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Promoting Cleaner Production through Innovative University Research Methods

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Abstract

Using private and government funding, researchers at the University of New Orleans (UNO) designed and built an Emissions Test Facility (ETF) under their clean technologies initiative which is being used to train graduate and undergraduate students. The role of Emissions Test Facility (ETF) is very important in developing clean/environmentally-friendly technologies. The ETF at UNO is scalable to the needs of the processes to be optimized and allows monitoring of process parameters and the quantity/characteristics of waste streams. This ETF also contains a two-stage air pollution control system to prevent contamination of the site being used for the research. An exhaust fan with flow controller is equipped to study the emission variations under variable ventilation conditions. Exhaust rates can also be related to wind speeds in case of processes performed in open-air conditions.

UNO's ETF has been successfully used to optimize dry abrasive blasting process commonly used to remove paint, rust and other surface contaminants before new paint application of metallic surfaces. Blast pressure, abrasive feed rate, type of abrasive, level and type of contamination, and many other process conditions influence (1) energy consumption, (2) material consumption, (3) productivity (how fast the surface is cleaned), (4) used-abrasive generation, and (5) quantities and characteristics of air emissions. By simulating the process within the ETF, various process, performance, and environmental (waste potential) parameters were measured. Thus ETF was helpful in understanding the inter-relationships among process parameters, types of abrasives, and emission potential which helped in developing predictive mathematical models. These models now can predict (1) productivity, (2) material/energy consumption, (3) air emissions, (4) used-abrasive generation rates, and (5) life cycle costs.

ETF is being used to simulate and optimize other industrial processes to increase understanding of inter-relationships and develop predictive and decision-support tools. This research setup and approach greatly supports the concepts of green engineering, design for the environment, clean/environmentally-friendly technologies, environmentally-preferred material selection, life cycle cost reduction, pollution prevention, health risk reduction, and overall improvement of quality of life. This paper presents some salient features of the research approach, recent experiences, and outcomes.

Key words: Abrasive Blasting, Particulate Emission Factors, Emissions Modeling, Waste from Abrasive Blasting, Abrasive Ranking

1 Introduction

The University of New Orleans (UNO) is a premier urban university located in the City of New Orleans, Louisiana, the United States of America (USA). The gulf coast region, states consisting of Texas, Louisiana, Mississippi, Alabama, and Florida, is rich with maritime industrial activities with many large, medium, and small shipbuilding and ship repair yards. UNO housed with the School of Naval Architecture and Marine Engineering (SNAME) and the Department of Civil & Environmental Engineering had perfect synergy to establish a Clean Technologies Initiative under private and government research funding. Under this initiative, necessary research infrastructure was procured to (1) train undergraduate and graduate students in the area of clean technologies, cleaner production, and sustainability, (2) conduct clean technologies research that is directly related to the maritime industry present in the gulf coast as well as in rest of the USA and the world. In order to facilitate clean technologies research activities and to train undergraduate and graduate students, a center named the Maritime Environmental Resources and Information Center (MERIC) was created at the University of New Orleans to focus on the clean technologies development to promote cleaner production within the maritime industry. Also, the mission of the initiative is to develop "clean technologies concepts" that are scalable to other industry sectors including but not limited to automotive, aerospace, metals manufacturing, chemical, metallurgical, and refining.

As per a report by the United States Environmental Protection Agency (*US EPA, 1994*), there a total of 437 active shipyards in the country and a good percentage of them are in the gulf coast region. Shipyards can be divided into two categories, shipbuilding facilities and ship repair facilities with shipbuilders concentrating on building new vessels and ship repair facilities concentrating on repair and maintenance activities. Shipyard processes include surface preparation, painting and coating, metal plating and surface finishing, solvent cleaning and degreasing, machining and metalworking, and vessel cleaning. Because of the size of the ships and their accessibility, most operations are done in open air conditions either in a dry-dock, or in the graving dock. These shipyard processes generate multimedia pollutants which vary based on the type of materials used, the process conditions, the worker training, and more.

In this paper, how UNO's clean technologies initiative efforts were directed to address one specific process, abrasive blasting is discussed.

2 UNO's Research Approach to Promote Cleaner Production

UNO's approach involved identification of critical maritime processes and development of research methods to address these critical processes to reduce their overall waste generation potential. Much of the knowledge was gained through collaboration with local shipyards under a broad-based study, Integrated Environmental Management Plan for Shipbuilding Facilities (IEMPSF). This project gave an insight into various processes, materials used, process types and their

variations, multimedia wastes generated from each process under various permutations and combinations, compliance requirements under state and federal laws, applicable control/treatment technologies, environmental costs, and potential health risks. Broad-based IEMPSF was a good start for the UNO researchers to undertake more focused research to optimize processes and to develop cleaner production methods. One such example that is being discussed in this paper is abrasive blasting process which is one of the important shipbuilding and ship repair processes. This process was investigated in detail with the help of an emissions test facility (ETF) to understand the inter-relationships among:

(1) Abrasive materials used

(2) Process conditions

(3) Product quality and productivity,

(4) Consumption of materials,

(5) Energy requirements,

(6) Used-abrasive generation rates,

(7) Particulate emissions,

(8) Production costs,

(9) Environmental costs,

(10) Life-cycle costs,

(11) Worker health and

(12) Public health

3 UNO's Research Methodology

As mentioned earlier, abrasive blasting is one of the important processes within the shipbuilding and ship repair yards. Abrasive blasting involves propelling abrasive materials at the metal surface at high speeds. This blast action removes rust, paint and any other contaminants from the surface being cleaned. The most common abrasive materials used are sand, steel shot, garnet, lead shot, copper slag and coal slag (*US EPA, 1994*). Because of its low cost, applicability, and effectiveness, abrasive blasting has been the method of choice for the shipbuilding industry.

Author's specific cleaner production research goals using emissions test facility with respect to abrasive blasting were:

- Evaluate "uncontrolled total particulate matter (uncontrolled TPM) emission factors (lb/lb; g/ft^2)" for six most used abrasives under variable blast pressures and feed rates within an emissions test facility using EPA's emission test procedures

- Evaluate other environmental parameters such as "productivity (ft^2/hr)" and "consumption (lb/ft^2)" for various process conditions

- Develop mathematical models to predict environmental parameters (uncontrolled TPM emissions, productivity, and consumption [also used-abrasive generation]) based on blast pressure and feed rate for each of the six abrasives which will assist in identification of:
    - Environmentally-friendly abrasives and their ranking

- Preferred blast pressures for a specific abrasive to achieve lowest emissions, lowest consumption, and highest productivity
- Preferred feed rate for a specific abrasive to achieve lowest emissions, lowest consumption, and highest productivity

For the purposes of the research, an ETF was designed and constructed at UNO. Figure 1 shows the salient features of the ETF.

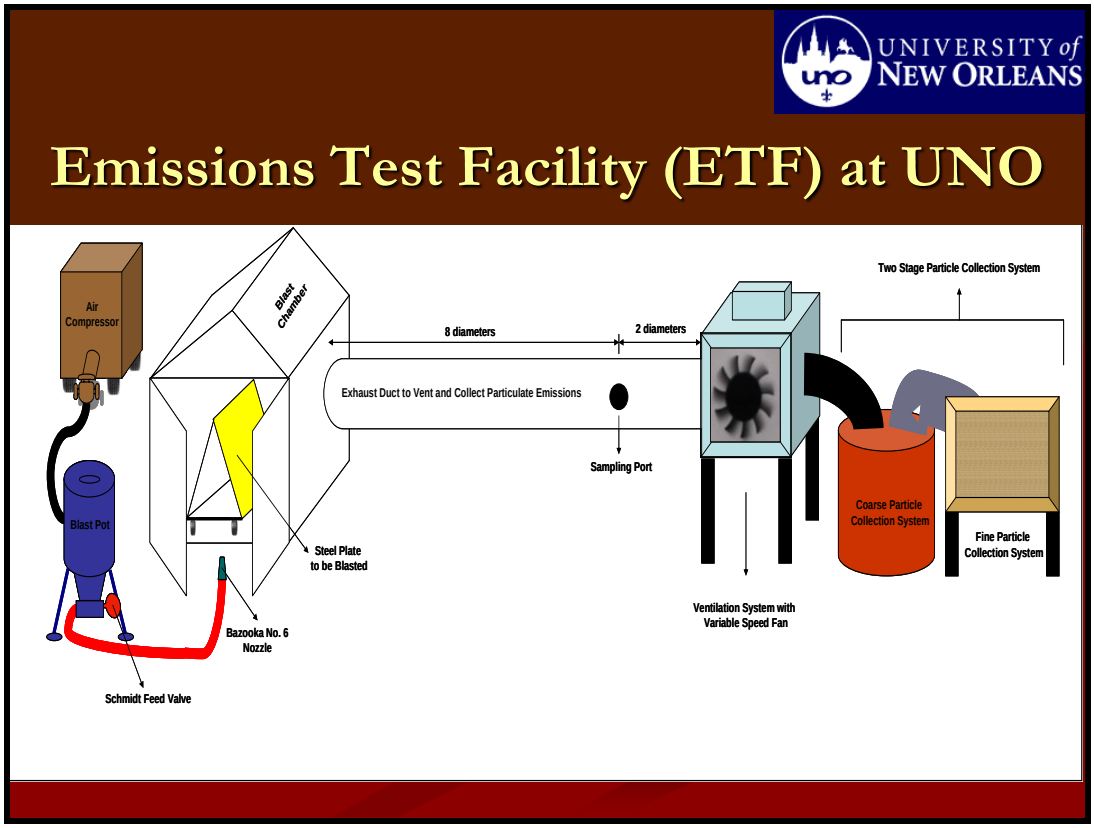

Figure 1: UNO's Emissions Test Facility (ETF) to Promote Cleaner Production Research.

Abrasive Materials Used

Based on the survey of the shipbuilding industry in the United States, most used six abrasives were identified for this research. These abrasives were, coal slag, copper slag, garnet, steel shot/grit, specialty sand, and hematite.

Process Conditions

Blast Pressure

Blast pressure is one of the important process parameter that has influence on productivity, abrasive consumption, and the emission potential. Optimization of these parameters will lead to cleaner production. Through discussions with the shipbuilders and the abrasive suppliers, it was understood that the blast pressure used for these six materials varied from 80 psi to 120 psi. Harder materials such as steel shot/grit will require higher blast pressures and specialty sand requires

lower blast pressures for their optimum performance. For this research, three distinct blast pressures were used, 80, 100, and 120 psi as use of two points will only give a linear relationship. Limited resources and time did not permit to increase the number of blast pressures observation points.

Abrasive Feed Rate

Another process parameter that influences productivity, abrasive consumption, and emission potential is abrasive feed rate. Survey of shipbuilders and ship repair yards indicated that the abrasive flow rate is regulated using a Schmidt feed valve. This was again used as one of the controlling parameter in the study. Turns of 3, 4, and 5 were used for the study to optimize various performance parameters.

Figure 2 shows the experimental design, with two process parameters (blast pressure on x-axis; abrasive feed rate on y-axis) and performance/output parameters on y-axis. These output measured were, (1) productivity, (2) abrasive consumption, and (3) particulate emissions.

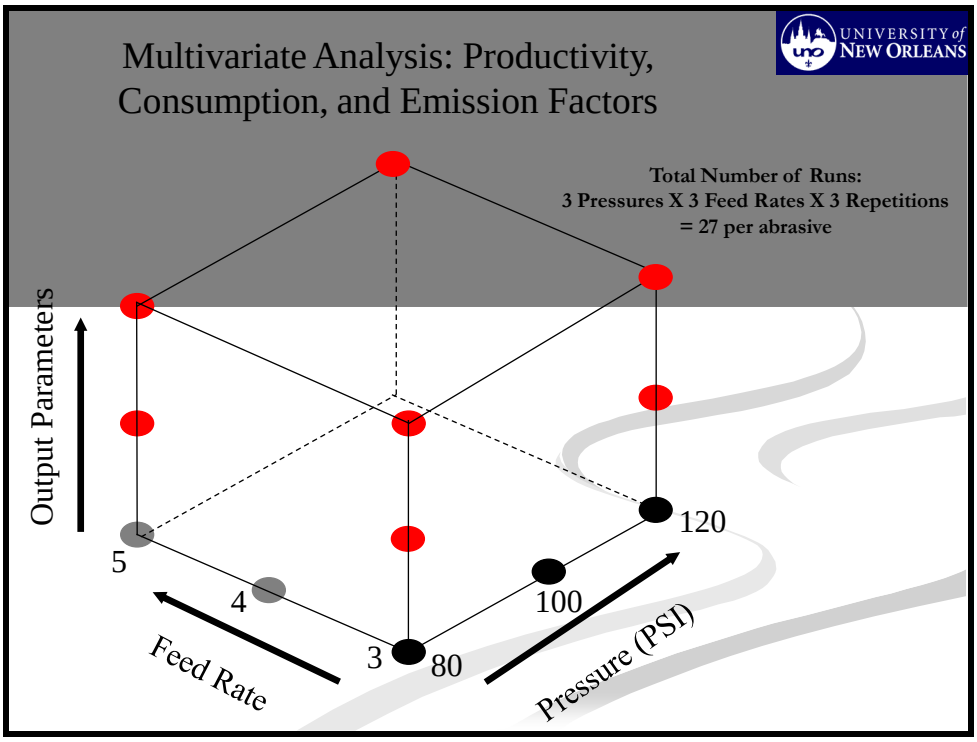

Figure 2: Experimental Design for Abrasive Blasting Optimization.

Blasting was performed inside the shed and particulate emissions generated were drawn through a 12" diameter duct with the help of a blower capable of variable flow rate in the range of 3500 to 5000 cubic feet per minute (CFM). Particulate emissions were measured using US EPA's source test procedures by using Method 1 through 5 (*US EPA Source Test Methods 1, 2, 3, 4, 5*). Sampling was conducted using iso-kinetic sampling procedures during blast operations for each run. Sampling was started few minutes before and lasted until dusty air is cleared inside the ETF. Figure 3 shows sampling train used in the research. In order to reach the research objectives, the following critical observations were made for calculating various parameters that define the cleaner production:

- Amount of abrasive used for each run
- Blasting time or cleaning time
- Area cleaned on the test plate (rusted plate and painted plates were used)
- Mass of total particulates emitted from the stack or source testing

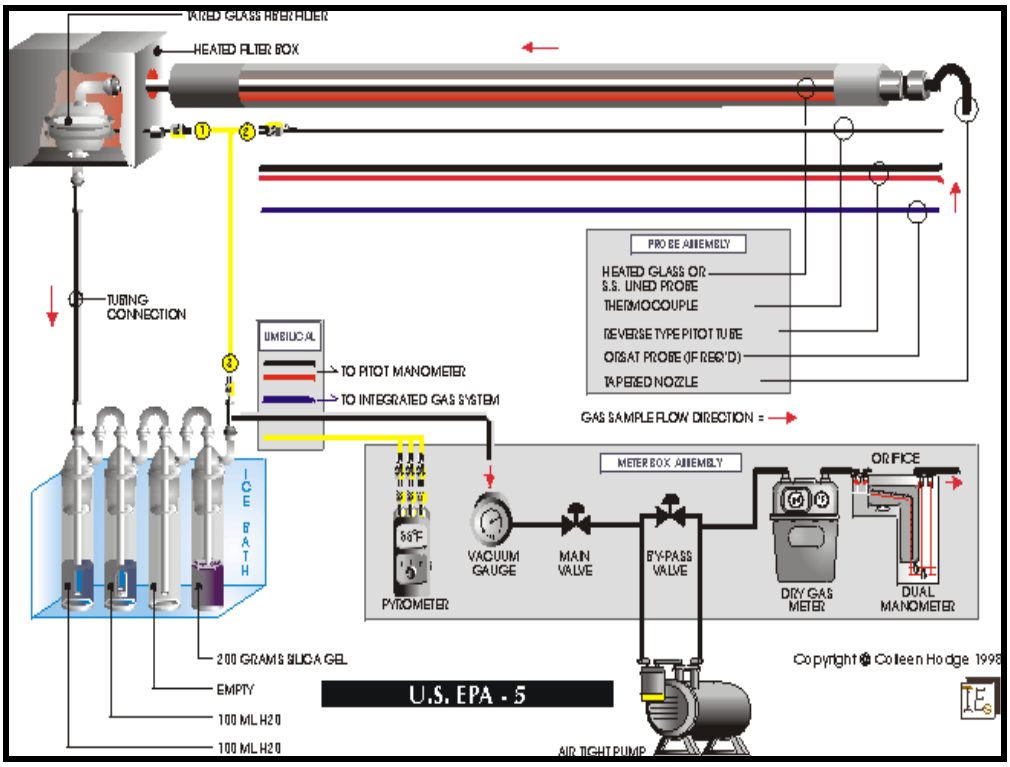

Figure 3: Sampling Train for Source Testing (US EPA – Method 5).

5 Results and Discussion

Based on the experimental data, critical cleaner production parameters were calculated to gain insight into the abrasive blasting.

Productivity was calculated using the area cleaned and the time required for cleaning. Productivity was expressed in the units of ft^2/hr or m^2/hr. Abrasive consumption was calculated using the abrasive material consumed and the area cleaned to express in the units of lb/ft^2 or kg/m^2. Abrasive consumption rate was calculated in the units of lb/hr or kg/hr. Particulate emissions were calculated knowing the particulate mass from the source testing and the area cleaned. Particulate emissions or emission factors (EF) were expressed in the units of "lb/short-ton" or "kg/metric ton" (*EPA – Procedures for Preparing Emission Factors Document, 1997)*. Emission factors were also expressed in the units of "lb/1000 ft^2 area cleaned" or "kg/1000 ft^2 area cleaned." Examples of data obtained are presented in Figures 4 through 5 for coal slag.

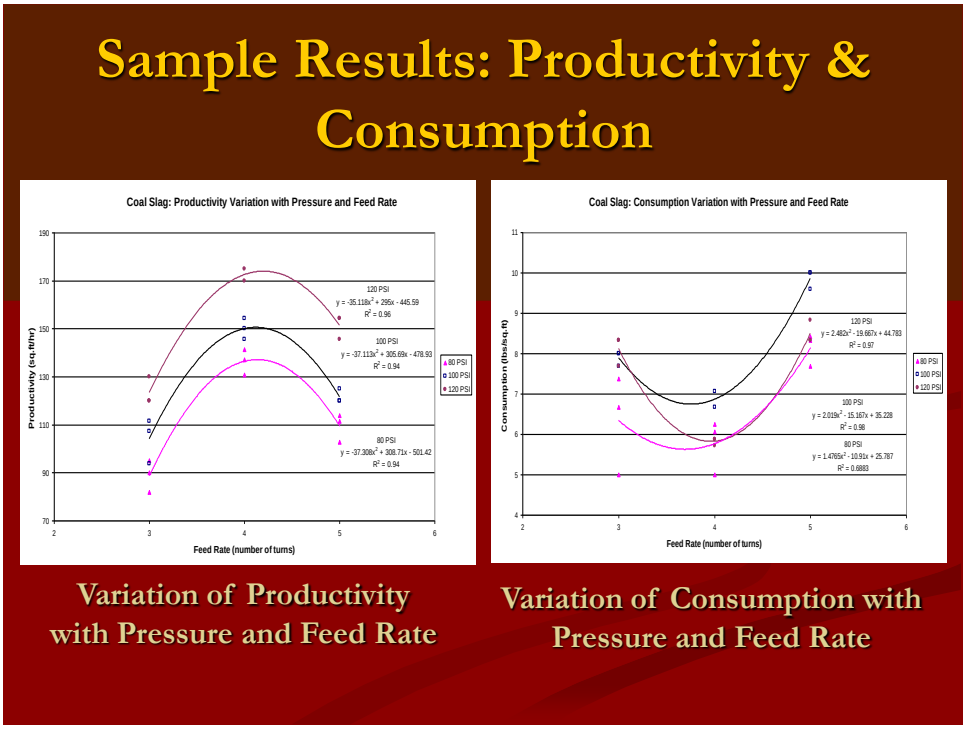

Figure 4: Sample Results for Coal Slag – Productivity and Consumption

Figure 4 shows the relationship between productivity and the feed rate for three blast pressures as well as the relationship between consumption and the feed rate for three blast pressures. There is a maximum productivity and minimum consumption which can be further evaluated for optimizing abrasive blasting to promote cleaner production.

Similarly, Figure 5 shows the relationship between particulate emissions and the feed rate for three blast pressures. Again there are low emission conditions which can be achieved by understanding the effect of the feed rate and the blast pressures.

5 Summary and Conclusions

UNO's research approach has been useful in developing research methods to promote cleaner production within the maritime industry as demonstrated with the abrasive blasting case study discussed in this paper. The role of ETF is very important in developing cleaner production processes by simulating industrial processes. Similar approach can be used in case of metal welding, metal cutting, painting, and or any other process that can be simulated within the ETF.

As explained briefly and demonstrated with the sample results, blast pressure, abrasive feed rate, type of abrasive, level and type of contamination, and many other process conditions influence (1) energy consumption, (2) material consumption, (3) productivity (how fast the surface is cleaned), (4) used-abrasive generation, and (5) quantities and characteristics of air emissions. Through simulation of the process within the ETF, process, performance, and environmental (waste potential) parameters were measured.

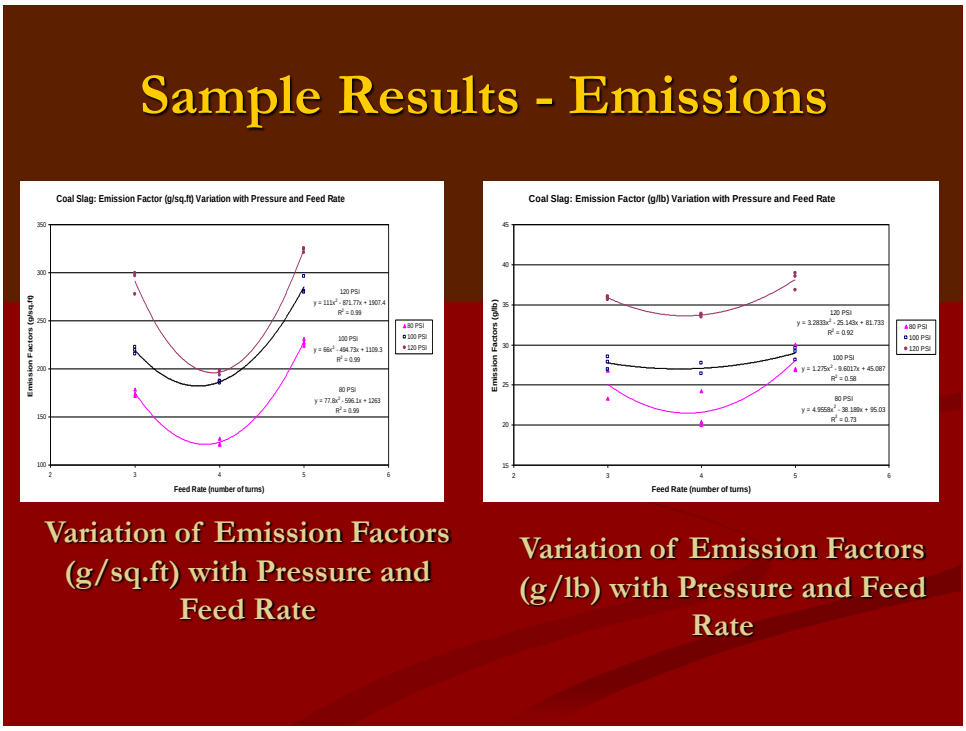

Figure 5: Sample Results for Coal Slag – Particulate Emissions

UNO's cleaner production research methodology was helpful in understanding the inter-relationships among process parameters, types of abrasives, and emission potential which helped in developing predictive mathematical models. These models will predict (1) productivity, (2) material/energy consumption, (3) air emissions, (4) used-abrasive generation rates, and (5) life cycle costs. The same approach is being used to understand other industrial processes and to develop predictive and decision-support systems.

UNO's infrastructure, the research approach greatly supports the cleaner production concept and should help in achieving conservation of materials, minimization of multimedia wastes, protection of worker health/public health, and overall reduction of life cycle costs.

6 References

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U.S. Environmental Protection Agency. 40 CFR Part 60, Appendix A. Method 2 – Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube).

U.S. Environmental Protection Agency. 40 CFR Part 60, Appendix A. Method 3 – Gas Analysis for the Determination of Dry Molecular Weight.

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