in tons or pounds), or the square footage of surface cleaned. E is usually expressed as the number of pounds of particles (often in a specific size fraction range) emitted into the air.

It is important to understand that an emission factor is concerned with the mass of the pollutant *emitted into the air* prior to removal or destruction of the pollutant by a control device (or other process). That is to say, an emission factor relates to the amount of pollutant emitted into the atmosphere, not necessary the total mass of pollutant generated by the activity.

For example, in the case of abrasive blasting, 10 pounds of particulate matter in the PM_{10} size range may be generated but only 1 pound is emitted into the atmosphere. As result of various physical and chemical properties of the abrasive and blasting process, 9 pounds remain with the larger particle size fractions that settle quickly to the ground at the process location. A control factor (if used) is then applied to the 1 pound of particles emitted into the air and not the total mass of PM_{10} sized particles generated by the blasting operations.

Emission Factor Development

The Mass-Size Fraction Distribution results reported in Task 5 of this study consist of all the particulates generated during the test in both the airborne (particulate matter that was exhausted from the test chamber and captured in a filter), and settled (particulate matter that remained on the floor of the test chamber) fractions. As such, these data represent the total mass-fraction generated by the blasting process under the established test conditions. These values cannot be considered emission factors as they include more than only the airborne fraction of the particulates generated. In other words, the mass-size fraction values represent the maximum potential to generate particulates in various size ranges. An emission factor, on the other hand, represents the estimated fraction of total particulates generated that are actually emitted into the atmosphere.

Therefore, in order to derive emission factors from mass-size fraction distribution data there must be an estimate of the percent of each mass-size fraction; airborne and settled. As particulate emission factors will be dependent on the test conditions under which they are derived (i.e. relative humidity, temperature, wind speed, etc.) it is believed that the most accurate estimate of the mass-size fraction partitioning would be from empirical data derived under the actual test conditions.

Five types of abrasives were tested to determine mass-size fraction distribution according to the protocol developed in Task 3 of this study. The test protocol provided for the collection, and commingling, of the spent abrasive from the test chamber and the exhaust air filter. This procedure, which prevented the separate analysis of airborne and settled fractions of particulates, was followed for all tests, except for the abrasive Hematite. In this case, the spent abrasive from the settled fraction and the airborne fraction were kept separate and analyzed independently. From this data set an airborne/settled ratio was calculated that could be applied to the other types of abrasives tested. This data is presented in Table 1 below.

Table 1: Comparison of Airborne Particles to Settled Particles – Hematite

Particle Size	**Settled Abrasive**			**Airborne Abrasive**			**Ratio**
	Cum. Mass	Interval	Interval	Cum. Mass	Interval	Interval	Air/Settled
(less than)	(%)	Mass %	Mass (lbs)	(%)	Mass (%)	Mass (lbs)	
PM1	0.03	0.03	0.1100	0.72	0.72	0.0144	0.131
PM2.5	0.13	0.1	0.3665	1.39	0.67	0.0134	0.037
PM4	0.15	0.05	0.1833	3.21	2.54	0.0508	0.277
PM10	0.42	0.37	1.3561	12.21	10.67	0.2134	0.157

Additionally it was recognized that particle density would affect the ratio of airborne/settled particles for each type of abrasive. That is to say denser particles will have a greater settling velocity than less dense particles of the same size. As only the data available from which an airborne to settled particles ratio could be derived was from Hematite, the emission factors for the other test abrasives must be adjusted by the ratio of their density to the density of Hematite.

The final equation to derive emission factors from the mass-size fraction distribution values, taking into account the factors described above, is as follows:

$$EF = PMmf_X \times AS \times \frac{D_H}{D_X \times 100}$$

where:

$PMmf_X$ = Particulate Matter Mass Fraction of Abrasive X

AS = Airborne/Settled Ratio for Particle Size range (i.e. PM1, PM4, etc.)

D_H = Density of Hematite

D_X = Density of Abrasive X

Note that $PMmf_X$ is the mass fraction interval of the particle size for which the emission factor is being calculated. For example, the value $PMmf_X$ for PM4 would equal the mass fraction of PM4 minus the mass fraction of PM2.5. Similarly the value of $PMmf_X$ for PM10 would equal the mass fraction of PM10 minus the mass fraction of PM4.

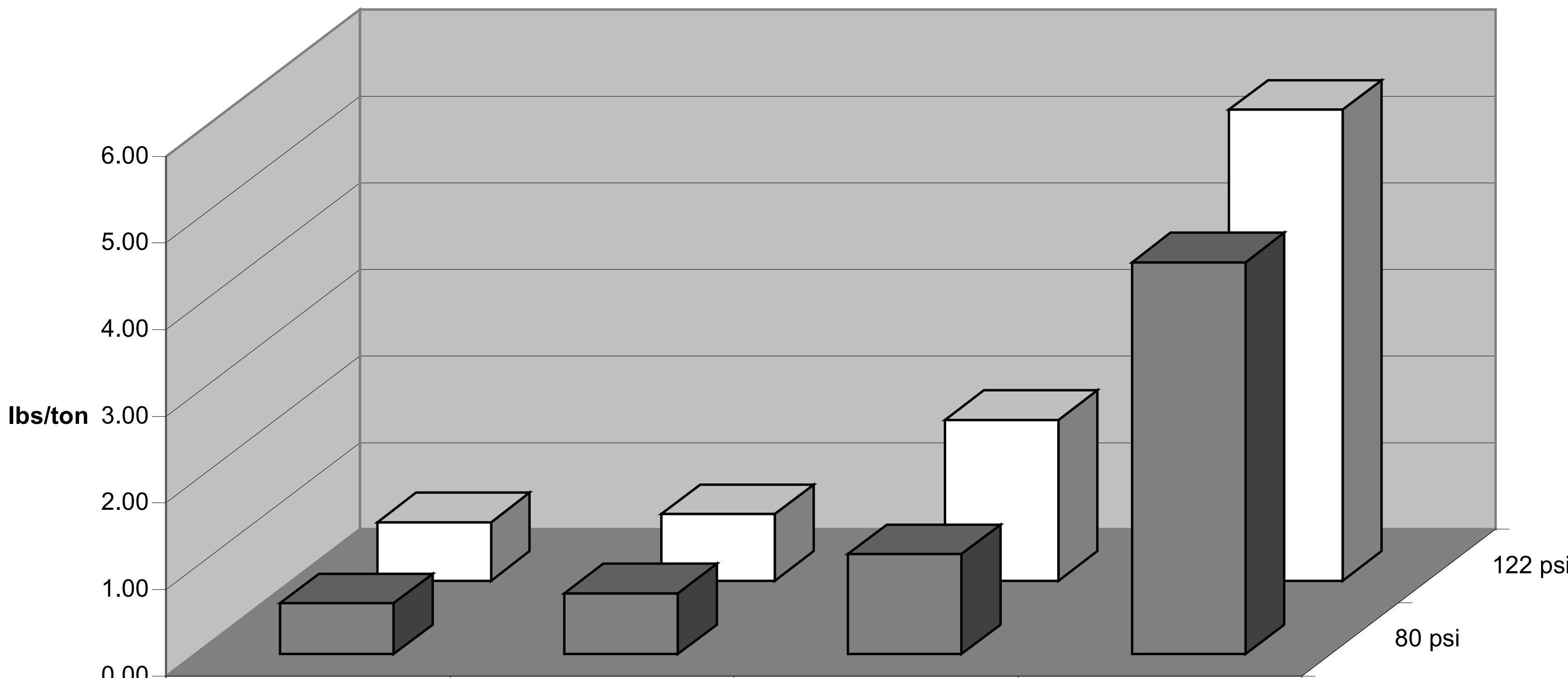
Using the equation described above emission factors for each abrasive tested was derived. Table 2 below presents the emission factors for each abrasive at each test nozzle pressure.

Table 2: Calculated Emission Factors for Test Abrasives and Pressures

Abrasive/PSI	Emission Factor (lbs emissions/ton abrasive)			
	PM1	PM2.5	PM4	PM10
Sand				
Sand/80 psi	0.59	0.70	1.15	4.52
Sand/122 psi	0.68	0.77	1.86	5.44
Coal Slag				
Coal Slag/80 psi	0.41	0.49	1.35	5.03
Coal Slag/122 psi	0.41	0.49	1.28	4.75
Copper Slag				
Copper Slag/80 psi	0.13	0.18	0.56	0.96
Copper Slag/122 psi	0.37	0.43	0.77	0.91
Garnet				
Garnet/80 psi	0.43	0.49	0.78	1.43
Garnet/122 psi	0.09	0.16	0.67	1.79
Hematite				
Hematite/80 psi	0.09	0.16	0.20	1.10
Hematite/122 psi	0.10	0.16	0.27	1.23

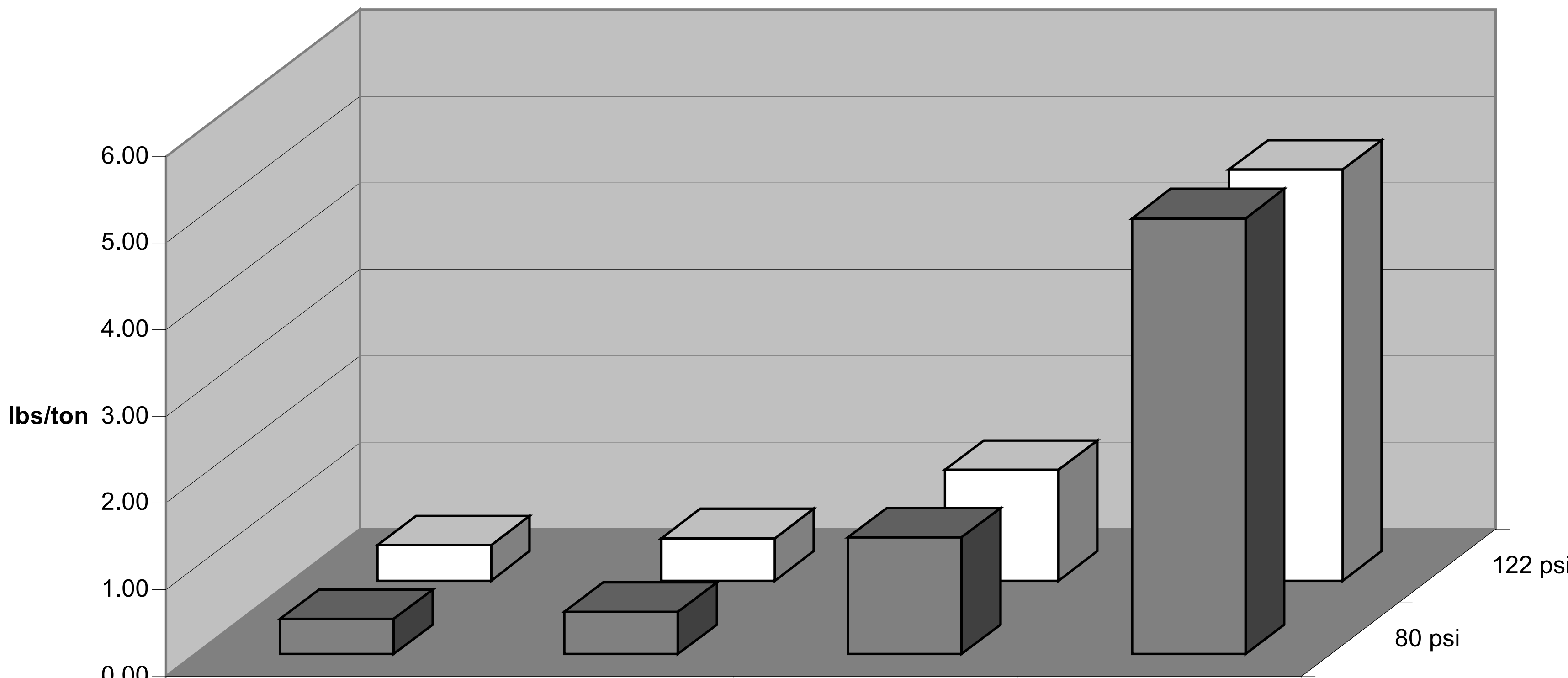
These data is represented graphically in the follow series of graphs. Note that Y-axis (emission factors in lbs/ton) in each graph has been set to a range of 0 to 6 lbs/ton for each graph to allow a straightforward comparison of emission factors between the different abrasives.

Sand Emission Factors



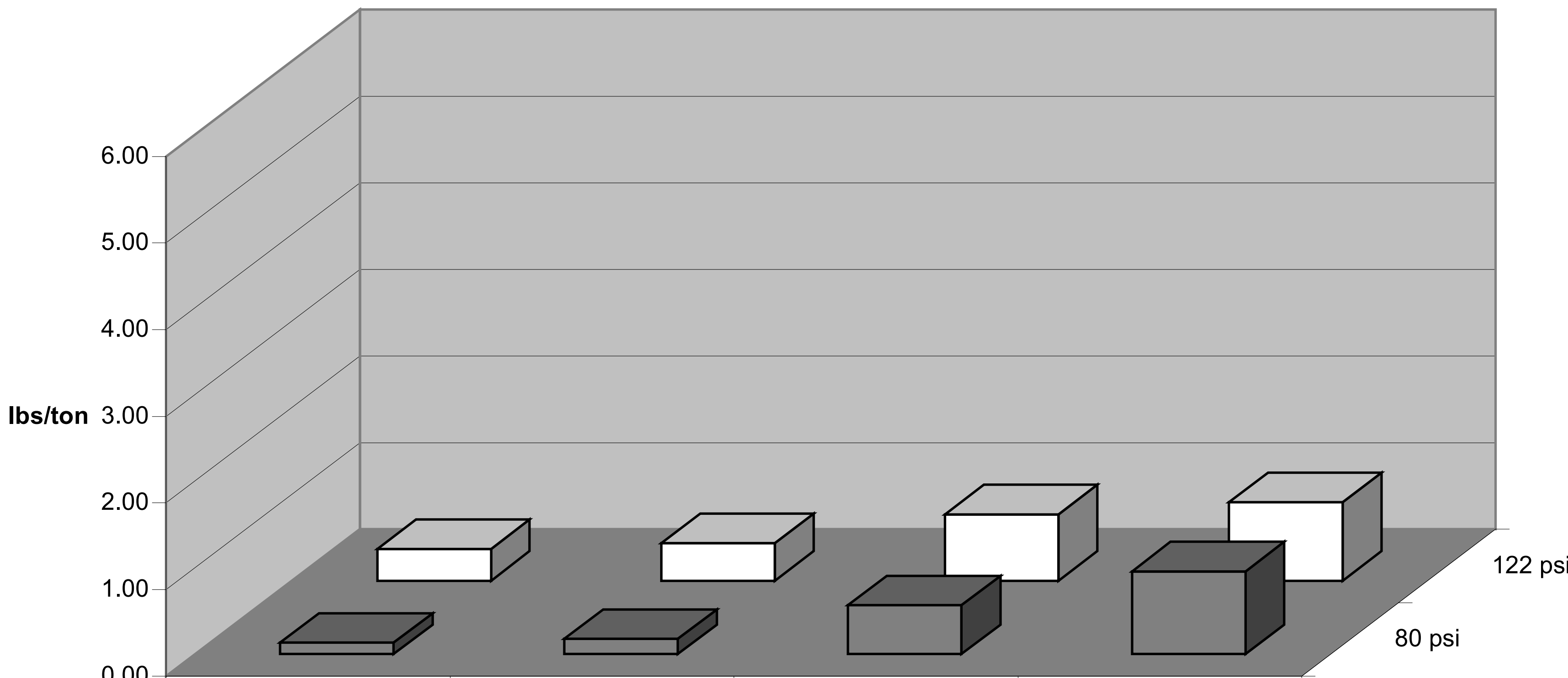
	PM1	PM2.5	PM4	PM10
80 psi	0.59	0.70	1.15	4.52
122 psi	0.68	0.77	1.86	5.44

Coal Slag Emission Factors



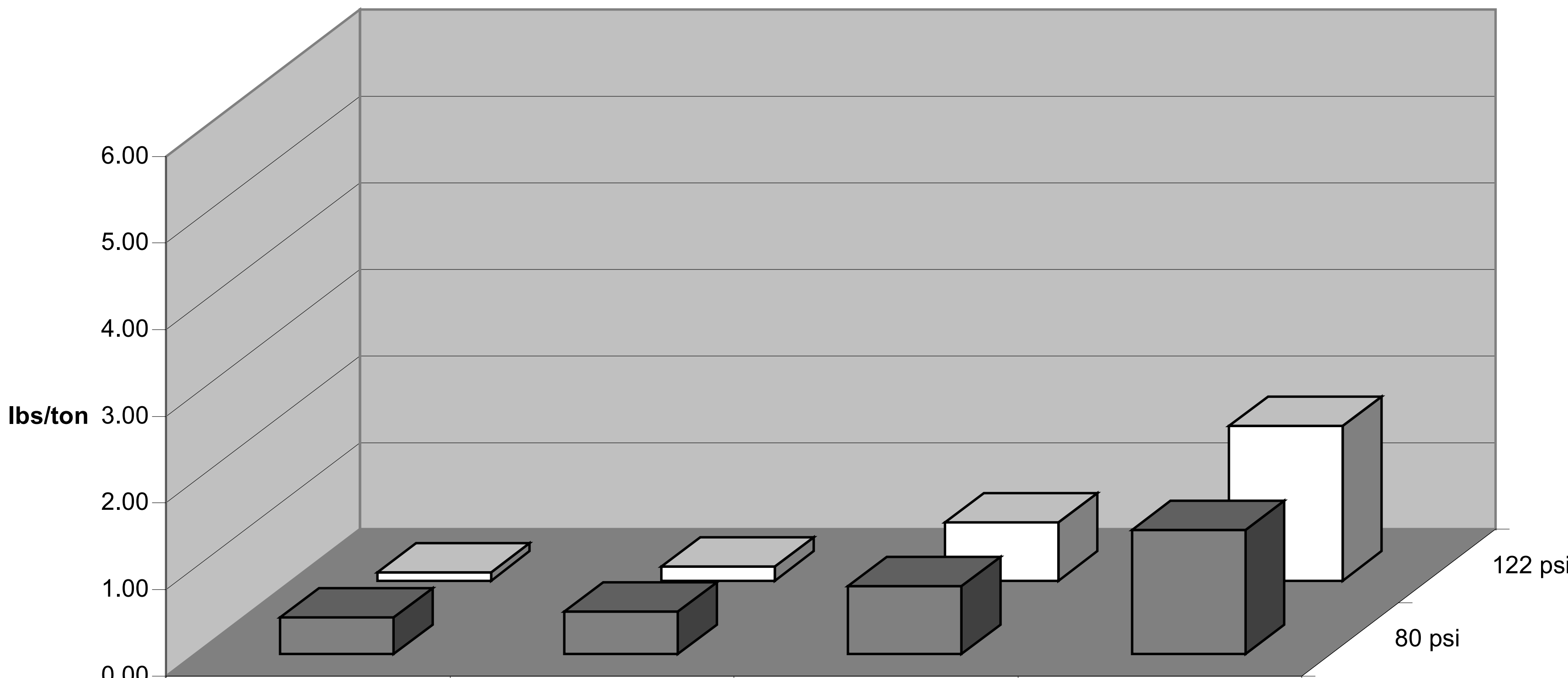
	PM1	PM2.5	PM4	PM10
80 psi	0.41	0.49	1.35	5.03
122 psi	0.41	0.49	1.28	4.75

Copper Slag Emission Factors



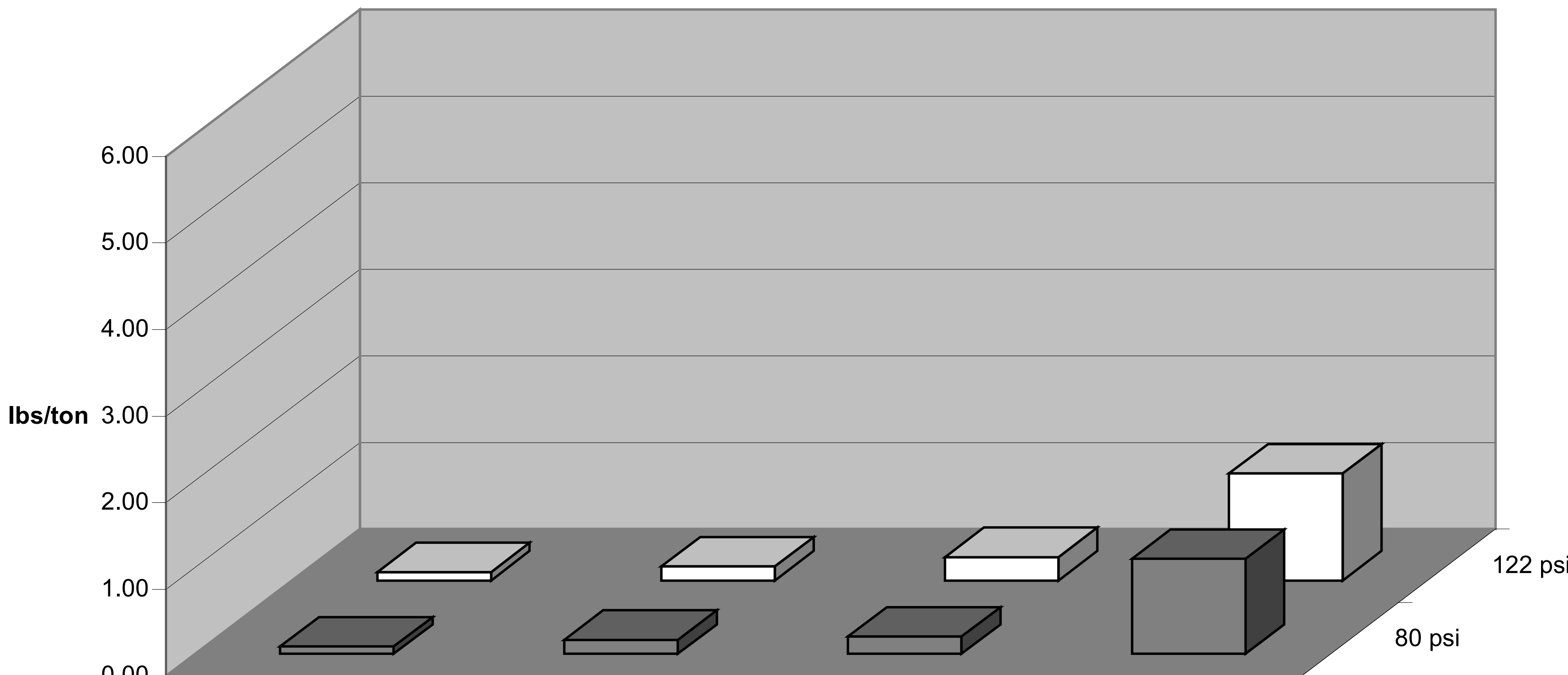
	PM1	PM2.5	PM4	PM10
80 psi	0.13	0.18	0.56	0.96
122 psi	0.37	0.43	0.77	0.91

Garnet Emission Factors

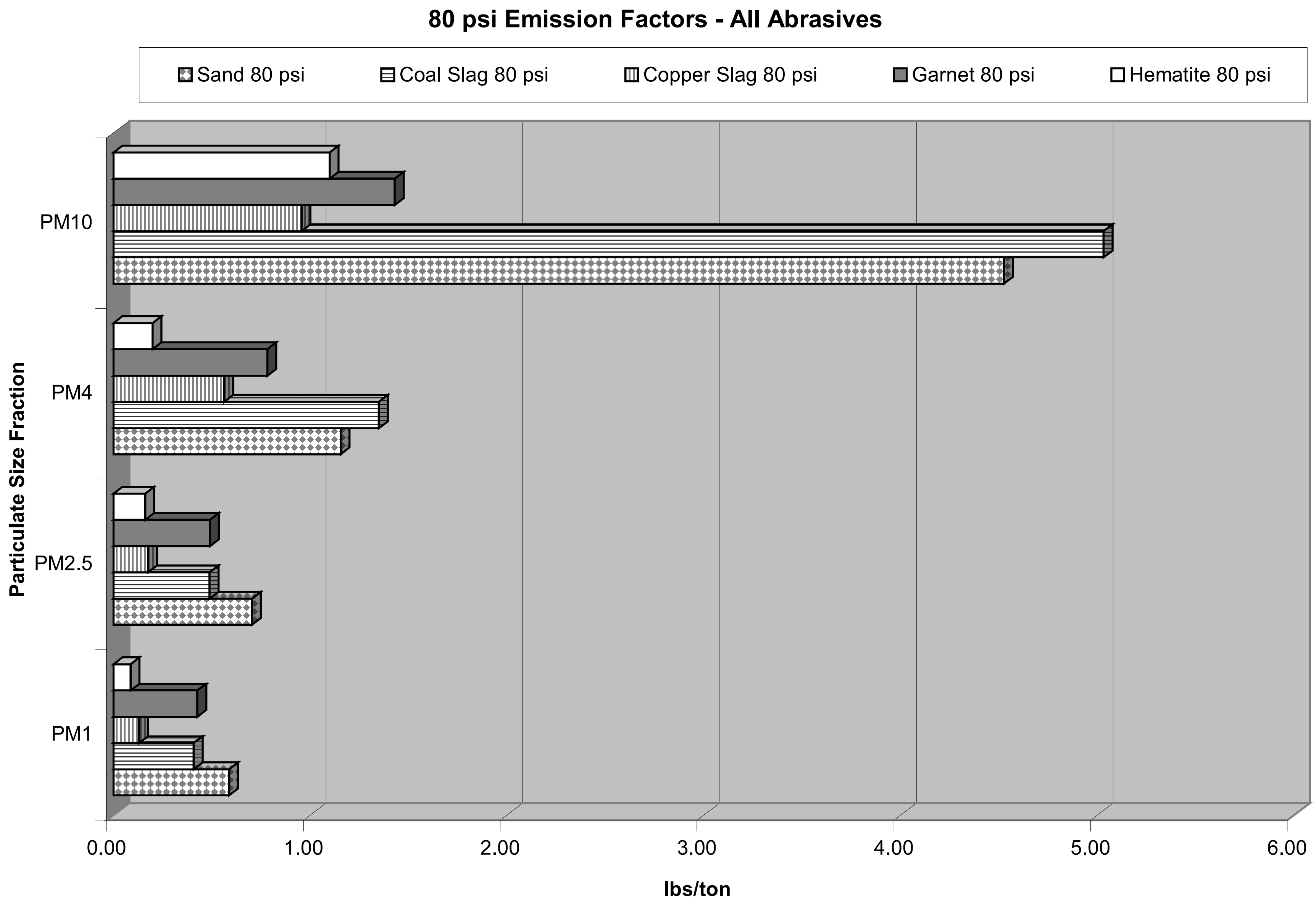


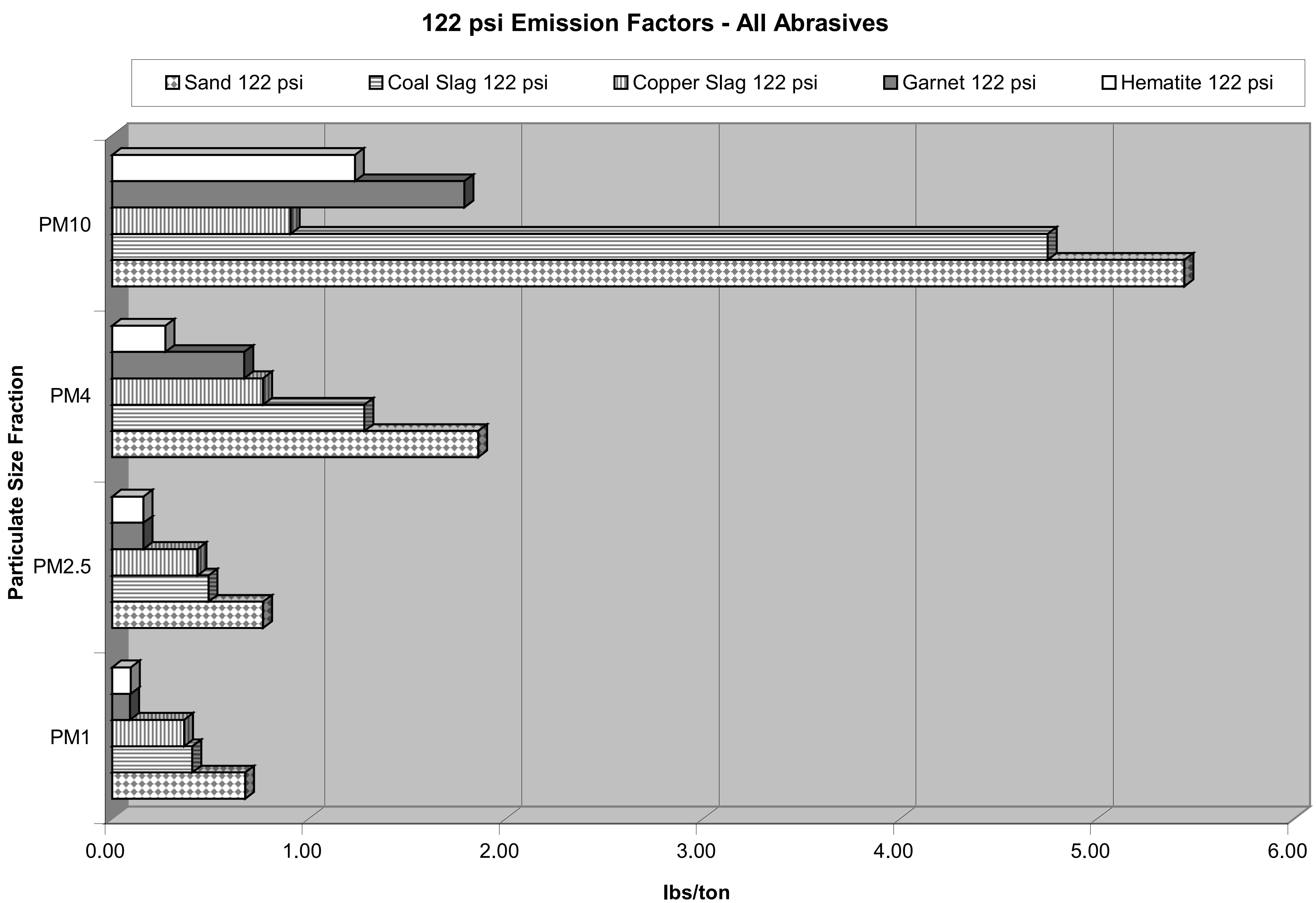
	PM1	PM2.5	PM4	PM10
80 psi	0.43	0.49	0.78	1.43
122 psi	0.09	0.16	0.67	1.79

Hematite Emission Factors



	PM1	PM2.5	PM4	PM10
80 psi	0.09	0.16	0.20	1.10
122 psi	0.10	0.16	0.27	1.23


80 psi Emission Factors - All Abrasives
Sand 80 psi
Coal Slag 80 psi
Copper Slag 80 psi
Garnet 80 psi
Hematite 80 psi
PM10
PM4
PM2.5
PM1
Particulate Size Fraction
0.00
1.00
2.00
3.00
4.00
5.00
6.00
lbs/ton


122 psi Emission Factors - All Abrasives
Sand 122 psi
Coal Slag 122 psi
Copper Slag 122 psi
Garnet 122 psi
Hematite 122 psi
PM10
PM4
PM2.5
PM1
Particulate Size Fraction
0.00
1.00
2.00
3.00
4.00
5.00
6.00
lbs/ton

Conclusions

Hematite tended to have the lowest emission factors for all PM size ranges and nozzle pressures. Sand had the highest emission factors for all PM size ranges and nozzle pressures, except PM4 at 80 psi, where coal slag had a slightly higher emission factor. As a group, Hematite, Garnet and Copper Slag had relatively low emission factors when compared to Coal Slag and Sand. The greatest difference in emission factors between these groups is seen in the PM10 fraction, with Coal Slag and Sand being approximately 5 times greater than Hematite, Garnet and Copper Slag. This difference is much less at the lower PM size fractions of PM4, PM2.5 and PM1.

In regards to the effect of nozzle pressure on emission factors general trends were abrasive specific. Coal Slag had significant[11] increases in emission factors for all PM size fractions from the lower to higher nozzle pressure. Coal Slag showed no significant changes in emission factors at different nozzle pressures. Copper Slag showed significant increases in emission factors at the higher nozzle pressure for PM1, PM2.5 and PM4 but not PM10. Garnet showed significant decreases in emission factors with increasing nozzle pressure for PM1, PM2.5 and PM4, but an increased emission factor for PM10. Hematite emission factors remained unchanged with increasing nozzle pressure for PM1 and PM2.5 but increased emission factors for PM4 and PM10.

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[11] Significant being defined as an increase or decrease of 5% or greater.

Particulate Emission Factors for Blasting Operations and Other Potential Sources
Project No. N1-97-04

Task 8: Project Summary and Guidance Document

Task 8 – Project Summary and Guidance Document

Introduction

NSRP Project No. N1-97-04: Emission Factors for Blasting Operations and Other Potential Sources was conducted to provide the Shipbuilding and Repair Industry with a comprehensive study of the potential sources of particulate matter from the shipyard in mass size fraction ranges of 10 microns and less. Additionally, testing to derive emission factors was conducted on abrasives currently in use by shipyards. The results of this study and testing have provided the industry with guidance in three areas:

1. Determining which shipyard operations and processes are significant contributors to particulate matter emissions;
2. Assisting the shipyard in selecting abrasives based on the potential to emit particulate matter; and
3. More accurately quantifying the particulate emissions derived from abrasive blasting operations.

This Task report provides a summary of study results as well as guidance on abrasive selection based upon the potential to emit particulate matter. Additionally, a recommendation for enhancing the acceptability of the study results by federal and state environmental agencies is provided.

Significant Contributors to Shipyard Particulate Emissions

Many shipyard operations and processes were determined to be potential sources of both primary and/or secondary generation of both coarse and fine particulate matter. While many of the shipyard operations and processes may be sources of particulate matter, most of these are likely to be insignificant due to the fact that either: 1) while the particulate emission factor may be relatively high, the material throughput is small, or 2) while the throughput may be relatively large, the emission factor is small.

The results of Task 1 provided some general observations that can be drawn concerning which shipyard operations and processes could be of concern as significant sources of particulate matter. These observations are bulleted below:

- Material Movement, Metal Processing, Fabrication and Machining, Surface Preparation, Transportation and Yard Services were identified as shipyard operations that included specific processes that were known primary sources of coarse particulate matter. Significant sources of coarse particulate matter appear to be confined to dry abrasive blasting. Marine coating operations conducted with paint spray equipment could also release a significant amount of coarse particulates, however, no data regarding the particle size distribution of coating overspray was located during the research phase of Task 1. Therefore, no reliable conclusion regarding coarse particulate matter generation from marine coating operations could be drawn.

- Yard Services and Surface Preparation were identified as shipyard operations that included specific processes that were known primary sources of fine particulate matter. Possible significant sources of fine particulate matter appear to be confined to dry abrasive blasting. Marine coating operations conducted with paint spray equipment could also release a significant amount of fine particulates, however, no data regarding the particle size distribution of coating overspray was located during the research phase of Task 1. Therefore no reliable conclusion regarding fine particulate matter generation from marine coating operations could be drawn.
- No shipyard operations or processes were positively identified as secondary sources of particulate. However, several shipyard operations included processes that were possible sources of chemical precursors to secondary sources of both coarse and fine particulate matter.

Dry abrasive blasting is presumably the most significant primary source of both coarse and fine particulate matter generation derived from shipyard operations. Other secondary sources of coarse and fine particulate matter may also be derived from shipyard operations. The level of significance of these sources cannot be estimated at this time due to the lack of reliable data regarding emissions factors, condensation rates, and particulate formation processes.

Abrasive Selection Based on Potential to Emit Particulate Matter

Testing of five abrasives at two nozzle pressures provided data from which several general conclusions can be drawn. These general conclusions are provided below:

- The emission factors developed resulted in the tested abrasives being divided into two distinct groups. These were:
    1. Sand and Coal Slag that had relatively high emission factors; and
    2. Copper Slag, Garnet and Hematite that had relatively low emission factors.
- There were no significant differences between the emission factors of abrasives within their respective grouping (higher or lower emission factors). This indicates that there is no advantage (i.e. lower particulate emissions) to selecting one abrasive over another within the same group.
- Sand and Coal Slag had emission factors that were approximately 4 to 5 times greater than Copper Slag, Garnet or Hematite at both 80 and 122 psi. This indicates that selecting Copper Slag, Garnet or Hematite, rather than Sand or Coal Slag would achieve a significant reduction in particulate emissions.

Quantifying Particulate Emissions from Abrasive Blasting Operations

Using the emission factors developed from this study a Microsoft Excel spreadsheet for quantifying particulate emission of PM10, PM4, PM2.5 and PM1 was developed. Additionally the spreadsheet allows the use of a control factor can be applied to those sources that have a control device, such as shrouds or baghouse dust collector.

Recommendations

This study has provided significant new information regarding particulate emissions derived from dry abrasive blasting operations. One finding of primary significance is the fact that emission factors for blasting operations currently in use by the EPA and some state agencies are most likely overestimating emissions by a factor of 2 to 5 times. As more accurate particulate emission inventories would be beneficial to the environment, shipyards and federal/state environmental agencies, it is important to establish the validity of the testing protocol used, and the results obtained in this study. We believe that this is best accomplished by preparing a formal paper presenting this study for submission to a peer reviewed scientific journal. Acceptence and publication by a recognized journal will substantiate the results and increase the credibility of the study.

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