IN-DEPTH SURVEY REPORT

EVALUATION OF AN AUTOMATED ABRASIVE BLASTING MACHINE

at

Marystown Shipyard
Marystown, Newfoundland
Canada

REPORT WRITTEN BY
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Plant Surveyed	Marystown Shipyard Marystown, Newfoundland, Canada
SIC Code	3731
Survey Dates	September 16-17, 1997
Survey Conducted by	Alan Echt James D McGlothlin
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Employee Representatives Contacted	Local 20, Marine and General Workers Union
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ABSTRACT

This site visit was part of a project to determine the feasibility of using automated paint-removal technology on steel structures (ships, bridges, storage tanks, etc) The major goal of the project was to determine the current status of the technology This involved determining the number of prototypes currently available, the development stage of each prototype, determining on which steel structures each prototype can be used and the percentage of each type of structure on which the automated technology can be used, and a comparison of costs of the automated method with traditional methods of lead-based paint removal Observation of prototype systems in operation was a critical component of this project

The system evaluated at this site incorporated the Pittman Vacuum Blasting Sytem (PVBS) Vacuum Abrasive Steel Cleaning and Reclamation System This system included the blast head, a trailer housing the cleaning and reclamation system, an electric winch, and a hand-held controller The PVBS marine vacuum blast head demonstrated on the ship *Quest*'s superstructure during the NIOSH site visit consisted of two conventional abrasive blasting nozzles connected via blast hoses to the blast pot The nozzles, located 18 inches apart, travelled inside the blast head on a slide mechanism which moved back and forth driven by an air cylinder Reed switches which sensed the magnetic piston inside the air cylinder controlled the stroke of the nozzles The blast head rode over the surface of the superstructure on rubber skirts The head was held in intimate contact with the hull surface by the force of the vacuum, however, some leakage of abrasive and debris was noted during the demonstration A newer model, which incorporated three blast nozzles and an improved seal was scheduled to be delivered after the demonstration The top and bottom skirts rode on skis to allow them to travel over obstructions Blast media, rust, and paint were mostly contained within the tool and immediately vacuumed to the cleaning and reclamation system A variable speed electric winch allowed the blast head to travel up and down the hull at the rate required to achieve the desired finish A single pass cleaned the tested portions of the superstructure to a white metal finish

Observations and air sampling data indicate that the PVBS automated blasting tool effectively removed and contained lead-based paint during the demonstration on the *Quest* While the NIOSH researchers observed some paint chips escaping from the ship-to-tool seal, either the particles' size, prevailing winds, or other conditions prevented them from reaching the breathing zones of the tool's operators Since this demonstration, both the tool and the seal have been modified, so that this leakage may no longer be a concern It would be interesting and worthwhile to repeat this evaluation during the operation of the PVBS automated blasting tool in its current configuration over several complete work shifts during a lead-based paint removal project

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is located in the Centers for Disease Control and Prevention (CDC), under the Department of Health and Human Services (DHHS) NIOSH was established in 1970 by the Occupational Safety and Health Act, at the same time that the Occupational Safety and Health Administration (OSHA) was established in the Department of Labor (DOL) The OSHAct legislation mandated NIOSH to conduct research and education programs separate from the standard-setting and enforcement functions conducted by OSHA An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards

The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering (ECTB) has been given the lead within NIOSH to study and develop engineering controls and assess their impact on reducing occupational illness Since 1976, ECTB has conducted a large number of studies to evaluate engineering control technology based upon industry, process, or control technique The objective of each of these studies has been to evaluate and document control techniques and to determine the effectiveness of the control techniques in reducing potential health hazards in an industry or for a specific process

This site visit was part of a project to determine the feasibility of using automated paint-removal technology on steel structures (ships, bridges, storage tanks, etc) The major goal of the project was to determine the current status of the technology This involved determining the number of prototypes currently available, the development stage of each prototype, determining on which steel structures each prototype can be used and the percentage of each type of structure on which the automated technology can be used, and a comparison of costs of the automated method with traditional methods of lead-based paint removal Observation of prototype systems in operation was a critical component of this project

A second goal of the project was to document the degree to which the automated technology reduces occupational exposures to lead This involved air sampling to determine employee exposures to lead while they operated or observed the operation of the automated equipment

HEALTH EFFECTS OF AIR CONTAMINANTS AND OCCUPATIONAL EXPOSURE CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ occupational exposure criteria for the assessment of a number of chemical and physical agents These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy) In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion These combined effects are often not considered in the evaluation criteria Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available

The primary sources of occupational exposure evaluation criteria for the workplace are (1) NIOSH Recommended Exposure Limits (RELs)[1], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs)[2] and (3) the U S Department of Labor, OSHA Permissible Exposure Limits (PELs)[3] In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations, however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease It should be noted when reviewing this report that employers in the United States are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values

Because this NIOSH evaluation was conducted outside of the United States, OSHA PELs are not included in this report In many Canadian jurisdictions, exposure limits are similar to the ACGIH TLVs Since the manner in which exposure limits are established, interpreted and implemented can vary, detailed information should be obtained from the appropriate government agency in each jurisdiction Because this is a NIOSH report, the NIOSH RELs are included Table 1 provides the RELs and TLVs for metals applicable to this survey

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8-to-10-hour workday Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term

OCCUPATIONAL EXPOSURE TO LEAD

An important goal of this project was to document the degree to which the automated technology reduces occupational exposures to lead Exposure to lead occurs via inhalation of dust and fume, and ingestion through contact with lead-contaminated hands, food, cigarettes, and clothing Absorbed lead accumulates in the body in the soft tissues and bones Lead is stored in bones for decades, and may cause health effects long after exposure as it is slowly released in the body

Symptoms of lead exposure include weakness, excessive tiredness, irritability, constipation, anorexia, abdominal discomfort (colic), fine tremors, and "wrist drop "[4,5,6] Overexposure to lead may also result in damage to the kidneys, anemia, high blood pressure, infertility and reduced sex drive in both sexes, and impotence An individual's blood lead level (BLL) is a good indication of recent exposure to, and current absorption of lead [7] The frequency and severity of symptoms associated with lead exposure generally increase with the BLL

ACGIH has proposed a TLV for lead of 50 $\mu g/m^3$ (8-hour TWA), with worker BLLs to be controlled to at or below 20 μg/dL, and designation of lead as an animal carcinogen [2] The U S Public Health Service has established a goal, by the year 2000, to eliminate all occupational exposures that result in BLLs greater than 25 μg/dL [8]

In homes with a family member occupationally exposed to lead, care must be taken to prevent "take home" of lead, that is, lead carried into the home on clothing, skin, and hair, and in vehicles High BLLs in resident children, and elevated concentrations of lead in the house dust, have been found in the homes of workers employed in industries associated with high lead exposure [9] Particular effort should be made to ensure that children of persons who work in areas of high lead exposure receive a BLL test Fetal exposure to lead is associated with reduced gestational age, birthweight, and early mental development with maternal BLLs as low as 10 to 15 μg/dL [10] Men and women who are planning on having children should limit their exposure to lead

PROCESS DESCRIPTION

Marystown Shipyard Limited's shipyard is located in Marystown, Newfoundland, Canada, on Newfoundland's Burin Peninsula, 306 km from St John's The company, which employs about 600, performs shipbuilding, ship repair, offshore, and industrial fabrication at the Marystown shipyard and Cowshead fabrication facility This site visit investigated the use of the PVBS automated abrasive blasting system to remove paint from the superstructure of the *Quest*, a Canadian oceanographic research ship

The system incorporates the PVBS Vacuum Abrasive Steel Cleaning and Reclamation System This system included the blast head, a trailer housing the cleaning and reclamation system, an electric winch, and a hand-held controller The PVBS marine vacuum blast head demonstrated on the *Quest*'s superstructure during the NIOSH site visit consisted of two conventional abrasive blasting nozzles connected via blast hoses to the blast pot The nozzles, located 18 inches apart, travelled inside the blast head on a slide mechanism which moved back and forth driven by an air cylinder Reed switches which sensed the magnetic piston inside the air cylinder controlled the stroke of the nozzles The blast head rode over the surface of the hull on rubber skirts The head was held in intimate contact with the hull surface by the force of the vacuum, however, some leakage of abrasive and debris was noted during the demonstration A newer model, which incorporated three blast nozzles and an improved seal was scheduled to be delivered after the demonstration The top and bottom skirts rode on skis to allow them to travel over obstructions Blast media, rust, and paint were mostly contained within the tool and immediately vacuumed to the cleaning and reclamation system A variable speed electric winch allowed the blast head to travel up and down the hull at the rate required to achieve the desired finish A single pass cleaned the tested portions of the superstructure to a white metal finish

The cleaning and recycling system includes a 7-ft diameter displacement chamber which allows heavy particles to leave the airstream for separation and recycling Smaller particles move with the airstream to the filtration system The filtration system is an on/off-line independent system housed in two tanks, each of which holds five cartridge filters The cartridge filters have a computer-controlled pulse jet reverse air wash cleaning system When one filter loads, it goes off-line and enters the cleaning cycle, while the other unit comes on-line As each cartridge is cleaned, a group of valves which connect the filter unit to the main vacuum in the displacement chamber via the paint dust filter open simultaneously The self-cleaning paint dust filter deposits the fine dusts into a drum for disposal

Abrasive is recycled from within the main vacuum unit by transporting spent abrasive from the displacement chamber via a vibratory conveyor A two-tier separation process takes place during transport One screen allows all of the fine material, such as spent abrasive, to be separated A second screen separates larger waste products, such as rust The material remaining in the vibratory conveyor is recyclable abrasive, which is fed to the blast pot via a vacuum line Patented compensation valve technology allows the use of one vacuum system to perform several tasks All equipment in the PVBS unit is computer controlled with operator input via a touch screen display

The manufacturer's literature claims a production rate of 600 ft^2/hour per tool to a white metal finish Savings in operating costs are realized by the ability for other trades to work alongside the unit, no need for containment or personal protective equipment, the ability of the equipment to run continuously, and conservation of abrasive through separation and reuse In addition to the automated unit described, hand-held tools are available for use with the PVBS unit

MEASUREMENT PROCEDURES

One purpose of this site visit was to determine the ability of the PVBS system to reduce exposures associated with the removal of lead paint from steel structures by controlling emissions at their source, reducing or eliminating the need to construct and maintain ventilated enclosures and eliminating or reducing the need for respiratory protection Thus, exposure monitoring was conducted to determine the airborne concentrations of metals and total particulate during operation of the PVBS system In addition, bulk samples of paint chips and spent abrasive blasting media were collected from various points of the process to provide information about the ability of the PVBS system to clean the media prior to reuse

On September 16, two PBZ samples and one General Area (GA) sample for metals and total particulate were collected for approximately one hour while two laborers used a PVBS hand-held tool to clean the deck in the NLO cabin aboard the *Quest* These samples were collected at a flow rate of 2 liters per minute (L/min) The laborers traded duties during the job, each taking a turn holding the hose or operating the tool

Two PBZ samples and one GA sample were also collected on September 16 during a brief demonstration of the PVBS automated blasting tool removing paint from the superstructure of the *Quest* PBZ samples were collected for 15 minutes on the top man and the operator The area sample was collected at the operator's position These samples were collected at a flow rate of 4 L/min

Two PBZ samples and one GA sample were collected on September 17 during another brief demonstration of the PVBS automated blasting tool removing paint from another portion of the *Quest*'s superstructure PBZ samples were collected for 21 and 22 minutes from the controller and the top man, respectively The area sample was collected on top of a welding box on the pier beneath the portion of the ship being depainted These samples were also collected at a flow rate of 4 L/min

Air samples for metal and total particulates were collected on 37-millimeter diameter, 5-micron pore-size polyvinyl chloride (PVC) filters in two piece cassettes connected via Tygon tubing to battery-powered air sampling pumps For personal breathing zone (PBZ) samples, the filter casette was clipped to the employee's lapel, while the sampling pump was worn on a belt around the employee's waist The air samples were analyzed for metals by inductively coupled argon plasma, atomic emission spectroscopy (ICAP-AES) and gravimetrically for total particulate using NIOSH Methods 7300 and 0500 (both with modifications), respectively [11] The air samples collected during the use of the hand-held tools were analyzed for elements by NIOSH Method 7300 (the list of elements and their analytical limits are provided in Table 2), modified for PVC filter digestion [11] The air samples collected during the use of the automated blasting head were analyzed for trace metals (arsenic, cadmium, lead, selenium, and thallium) by NIOSH Method 7300 [11] These samples were digested and analyzed according to the method However, each sample was diluted to a final volume of 25 mL rather than 10mL, because of the probability that there would not be enough sample to perform the trace analysis

Four bulk samples were collected during this site visit one from the deck of the NLO cabin after cleaning using a PVBS hand-held tool (blasting grit and paint particles), one from the waste hopper of the PVBS trailer, a sample of settled dust (mostly paint chips) from the top of the welding box on the pier beneath the area of the ship that was depainted, and one (paint chips and blasting grit) from inside the lip of the automated blasting tool

The bulk sample of paint chips collected from the top of the welding box was analyzed for lead using flame atomic absorption spectrophotometry The limit of detection of this method was

0 004% by weight The limit of quantitation was 0 01% by weight The remaining bulk samples were analyzed for metals according to NIOSH Method 7300 [11]

RESULTS

Air Samples

No arsenic, cadmium, lead, selenium or thallium were detected on any of the air samples collected during the operation of the automated blasting tool The limits of detection for these samples ranged from 0 01 μg/filter for cadmium to 0 08μg/filter for lead For a maximum sample volume of 88 L for this set of samples, the minimum detectable concentrations ranged from 0 11 $\mu g/m^3$ for cadmium to 0 91 $\mu g/m^3$ for lead The minimum quantifiable concentrations ranged from 0 23 $\mu g/m^3$ to 3 4 $\mu g/m^3$, based upon a maximum sample volume of 88 L, and limits of quantitation which ranged from 0 02 μg/filter for cadmium to 0 3 μg/filter for lead Total particulate analyses of these samples also produced results less than the limit of detection (0 02 mg)

The results of the elemental analyses of air samples collected during the use of the hand-held tool are provided in Table 3 Analyses of these samples for total particulate revealed results that were less than the 0 02 mg limit of detection for this method The results in Table 3 were calculated based upon the actual time the workers used the PVBS hand-held tool These results can be compared against the relevant occupational exposure criteria if one asssumes that exposures would have remained constant during the remaining seven hours of the work day This may have some predictive value for similar operations during future projects The results in Table 4 were calculated assuming that no further exposure occurred during the remainder of the day, which was in fact what happened None of the exposures exceeded their applicable occupational exposure criteria

Bulk Samples

Analysis of the bulk sample of paint chips revealed that the paint removed from the superstructure during the demonstration contained 0 03% lead by weight Results of the analyses of the remaining bulk samples are provided in Table 5 These results indicate that the separation process effectively concentrated the lead waste in the waste hopper However, without samples of both unused and recycled shot, the remaining results are difficult to interpret

Discussion and Conclusion

Observations and air sampling data indicate that the PVBS automated blasting tool effectively removed and contained lead-based paint during the demonstration on the *Quest* While the NIOSH researchers observed some paint chips escaping from the ship-to-tool seal, either their particle size, prevailing winds, or other conditions prevented them from reaching the breathing zones of the tool's operators Following this demonstration, both the tool and the seal were modified, so that this leakage may no longer be a concern It would be interesting and worthwhile to repeat this evaluation during the operation of the PVBS automated blasting tool in its current configuration over several complete work shifts during a lead-based paint removal project

It would also be worthwhile to confirm the effectiveness of the waste separation and concentration process during shot recycling Multiple homogeneous samples of fresh shot, recycled shot, waste material, and the coating/substrate matrix would have to be obtained and analyzed in order to have confidence in the results of that analysis Preliminary data collected during this brief study indicated that the system removes and concentrates lead from the spent shot during the recycling process and deposits the lead in the waste hopper

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Table 1 Eight-Hour Time-Weighted Average Occupational Exposure Limits for Selected Metals
Marystown Shipyard
Marystown, NF, Canada
9/16/97
(in µg/m³)

	NIOSH REL	ACGIH® TLV®
Al	50000	10000
As	2C	10, A1
Ba	none	500, A4
Be	0 5 Ca	2, A1
Cd	Ca	10, A2
Co	50	20, A3
Cr	500	500, A4
Cu	100	1000
Fe_2O_3 (as Fe)	5000	5000, A4
MgO	none	10000
Mn	1000, 3000 ST	200
Mo	none	10000
Ni	Ca 15	1000
Pb	100	50, A3
Pt	1000	1000
Se	200	200
Ag	10	100
Te	100	100
Tl	100	100
TiO_2	Ca	10000
V_2O_5	50C	50, A4
Y	1000	1000
ZnO	5000, 10000 ST	10000
Zr	5000, 10000 ST	5000, 10000 ST, A4

Notes to Table 1

C means a ceiling limit, a value which is not to be exceeded at any time during the work day

Ca means that the substance is considered a potential occupational carcinogen by NIOSH, in accordance with the OSHA classification outlined in 29 CFR 1990 103, and that occupational exposures should be limited to the lowest feasible concentration

ST denotes a short term exposure limit

A1 indicates that ACGIH has classified this substance as a confirmed human carcinogen

A2 indicates that ACGIH has classified this substance as a suspected human carcinogen

A3 indicates that ACGIH has classified this substance as an animal carcinogen, but available evidence suggests that the substance is not likely to cause cancer in humans except under uncommon or unlikely routes or levels of exposure

A4 indicates that ACGIH has determined that this substance is not classifiable as a human carcinogen there are inadequate data on which to make a classification in terms of its carcinogenicity in humans and or animals

Table 2 Analytical Limits for Metal Samples Collected During
Use of PVBS Hand-Held Tools Inside NLO Cabin
Aboard *Quest*, Marystown Shipyard
Marystown, NF, Canada
9/16/97
(µg/filter)

	LOD	LOQ
Al	0 4	1
As	0 9	3
Ba	0 02	0 07
Be	0 004	0 01
Ca	0 9	3
Cd	0 03	0 1
Co	0 05	0 2
Cr	0 2	0 7
Cu	0 03	0 1
Li	0 009	0 03
Fe	0 3	1
Mg	0 2	0 7
Mn	0 004	0 01
Mo	0 1	0 3
Na	0 8	3
Ni	0 2	0 4
Pb	0 2	0 7
P	0 5	2
Pt	0 9	3
Se	0 5	2
Ag	0 03	0 1
Te	0 3	1
Tl	0 9	3
Ti	0 05	0 2
V	0 03	0 1
Y	0 005	0 02
Zn	0.2	0 7
Zr	0 03	0 1

LOD means limit of detection
LOQ means limit of quantitation

Table 3 Metal Exposures During Use of PVBS Hand-Held Tools Inside NLO Cabin
Aboard *Quest*, Marystown Shipyard
Marystown, NF, Canada
9/16/97
(micrograms [μg]/cubic meter[m^3])

	Laborer	Area Sample	Laborer
Volume Sample (liters)	132	130	136
Al	ND	ND	ND
As	ND	ND	ND
Ba	0 55	ND	trace
Be	0 60	trace	ND
Cd	trace	ND	ND
Co	1 8	ND	ND
Cr	ND	ND	ND
Cu	trace	ND	trace
Fe_2O_3 (as Fe)	15	ND	25
MgO	trace	trace	ND
Mn	0 21	ND	0 26
Mo	ND	ND	ND
Ni	ND	ND	ND
Pb	ND	ND	ND
Pt	ND	ND	trace
Se	ND	ND	ND
Ag	trace	ND	ND
Te	ND	ND	ND
Tl	ND	ND	ND
TiO_2	trace	ND	trace
V_2O_5	ND	trace	ND
Y	ND	ND	ND
ZnO	53	8 6	55
Zr	ND	ND	ND

ND means a value below the limit of detection
trace means a value between the limit of detection and the limit of quantitation

Table 4 Eight-Hour Time-Weighted Average Metal Exposures During Use of PVBS Hand-Held Tools Inside NLO Cabin Aboard *Quest*, Marystown Shipyard
Marystown, NF, Canada
9/16/97

($\mu g/m^3$)

	Laborer	Area Sample	Laborer
Sample Duration (minutes)	66	65	68
Al	ND	ND	ND
As	ND	ND	ND
Ba	0 076	ND	trace
Be	0 083	trace	ND
Cd	trace	ND	ND
Co	0 25	ND	ND
Cr	ND	ND	ND
Cu	trace	ND	trace
Fe_2O_3 (as Fe)	2 1	ND	3 5
MgO	trace	trace	ND
Mn	0 029	ND	0 037
Mo	ND	ND	ND
Ni	ND	ND	ND
Pb	ND	ND	ND
Pt	ND	ND	trace
Se	ND	ND	ND
Ag	trace	ND	ND
Te	ND	ND	ND
Tl	ND	ND	ND
TiO_2	trace	ND	trace
V_2O_5	ND	trace	ND
Y	ND	ND	ND
ZnO	7 3	1 2	7 8
Zr	ND	ND	ND

ND means a value below the limit of detection
trace means a value between the limit of detection and the limit of quantitation

Table 5 Results of Bulk Sample Analyses
Marystown Shipyard, Marystown, NF, Canada - 9/16/97

Analyte	Bulk Sample Results (microgram/gram)		
	NLO Cabin	Blasting Tool	Waste Hopper
Aluminum	380	350	4700
Arsenic	54	68	50
Barium	13	51	7400
Beryllium	3 0	3 9	2 1
Calcium	180	trace	6400
Cadmium	30	32	24
Chromium	1500	1700	800
Cobalt	48	51	70
Copper	1200	1300	940
Iron	850000	860000	390000
Lithium	ND	ND	6 6
Magnesium	110	94	10000
Manganese	8000	8700	4200
Molybdenum	330	340	120
Nickel	740	770	350
Lead	49	48	2000
Phosphorus	370	390	420
Platinum	2800	3100	1200
Selenium	ND	ND	ND
Silver	ND	ND	ND
Sodium	330	ND	2200
Tellurium	80	73	34
Thallium	ND	ND	ND
Titanium	34	16	240
Vanadium	98	95	44
Yttrium	trace	ND	1 5
Zinc	1900	820	38000
Zirconium	ND	ND	5 9

ND means a result less than the limit of detection Trace means a result between the limit of detection and the limit of quantitation