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HETA 97-0260-2716
Avondale Shipyards
New Orleans, Louisiana

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PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Max Kiefer and Doug Trout of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS), and Marjorie E. Wallace of the Engineering and Control Technology Branch, Division of Physical Sciences and Engineering. Field assistance was provided by Dave Sylvain, Janie Gittleman, and Sue Ting. Analytical support was provided by DPSE/ACS. Desktop publishing was performed by Pat Lovell and Nichole Herbert. Review and preparation for printing was performed by Penny Arthur.

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For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Health Hazard Evaluation Report 97-0260-2716
Avondale Shipyards
Avondale, Louisiana
November 1998

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Doug Trout
Marjorie E. Wallace

SUMMARY

On July 9, 1997, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Machinist Union, New Orleans Metal Trades Council, for a health hazard evaluation (HHE) at the Avondale Shipyards facility in Avondale, Louisiana. The request indicated that some shipyard employees have experienced health problems possibly associated with workplace exposures. Potential exposures listed on the request were dust from sandblasting, welding fumes, contaminants from burning paint, and various solvents associated with fiberglass work. Reported health effects included breathing problems and nose bleeding.

On August 27, 1997, NIOSH investigators conducted an initial site visit at the Avondale Shipyard to review the processes and work practices in a large fabrication building referred to as the Factory and the abrasive blasting building (Shot House). Company environmental monitoring data, the Avondale medical surveillance program for personnel in the arsenic and lead program, and company accident logs were reviewed. On October 22, 1997, personal breathing zone (PBZ) air sampling was conducted during the day shift to assess worker exposure to welding fume in the factory. Bulk samples of both new and recycled grit used in the Shot House were collected to determine metal composition. During the night shift on October 22 and 23, PBZ samples were collected in the Shot House to evaluate worker exposure to contaminants generated during abrasive blasting of ship parts.

Only passive general ventilation had been installed in the Factory. The highest measured welding fume particulate concentration (55 milligrams per cubic meter [mg/m^3]) was from a worker welding in a confined area (inside an Inner Bottom Unit) for approximately 1.5 hours. NIOSH recommends controlling exposure to welding fume to the lowest feasible concentration and meeting the exposure limit for each welding fume constituent. The other four time-weighted average (TWA) welding fume particulate concentrations ranged from 3.15 mg/m^3 to 19.1 mg/m^3. Measured lead concentrations in the Factory ranged from 0.003 mg/m^3 to 0.010 mg/m^3 and were all below the Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) of 0.05 mg/m^3. Arsenic was not detected in any of the samples collected in the Factory.

All workers evaluated in the Shot House wore supplied-air abrasive blasting respirators equipped with a vortex tube for cooling. The Shot House decontamination trailer had a sound design and, if used properly, should help reduce the potential for workers to "take home" contaminants such as lead. All measured exposures to iron and manganese outside the workers' abrasive blast hoods in the Shot House exceeded the NIOSH recommended exposure limit (REL) (5.0 mg/m^3 for iron, 1.0 mg/m^3 for manganese). Except for one measurement that was between the analytical limit of detection (LOD) and the limit of quantification (LOQ), all metal concentrations from samples collected inside the abrasive blast hood were below NIOSH RELs. Assessment of respirator

performance in the Shot House found that the abrasive blast hoods were performing well. The company's biological monitoring of workers in the Shot House includes measurement of total urinary arsenic; this alone is not an adequate method of assessing workplace arsenic exposure as it does not exclude non-toxic organic arsenic compounds found in seafood.

Air samples collected outside the abrasive blast hood in the Shot House contain large inertia-driven (rebound) abrasive grit particles. In samples collected during this evaluation, the large particles contributed over 95% of the total particulate, iron, and manganese content. Significant levels of lead or arsenic were not detected in the Factory.

The limited medical component of this HHE does not allow NIOSH investigators to draw conclusions concerning the potential occupational exposures which could account for the respiratory complaints reported in the HHE request. Concentrations of air contaminants (welding fume in the Factory, total particulate and metals in the Shot House) higher than those documented in our survey and/or improper use of respiratory protection among exposed workers are factors that could potentially contribute to respiratory health effects among these workers. Welding flash burns were the most commonly recorded injury in the Factory, and there is a need to ensure that appropriate shielding is used to reduce the potential for exposure, of both workers and others in the area, to the welding arc.

Monitored exposures to welding fume components exceeded applicable guidelines in the Factory; with one exception, respiratory protection worn by Factory welders was sufficiently protective. Measured exposure during welding in a confined area, even when forced-air ventilation was provided, indicates that a higher level of respiratory protection is warranted until engineering or work practice controls are implemented. The source of lead and arsenic contamination in the Shot House is likely the steel grit used as the abrasive blasting agent. The controls in place during abrasive blasting appeared to adequately protect workers. Current sampling methodology for abrasive blasting overestimates worker exposure to lead and other contaminants because non-inhalable abrasive grit enters the filter cassette. Sampling inside the abrasive blast hood provides a more representative estimate of worker exposure. Recommendations to help control exposure to welding fume in the Factory are provided in this report.

Keywords: SIC 3731 (Ship Building and Repairing). Abrasive blasting, air sampling, lead, arsenic, welding fume, ventilation.

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INTRODUCTION

In response to a request for a health hazard evaluation (HHE) received on July 9, 1997, from the Machinist Union, New Orleans Metal Trades Council, the National Institute for Occupational Safety and Health (NIOSH) conducted an initial site visit on August 27, 1997, and a follow-up survey on October 21-23, 1997, at the Avondale Shipyards in Avondale, Louisiana. Dust from sandblasting, welding fumes, contaminants from burning paint, and various solvents associated with fiberglass work were potential exposures listed on the request. Health problems reported in the request included breathing problems and nose bleeds. An interim report describing the actions taken by NIOSH during the initial site visit, and providing preliminary findings and recommendations, was issued on September 23, 1997.

BACKGROUND

Avondale Shipyards encompasses approximately 100 acres on the west bank of the Mississippi river outside of New Orleans, Louisiana. The shipyard has been in operation for approximately 60 years and employs 6000 workers. Most work is completed on two shifts (7:00 a.m. - 3:30 p.m., 3 p.m. - 11:00 p.m.), with a "skeleton" crew working the 3rd shift (11:00 p.m. - 7:00 a.m.). The majority of the work at the shipyard entails construction of naval vessels, with a smaller component engaged in commercial vessel construction. Although some ship repair occurs, most of the work at the shipyard is new construction. The shipyard has two large floating dry docks, various production shops and assembly areas, machine shops, and engineering design centers.

Factory

The Factory is a 400,000 ft^2 facility with four production lines that add structural components to plate steel. Prior to the construction of the facility in 1995, these activities were conducted outdoors without covering. The building is equipped with large cranes and hydraulic lifts and has a ceiling height of approximately 65 ft. The northeast side of the building is connected to the plate shop, and the other sides have large open panels. Only new construction occurs in this facility, with the major activities entailing welding and ship fitting. A red or gray water-based primer is applied to some of the metal components for anti-corrosion purposes. No other painting or fiberglass work occurs in the factory. Depending on the workload, there can be from 350 to 500 workers over three shifts assigned to the factory. The welders are not at fixed locations and must frequently move about the work area. There are approximately 35 welding stations per production line. Welding operations occur in the Factory area where subsections, subassemblies, and units are constructed.

Assembly advances through four separate departments referred to as Fabrication, Web, CPSU, and Unit. At the beginning of the process flow, large steel plates are fabricated into parts for subsections. These subsections are then joined to fabricate a larger subassembly. At the final stage of the process flow, the subassemblies are combined to form large units. The units are then moved out of the Factory, inspected and blasted in the Shot House, and then transported to be joined on board the ship. The Factory produces approximately 18 units per week. As work progresses, the sections become more complex, and welding in confined areas occurs more frequently.

The primary purpose of constructing the factory was to provide shade and shelter from adverse weather conditions. Only passive ventilation was designed in the factory (ridge vent), and there are no existing provisions for local or general mechanical exhaust. According to Avondale Safety and Health department personnel, welders utilize half-mask air-purifying respirators when working in open areas. For some specific welding activities (carbon arc process) in more confined areas, or when there is no forced air ventilation, employees are required to use supplied air respirators. Reported employee concerns include the presence of a haze/smoke in the factory from a build-up of welding emissions, and inadequate lighting during the night shifts.

To address employee concerns of exposure to welding emissions, Avondale contracted for an industrial hygiene evaluation to assess general and personal exposures in the factory. The evaluation was conducted over a six-month time frame to encompass seasonal changes. This survey found that exposures to various welding-related contaminants (manganese, total particulate) exceeded permissible exposure limits during certain welding tasks in semi-confined areas. As a result of this survey, Avondale safety and health personnel have been investigating providing mechanical ventilation to reduce contaminant levels in the factory.

Shot House

After the assembled ship parts leave the factory, they are transported to the Blast and Paint building (Shot House) located on the north side of the factory. Approximately 50 employees work in this enclosed building, where abrasive blasting is conducted on the second shift to remove the primer and prepare the steel surfaces for painting. Steel shot, or grit, delivered from two blast pots on each side of the Shot House is used as the blasting agent; dry blasting is utilized (no vacuum-assisted or wet blasting). The building is equipped with forced air ventilation and a dust collection system. A blast grit recovery system utilizing floor grates and a conveyor is present, where used shot is collected and then separated in the recovery system based on size (fine and coarse reject); grit meeting the size criteria is reused. Because of the complexity of the ship parts, workers must frequently conduct abrasive blasting in confined areas.

As a result of a company industrial hygiene investigation that identified worker exposures to lead and arsenic exceeding Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs), the Shot House has been designated a regulated area as described in the OSHA comprehensive standards for lead (29 CFR 1910.1025) and arsenic (29 CFR 1910.1018). Because only new mild steel coated with water-based, "lead-free" primers undergo abrasive blasting in this facility, the presence of lead and arsenic was an unexpected finding and the source had not been determined. Analysis of welding fume during the process step prior to abrasive blasting (Factory Assembly) by Avondale did not identify the presence of lead or arsenic. Personnel assigned to, or who may have a need to work in this facility, participate in the lead and arsenic program. This program includes exposure assessment (air sampling, biological monitoring), training, personal protective equipment (PPE), etc. A decontamination trailer (lockers, showers, "clean" and "dirty" side) has been installed adjacent to the Shot House, and each worker is provided two sets of clothing per day. Work clothing is laundered by a contractor.

METHODS

General

Upon receipt of the HHE request, additional information regarding the reported health problems and suspect environmental contaminants was obtained from the requestor. Specific areas of concern identified by the HHE requestor were the Factory and the abrasive blasting operation. Discussions were held with Avondale safety and health personnel to obtain process and job descriptions for operations in these areas. During these discussions, Avondale representatives indicated that additional ventilation controls and evaluation techniques were being considered for certain activities involving the lead program.

Initial Site Visit

On August 27, 1997, NIOSH conducted an initial site visit at the Avondale Shipyards facility. The purposes of this site visit were to identify areas where a NIOSH evaluation would be productive and to define the scope of any future activities. To accomplish this objective, efforts were focused on the following:

- Company lead and arsenic program (medical surveillance, environmental monitoring, controls)
- (OSHA) Log and Summary of Occupational Injuries and Illnesses (Form 200) for 1997
- Activities involving welding/torch cutting in the Factory
- Abrasive blasting activities and procedures

During this site visit, a walkthrough inspection was conducted of the Factory, the Shot House, and the decontamination facilities for personnel in the lead and arsenic program. Avondale representatives provided an overview of the shipyard industrial hygiene and safety program and a copy of a report from a recent (March 1995) comprehensive safety and health program evaluation prepared by the OSHA Director of Maritime Standards.

Follow-up Site Visit

On October 21-23, 1997, NIOSH investigators conducted a follow-up site visit at the Avondale facility. During this site visit, personal breathing zone (PBZ) air samples were collected to evaluate worker exposure to welding fume in the factory and contaminants generated during abrasive blasting operations in the Shot House. A detailed review of welding activities was conducted to better understand the welding tasks in the factory and to allow NIOSH to offer specific ventilation or work practice controls recommendations. PPE practices were also reviewed during this survey. Bulk samples of both new and used abrasive blasting grit were obtained for metal analysis. The biologic monitoring results for employees participating in Avondale's lead and arsenic exposure programs for the period 1995 to the present were reviewed. Along with the biologic monitoring data, Avondale also provided environmental sampling results for arsenic and lead performed in the Shot House.

Welding Fume

Full-shift welding fume exposures were measured on five welders during the first shift (7:00 a.m. - 3:30 p.m.) on October 22. To prevent overloading, sample filter cassettes were replaced with new ones during the lunch period. The morning sampling period ran from 7:00 a.m. - 12:00 p.m., and the afternoon sampling period was from 12:30 p.m. - 3:30 p.m.. Two of the welders sampled worked on the same unit in the Unit Department, one welder worked along Platen 20 in the CPSU Department, and one welder worked along Platen 40. A fifth welder was sampled for part of the afternoon while he worked in a confined space (Inner Bottom) inside one of the units.

Abrasive Blasting

PBZ air samples were collected from 11 abrasive blasters during the second shift on October 22 and 23 in the Shot House. For each abrasive blaster monitored, air samples were collected both inside and outside the abrasive blasting hood. Additionally, each abrasive blaster wore a "passive" monitor to determine the extent of rebound, or inertia-driven, shot that entered the sampling cassette. The sample collected outside the abrasive blaster's hood, and the passive sample, were further analyzed by removing the larger size particulate fraction (loose bulk) from the filter cassette and analyzing this portion separately. This monitoring strategy was employed to help determine the extent to which large (believed to be non-inhalable) particles of blasting materials affect the sampling results.

All PBZ samples (both welding and abrasive blasting) were analyzed gravimetrically to determine the total particulate concentration, and chemically, to determine the concentration of the following metals: lead, arsenic, iron, manganese, copper, and chromium.

Bulk Samples

Eight bulk samples of new and recycled shot were collected in duplicate from the Shot House for metal analysis to help determine the source of lead and arsenic previously detected in air samples collected by Avondale. Steel grit samples were collected from both grit pots (north and south side) servicing the Shot House, from the coarse and fine reject collectors, and from inside the Shot House floor. All air samples were placed on hold until the bulk sampling results became available, to ensure that appropriate elemental analysis was conducted.

The analytical methodology used for the air and bulk samples is described in Appendix A.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation 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 environmental 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 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 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.

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.

Welding Hazards

The effect of welding fumes on an individual's health can vary depending on such factors as the length and intensity of the exposure and the specific metals involved. The content of welding fumes depends on the base metal being welded, the welding process and parameters (such as voltage and amperage), the composition of the consumable welding electrode or wire, the shielding gas, and any surface coatings or contaminants on the base metal. It has been suggested that as much as 95% of the welding fume actually originates from the melting of the electrode or wire.[4] The flux coating (or core) of the electrode/wire may contain up to 30 organic and inorganic compounds. The primary purpose of the flux is to release a shielding gas to insulate the weld puddle from air, thereby protecting against oxidation.[5] The size of welding fume particulate is highly variable and ranges in diameter from less than 1-micrometer (µm) (not visible) to 50-µm (seen as smoke).[6]

In general, welding fume constituents may include minerals, such as silica and fluorides, and metals, such as arsenic, beryllium, cadmium, chromium, cobalt, nickel, copper, iron, lead, magnesium, manganese, molybdenum, tin, vanadium, and zinc.[6,7,8] Low-carbon steel, or mild steel, is distinguished from other steels by a carbon content of less than 0.30%. This type of steel consists mainly of iron, carbon, and manganese, but may also contain phosphorus, sulphur, and silicon. Most toxic metals, such as nickel and chromium which are present in stainless steel, are not present in low carbon steel.

A PEL for total welding fumes has not been established by OSHA; however, PELs have been set for individual welding fume constituents (e.g., iron, manganese), and the PEL for total particulates not otherwise regulated is 15 milligrams per cubic meter (mg/m^3) as an 8-hour TWA.[9] The ACGIH has established a TLV of 5 mg/m^3 TWA for welding fumes. The ACGIH suggests that "conclusions based on total fume concentration are generally adequate if no toxic elements are present in the welding rod, metal, or metal coating and if conditions are not conducive to the formation of toxic gases."[2] The ACGIH also recommends that arc welding fumes be tested frequently to determine whether exposure levels are exceeded for individual constituents.[2] NIOSH has concluded that it is not possible to establish an exposure limit for total welding emissions since the composition of welding fumes and gases vary greatly, and the welding constituents may interact to produce adverse health effects. Therefore, NIOSH recommends controlling total welding fume to the lowest feasible concentration (LFC) and meeting the exposure limit for each welding fume constituent.[10] The potential health effects and NIOSH RELs for the metals measured in the environmental samples during this survey are shown in the following table. Evaluation criteria for lead and arsenic are presented separately.

Element	NIOSH REL (mg/m^3)	Principle Health Effects[11]
Chromium	0.5*	skin and mucous membrane irritation, possible lung cancer
Iron	5	benign pneumoconiosis (siderosis)
Manganese	1 TWA 3 STEL	central nervous system effects, pneumonitis, headaches
Copper	0.1 (fume) 1 (dust/mist)	upper respiratory irritation, metal fume fever

* = Chromium can occur in various oxidation states. Certain hexavalent chromium compounds (chromic acid and chromates) have been shown to be carcinogenic. NIOSH recommends controlling exposure to the LFC for these compounds. Hexavalent chromium compounds have been detected in stainless steel welding processes.[7]

In addition to welding particulate (known as fume), many other potential health hazards exist for welders. Welding operations can produce gaseous emissions such as ozone, carbon monoxide, nitrogen dioxide, and phosgene (formed from chlorinated solvent decomposition).[6,7,8] Welders can also be exposed to hazardous levels of ultraviolet light from the welding arc if welding screens or other precautions are not used. Ergonomic problems are also a consideration due to various contorted positions welders assume for some welding tasks.

A detailed review of control options for reducing exposure to welding fume is provided in Appendix B.

Abrasive Blasting

Abrasive blasting entails using pneumatic or hydraulic pressure or centrifugal force to direct a blast of abrasive material (wet or dry) against a surface to clean, remove burrs, or develop a surface finish. Abrasive blasting is used in a variety of industries, and there are a wide variety of blasting techniques, involving both handheld or automatic equipment.[12] A large number of metallic and non-metallic abrasives are commonly used. Because large quantities of dust are generated, abrasive blasting is usually conducted in exhausted enclosures, often equipped with air pollution control devices and abrasive recycling systems. In the United States, the use of sand containing high concentrations of free silica as an abrasive blasting agent continues to present a major hazard to workers.[12,13] Workers conducting abrasive blasting are exposed to both safety (rebound shot, high pressure, etc.) and health (high levels of dust from abrasives and material being blasted) hazards, and a number of precautions are necessary to ensure adequate protection. OSHA has established regulatory requirements for ventilation, enclosures, and PPE during abrasive blasting. Airline respirators specifically designed for abrasive blasting (Type “CE” supplied-air) are required for work inside of blast-cleaning rooms. These respirators are of rugged construction and equipped with coverings to provide head, neck and upper body protection from rebounding abrasive blasting material.[14]

Assessing exposure during abrasive blasting for compliance purposes requires collecting the sample outside the abrasive blast hood. These efforts to monitor worker exposure during abrasive blasting within enclosures often result in measuring concentrations far exceeding recommended limits.[15] This is because of the high dust concentrations generated in an abrasive blasting environment and the potential for rebound shot to affect the sampling results. The larger rebound shot enters the sampling cassette and, even though it is not “inhalable,” contributes, disproportionately, to the measured PBZ exposure.

Arsenic

Arsenic is a naturally occurring element which can form a variety of inorganic and organic compounds, which have different toxicities. Various arsenic compounds are also found in some foods (e.g., certain marine species may contain very high concentrations of non-toxic organic arsenic).[11,16,17] Most (68%) industrial use for arsenic is for pesticides (wood preservatives primarily). Other uses include agricultural chemicals (23%), glass (4%) and non-ferrous alloy (3%) manufacturing.[19] Arsenic is found in most fossil fuels and in cigarette smoke. The natural arsenic content of soil varies between 0.1 and 80 parts per million, (ppm).[17] In general, soluble inorganic arsenic compounds (arsenic combined with oxygen, chlorine, or sulfur) are considered to be the principal toxic species. Conversely, most organic arsenic compounds have relatively low toxicity.[17,18]

Inorganic arsenic compounds may cause adverse health effects following exposure via inhalation, ingestion, or dermal contact. Acute exposure to inorganic arsenic can cause nausea, vomiting, diarrhea, weakness, loss of appetite, cough, and headache. Chronic exposure can result in weakness, nausea, vomiting, skin and eye irritation, hyperpigmentation, dermatitis, and numbness and weakness in the legs and feet.[11] Peripheral vascular disease ("Blackfoot disease") has been reported to occur in association with chronic arsenic exposure from contaminated drinking water and among wine makers exposed to arsenical pesticides.[17]

There is clear evidence that chronic oral exposure to elevated levels of arsenic increases the risk of skin cancer. Inhalation of certain arsenic compounds can also result in lung cancer.[17,18] NIOSH considers arsenic a potential occupational carcinogen, recommends controlling occupational exposures to the lowest feasible concentration, and has established an REL of 2 micrograms per cubic meter ($\mu g/m^3$) as a 15-minute ceiling limit.[1]

The OSHA arsenic standard (29 CFR 1910.1018) requires a medical surveillance program for workers exposed to arsenic in the workplace. In 1996, OSHA issued a memorandum stating that sputum cytology (part of the OSHA medical surveillance program) is not appropriate in the surveillance of arsenic-exposed workers and that worksites not performing sputum cytology would not be issued citations (Memorandum from OSHA Directorate of Compliance Programs, August 1996).

Determination of urinary arsenic is not included in the standard, although biologic monitoring for arsenic is available as a means of assessing exposure to arsenic compounds. Analysis for total arsenic may be heavily influenced by organic arsenic compounds found in seafood.[11] Biologic monitoring for occupational exposure to arsenic is best conducted by analyzing inorganic arsenic and its metabolites, monomethylarsonic acid and cacodylic acid, as these compounds represent only inorganic arsenic exposure.

Detection of arsenic in urine is an indication of a recent exposure only (within a few days); arsenic is rapidly excreted in urine and has a biological half-life of only one or two days. Normal values of total arsenic in urine vary from 13 to 46 µg/L.[19] The ACGIH biological exposure index (BEI) for occupational exposure to arsenic (including inorganic arsenic and methylated metabolites) is 50 micrograms per gram creatinine (ug/g creat) in urine samples taken at the end of a workweek.[2]

Lead

Lead is a bluish-gray heavy metal with no characteristic taste or smell and is ubiquitous in U.S. urban environments due to the widespread use of lead compounds in industry, gasoline, and paints during the past century. 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.

Lead can enter the body by inhalation or ingestion and can adversely affect numerous body systems. Skin absorption does not occur except for certain organo-lead compounds such as tetraethyl lead. Although lead is a naturally occurring element, most exposures to lead occur from human activities.[20] Inhalation is considered to be the most important occupational exposure route. Lead is a systemic poison that serves no useful function after absorption in the body, the health consequences of which can occur after periods of exposure as short as days or as long as several years.[21] Once absorbed, lead is excreted from the body very slowly. Absorbed lead can damage the kidneys, peripheral and central nervous systems, and the blood forming organs (bone marrow).[11] These effects may be felt as weakness, tiredness, irritability, digestive disturbances, high blood pressure, kidney damage, mental deficiency, or slowed reaction times. Damage to the central nervous system in general, and the brain (encephalopathy) in particular, is one of the most severe forms of lead poisoning.[11,21] Chronic lead exposure is associated with infertility and with fetal damage in pregnant women.[11] Although the hazards of lead have been known for some time, occupational exposure to lead is still a significant problem in some industries (battery reclamation, radiator repair, construction). In 1990, the U.S. Public Health Service established a national goal to eliminate worker exposures resulting in blood lead (PbB) concentrations greater than 25 micrograms per deciliter (µg/dl).[22]

Avondale is governed by the OSHA Maritime Lead Standard (CFR 1915.1025), which is identical to the General Industry Lead Standard (CFR 1910.1025). The standard establishes a PEL for airborne lead of 50 µg/m^3, and an action level of 30 µg/m^3.[23,21] The portion of the lead standard dealing with biologic monitoring calls for employees exposed above the action level to have available to them measurement of PbB and zinc protoporphyrin (ZPP) every six months after initial testing is done. PbB levels greater than 40 micrograms (µg) per 100 grams (µg/100g [1 µg/100g = 1 µg/dl]) call for increased testing frequency, and PbB levels above 50 ug/100g call for removal from exposure until the PbB level falls below 40 µg/100g. The measurement of ZPP in the blood is used in monitoring employees as a measure of longer-term biologic effect of lead exposure.[11,2] Measurements of ZPP of greater than 50 µg/dl have been used as an indication of excess lead exposure.[11,24] However, the ZPP test is felt to be an insensitive and non-specific test for lower-level occupational exposure.[2]

A review of the correlation of airborne lead levels and PbB levels suggests there is no good way to correlate airborne lead exposures with subsequent PbB levels.[25]

RESULTS

Industrial Hygiene

According to Avondale representatives, silica has not been used as an abrasive blasting agent since 1972, and there is currently no fiberglass work at the shipyard. All fiberglass work (including the use of related chemicals acetone and styrene) was completed in May 1997, when the last of four Navy Minehunter vessels was refurbished.

Factory

Workplace Observations

All welding observed was on carbon steel; approximately 65% of the welding operations in the Factory, and 90% of the work in the Unit Department, were flux cored arc welding (FCAW). During FCAW, a consumable wire (0.052" diameter Dualshield T-1 & T-2 Flux Core, ESAB Group, Inc.) is continuously fed through a welding gun. The wire is hollow and filled with a flux core composed of various metals or minerals that promote the weld process by removing impurities and preventing oxidation. Shielding gas (carbon dioxide) is supplied at the gun tip to prevent oxidation of the base metal during the FCAW process.

The remainder of the welders in the Factory primarily use the shielded metal arc welding (SMAW or “stick welding”) process. For example, tacking of the tie-downs (or cloverleafs) onto grids in the Unit Department was done with SMAW. The SMAW technique requires the use of a hand held, flux-coated consumable electrode of a finite length to produce an arc. No shield gas is used with this process.

The ventilation system in the Factory consists of ridge vents which provide passive general ventilation (no mechanical general dilution ventilation has been installed). Portable blowers are used in the Unit Department to provide large quantities of air during some confined space welding operations. The portable ventilation units observed during this site visit consisted of collapsible duct with a blower, usually mounted on the top of the unit, that forces air into the confined area where welding is occurring.

Welders wear half-mask air purifying respirators (APR) with either high efficiency air purifying (HEPA) filters or combination organic vapor cartridges with a particulate filter, when working in open areas. According to Avondale representatives, welders are provided with supplied air respirators when conducting certain tasks (Arc Gouging) in confined areas, or when there is no forced air ventilation for confined area work. No workers wearing supplied air respirators were observed. Welders also utilized welding hoods and protective gloves. Some welding tasks require workers to stay in a fixed location for the majority of the work shift. Other welding tasks (e.g., tack welding tie-downs) required the workers to frequently move to different locations. No welding screens or shielding to prevent or reduce exposure to welding flash were in use in the Factory

An automated welding process (“tripod welder”), which was installed as an ergonomic control measure, was observed. The electrode was positioned over the area to be welded, at an angle, situated in a tripod holder. This was a semi-automatic device; as the electrode melted, gravity pulled the electrode down and the weld traveled along the work piece. After the electrode was consumed it was manually replaced with another electrode and the tripod welder was moved further down the piece.

Air Sampling Results

The results of the air samples collected from welders in the Factory are shown in Table 1. The highest measured total particulate weld fume sample (55 mg/m^3) was from a worker welding in a confined area (inside an Inner Bottom Unit) for approximately 1.5 hours. Forced air ventilation was provided during this work from a blower and collapsible duct system. This worker wore a half-mask APR with a HEPA filter while welding. The other four welding fume samples were collected over the majority of the work shift (approximately 400 minutes), and the total particulate weld fume results ranged from 3.15 mg/m^3 to 19.1 mg/m^3. Iron was the highest measured metal. The highest iron concentration detected (12.5 mg/m^3) was in the sample from the welder in the confined area. Exposures measured on the other four welders ranged from 0.98 mg/m^3 to 6.1 mg/m^3. The NIOSH REL for iron oxide fume is 5 mg/m^3. Measured lead concentrations ranged from 0.003 mg/m^3 to 0.010 mg/m^3 and were all below both the NIOSH REL (0.1 mg/m^3) and OSHA PEL (0.05 mg/m^3). Arsenic was not detected in any of the samples collected.

Shot House

All workers evaluated wore supplied-air abrasive blasting respirators (Bullard 88 Type "CE") equipped with a vortex tube for cooling. These workers also wore half-mask APR's equipped with HEPA filters as additional protection. Although the APR's were not an integral part of the blast hood, the workers monitored indicated that use of the additional respirator was a common practice during abrasive blasting. Avondale representatives indicated the supplied air system is designed to provide clean air at a delivery rate within a range of 6 cubic feet per minute (cfm) to 15 cfm. These workers also indicated the vortex tube provided considerable cooling during use and significantly reduced heat exposure.

Abrasive blasting only occurs during the second (night shift) at Avondale. A review of the decontamination trailer found the design to be sound. The trailer was equipped with a "dirty" and "clean" side, showers and lockers. Clean work clothes (two sets per day) are furnished by Avondale for employees who work in the Shot House. The decontamination trailer has a dedicated lunchroom area for workers; Avondale Safety and Health representatives indicated that periodic wipe sampling for lead is conducted to verify the area is free from contamination.

Air Sampling Results

Eleven abrasive blasters were monitored in the Shot House on successive days (October 22-23, 1998). The results of the air sampling conducted in the Shot House are shown in Tables 2 (gravimetric) and 3 (elemental). As previously described, three sample sets (inside the hood, outside the hood, "passive") were collected from each abrasive blaster, and on two of the sample sets (outside the hood, passive), that portion of the sample that was loose bulk (large grit) was separated and analyzed separately. All air samples collected outside the abrasive blast hood greatly exceeded the OSHA PEL and ACGIH TLV for total particulate and the NIOSH REL for iron for both the "small particle"* (OH-A) and "large particle" (OH-B) fraction. The small particle gravimetric air sample results ranged from 34.6 mg/m^3 (AB #6) to 64.1 mg/m^3 (AB #11). The large particle component concentrations ranged from 250.3 mg/m^3 (AB #8) to 5860.7 mg/m^3 (AB #9). Corresponding ranges of iron measured in the small particle portion of the sample were 15.2 mg/m^3 (AB #6) to 29.2 mg/m^3 (AB #5, #11), and 172.3 mg/m^3

** For purposes of discussion, the "small particle" fraction of the sample is that portion remaining on the filter after removal of large loose grit from the filter cassette prior to analysis. A more robust definition is not available as a specific size range (e.g. minimum and maximum particle diameter) for the "small particle" fraction was not determined, but was subjectively determined by the analyst. The component of the sample removed ("large particle")was primarily rebound shot and considered too large to pose an inhalation hazard.*

(AB #8) to 1926 mg/m^3 (AB #9). The NIOSH REL for iron oxide dust (as iron) is 5 mg/m^3.

The lead concentrations measured in the "outside the hood" samples ranged from 1 microgram per cubic meter (µg/m^3) to 10 µg/m^3 for the small particle component and 8 µg/m^3 to 260 µg/m^3 for the large particle portion (Figure 1). Four of the 11 arsenic samples collected outside the hood exceeded the NIOSH REL of 2 µg/m^3. These samples (large particle fraction) ranged from 30 µg/m^3 to 50 µg/m^3.

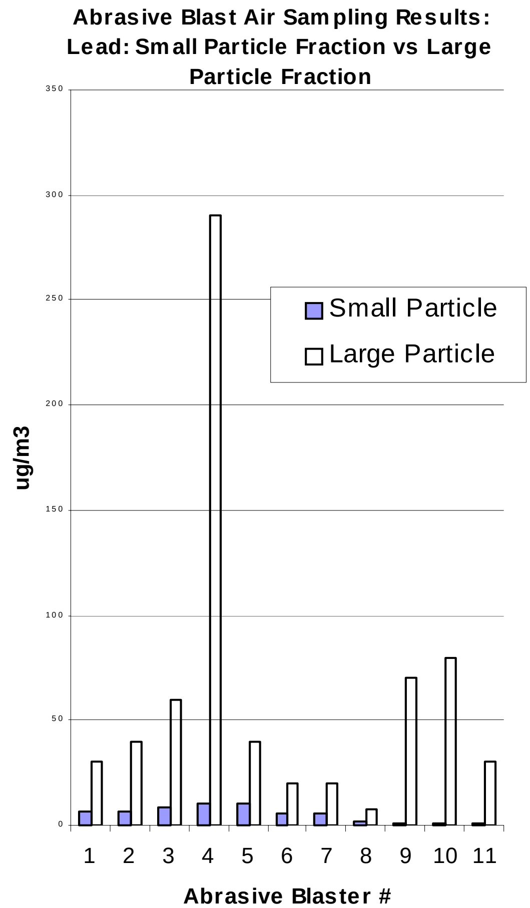

Figure 1-Outside the Blast Hood Lead Results

Several samples were between the analytical limit of detection (LOD) and the limit of quantification (LOQ), or had an LOD exceeding the NIOSH REL. The small particle component of one outside the hood arsenic sample (AB #11) showed a concentration (8 µg/m^3) that exceeded the NIOSH REL.

For the other elements measured in the "outside the hood" samples, manganese exceeded the NIOSH REL of 1.0 mg/m^3 on the large particle component of all samples, but not on any small particle fractions. For both copper (NIOSH REL = 1.0 mg/m^3) and chromium (NIOSH REL = 0.5 mg/m^3), the large particle portion of the sample exceeded the REL on 3/11 samples, but on none of the small particle portions.

The outside the hood sample results show that the large particle steel grit component of the air sample is the primary contributor to the reported total concentrations. That portion of the air sample considered to represent the small particle fraction entailed an average of only 3.5 % of the total gravimetric sampling results (Figure 2).

The "passive" samples collected outside the workers abrasive blast hood contained a highly variable but significant amount of inertia-driven (rebound) grit (Figure 3). The mass of grit detected on the "passive" samples ranged from 1.58 mg to 366.5 mg. If these weights were detected on a filter connected to an air sampling pump with an average flow rate of 2 l/m for 400 min (800 l volume), the range of concentrations would have been 2 mg/m^3 to 458 mg/m^3. This finding further substantiates the contention that there is a significant contribution of

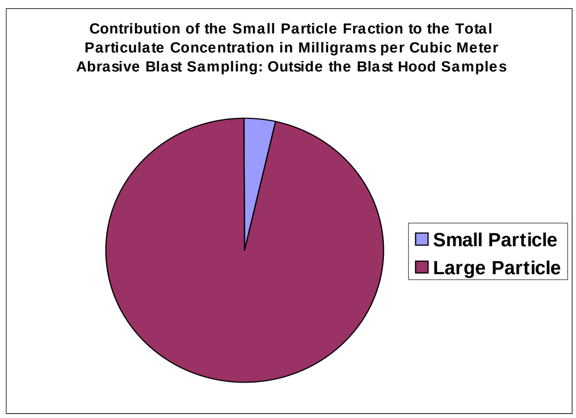

Figure 2

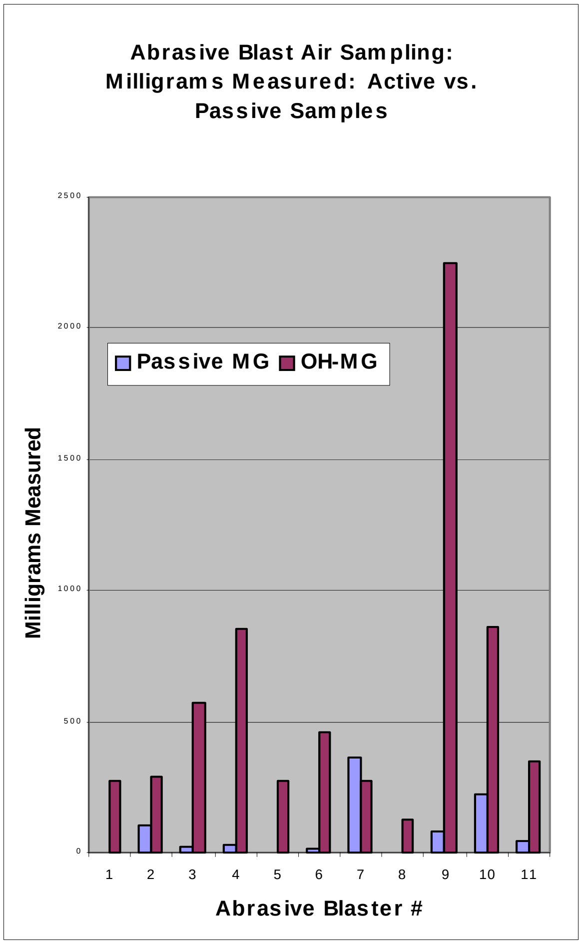

Figure 3-Outside the Blast Hood (OH-MG) versus Passive Air Samples (Passive MG)

large particle aerosol when assessing exposure to abrasive blasting and collecting the sample outside the abrasive blast hood.

All of the inside the hood air samples except arsenic were below applicable NIOSH RELs. For some of the inside the hood air samples, the analytical LOD for arsenic exceeded the NIOSH REL, thus adherence to the REL could not be demonstrated. One sample (AB #6) showed an arsenic concentration that was between the LOD and LOQ. Several of the metals measured were below the analytical LOD. These results indicate the abrasive blast hoods were being worn properly and were providing sufficient protection.

Respirator Efficacy

Because data was collected from both inside and outside the supplied air respirator worn by the abrasive blasters, the efficacy of the respiratory protection was assessed for each worker. In general, the protection that a given respirator will provide is determined by multiplying the exposure limit for the contaminant by the assigned protection factor (APF) for that specific class of respirators.[26] The APF is considered the minimum anticipated level of protection a properly functioning respirator, or class of respirators, will provide to a percentage of properly trained and fitted users.[26] The actual performance of a correctly worn respirator under workplace conditions is determined by calculating the workplace protection factor (WPF). The WPF is defined as the ratio of the estimated contaminant concentration outside the respirator to the contaminant concentration inside the respirator (when TWA samples are collected simultaneously while the respirator is properly worn during normal work activities).[26] During this survey, WPF's were calculated using the combined (small and large particle fraction) concentration for each contaminant measured to determine the effect of contaminant selection on the WPF (Figure 4). The lowest calculated WPF using the combined measured concentrations showed a respirator protection factor of 2817. WPF's for several of the workers monitored were in excess of 10,000. WPFs were also determined using that portion of the air sample considered to represent the small particle fraction. Using the smaller size particle concentration, the calculated WPFs were much lower, and ranged from 183 to 1282 for the gravimetric measurements, and 210 to 3700 for specific metal concentrations. Because some of the measured contaminants were not detected in the inside the hood air samples, no WPFs' were calculated for these components.

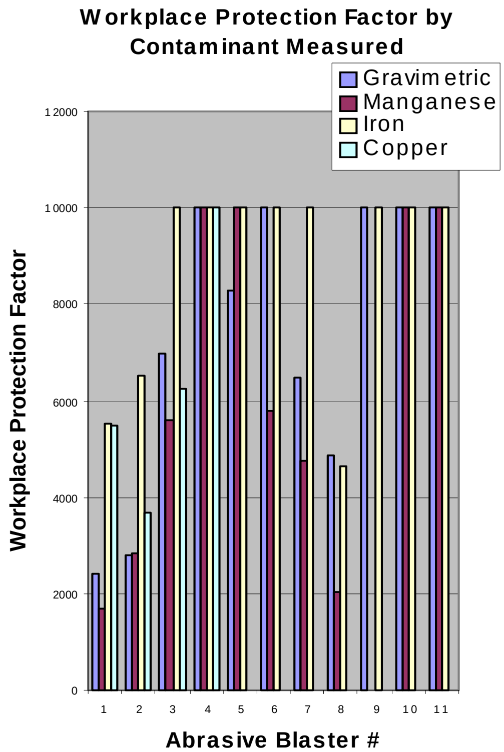

Figure 4 - Workplace Protection Factors Determined by Contaminant Measured Using the Combined (small and large particle) Concentration

Bulk Sampling Results

The results of the bulk samples are reported in Table 4. The steel grit utilized for the blasting (Metgrain G-40, Chesapeake Specialty Products) has a size range of 0.0394 to 1.0 millimeter (mm) (all pass through a #18 screen). The reject system is designed to discard all particles smaller than approximately 212 µm (pass through a #65 mesh screen). No cadmium was detected in any of the bulk samples; thus, no air samples were analyzed for this metal. The bulk samples showed elemental concentrations of lead in the range of 4.3 µg/g (or part per million) in the virgin shot to 223.4 µg/g in the fine reject sample, and arsenic in the range of 16.1 µg/g (fine reject) to 74.1 µg/g (recycle grit). Analysis did not indicate that high iron concentrations interfere with detecting low levels of lead or arsenic using inductively coupled plasma emission spectroscopy (ICAP) as described in NIOSH Manual of Analytical Methods, 4th edition, method #7300. There was some variation in results between the two laboratories as shown in the table.

Initial analysis of the bulk sample of steel plate (Steel Grade AH 36, U.S. Steel Group) from the Factory indicated a substantial lead contact (16,829 ug/gm). However, analysis of a second sample and re-analysis of the first steel plate sample did not confirm this initial finding and only low levels of lead were detected (10.8 ug/gm, 18 ug/gm, respectively). Analysis of the 2-part epoxy resin (Amercoat 3207 Cure and Resin) used as a pre-construction primer in the Factory found a low level of lead (2.9 ug/gm) in the resin, and less than detectable (<0.42 ug/gm) in the cure.

Medical

Records Review

Employees from welding-unit construction and shipfitting-unit construction in the Factory had 71 entries in the OSHA 200 log for the first eight months of 1997. Welding-flash burns made up 42 (59%) of the entries, with some of the other entries consisting of chemical irritation (13 [18%]), heat stress (6 [8%]), musculoskeletal problems (3 [4%]), and chemical inhalation (3 [4%]). Employees from the paint department and paint-unit construction who conduct painting and/or abrasive blasting in the Shot House had 33 entries in the OSHA 200 log, with 18 (55%) involving chemical irritation, 6 (18%) involving abrasion, 5 (15%) involving contusion, and the remainder made up of 1 each of “lung disease,” pleural plaques, rash, and “sand in face.”

Lead Program

At the time of the NIOSH site visit, there were approximately 70 Avondale employees participating in the lead program. The number of participants in the program was reported to vary depending on the types of work in the shipyard at any given time; employees potentially exposed to lead above the action level, as identified by the industrial hygiene department, are enrolled in the lead surveillance program. For example, during a recent refurbishing job (American Heavy Lift) involving work with lead-containing material, 235 workers were entered into the program. Some employees, such as employees in the repair department and the Shot House, are maintained in the lead program continuously.

Avondale lead air sampling results included 347 measurements of airborne lead among 73 different employees involved in abrasive blasting. The mean air lead concentration was 32.0 ug/m^3 (median - 4.3 ug/m^3; range - 0 to 1,071 ug/m^3). The biologic monitoring data included 234 measurements of PbB and ZPP among 67 different employees involved in the abrasive blasting operation. The mean PbB level was 4.4 ug/dl (median - 4.0 ug/dl; range - 0 to 18 ug/dl). The mean ZPP level was 41.4 ug/dl (median - 40.0 ug/dl; range - 22 to 72 ug/dl). Avondale reported that the PbB and ZPP determinations were performed by an OSHA-approved contract laboratory.

Arsenic

Avondale reported that all employees working in the Shot House were enrolled in the arsenic exposure surveillance program. The data from this program included measurements of total urine arsenic in employees involved in the abrasive blasting operation from January 1995 through October 1997. Ninety measurements were made among 54 different employees. The mean urine arsenic level for all tests was 41.3 micrograms per liter (ug/l) (median - 30 ug/l; range - 0 to 180.3 ug/l). There were 22 samples with a total arsenic level above the ACGIH BEI (which excludes organic arsenic of marine origin) of 50 ug/g creatinine. Avondale reported at the time of the review that elevated arsenic levels were followed-up with additional medical testing. As part of the arsenic surveillance program, Avondale has been collecting sputum samples as required by the original OSHA standard; none were found to be positive for malignancy.

DISCUSSION

Welding activities in the Factory result in substantial exposure to welding fume, and continued adherence to the proper use of respiratory protection is necessary until effective engineering or administrative controls can be implemented. With one exception, the use of respirators in the Factory appeared to be adequately protecting workers. One welder working in a confined area (Inner Bottom) for approximately 100 minutes had a measured exposure of 55 mg/m^3, despite the use of forced air ventilation. This measured concentration and observation of the work practices suggest a higher degree (supplied air) of respiratory protection is needed for this activity. A half-mask air purifying respirator has an assigned protection factor of 10, indicating that, if properly worn, the device would provide protection in a contaminant concentration up to 10 times the applicable limit. As the ACGIH TLV for welding fume is 5 mg/m^3, the measured concentration (albeit not a full-shift TWA measurement) during confined area welding exceeded this criterion by more than 10 times. No other constituents of the weld plume (gases such as carbon monoxide, fluorides, etc.) were measured during this survey, but it is likely that these contaminants are also generated during the welding process.

The limited medical component of this HHE does not allow NIOSH investigators to draw conclusions concerning the potential occupational exposures which could account for the respiratory complaints reported in the HHE request. Concentrations of air contaminants (welding fume in the Factory, total particulate and metals in the Shot House) higher than those documented in our survey and/or improper use of respiratory protection among exposed workers are factors that could potentially contribute to respiratory health effects among these workers. Welding flash burns were the most commonly recorded injury in the Factory, and there is a need to ensure that appropriate shielding is used to reduce the potential for exposure, of both workers and others in the area, to the welding arc.

Because of the size of the Factory and the mobility of the welders, ensuring an effective ventilation system to reduce welding fume exposures presents a difficult and complex design issue. Avondale has been considering providing general dilution ventilation (GDV) or local exhaust ventilation (LEV). While GDV may result in some reduction in the visible haze and overall contaminant levels, it would likely have little impact in reducing exposures for welders. The benefit of LEV is efficiency by contaminant capture at the point of generation. LEV, alone or in conjunction with GDV, would provide superior protection to the welder as compared to just a general exhaust system for the facility. Implementation of effective LEV systems as a control option is complicated by the large number of mobile welders in the Factory. Additional information on ventilation as a welding fume control is provided in Appendix B.

Although measured exposures outside the abrasive blast hoods on all workers in the Shot House exceeded NIOSH RELs, all but one of the samples collected inside the workers' blast hoods indicate that these devices are being used properly and are sufficiently protective. One sample for arsenic showed an inside-the-hood concentration that was between the analytical LOD and LOQ. Additional protection is afforded by the work practice of wearing a half-mask APR with HEPA filter to augment the blast hood. All PbB levels were < 20 ug/dl. The company's biological monitoring and air sampling data, as well as the NIOSH air sampling data, indicate that the Shot House safety and health program is effective in protecting against overexposure to lead.

The source of the lead detected in the Shot House does not appear to be materials from the Factory. The airborne lead is likely due to the small amounts present in the steel grit. From the limited number of samples collected, it appears that the lead content of the small fine component of the abrasive grit is higher than in the new, or larger-size, grit. One possible explanation for this finding is that during use, finer lead dust particles are continuously generated from the fracturing of grit during blasting, and then recirculated through the system, resulting in a build-up of lead in the recycle stream.

PBZ arsenic concentrations outside the blast hood exceeded the NIOSH REL of 2 $\mu g/m^3$, indicating that the potential for arsenic exposure does exist during blasting operations in the Shot House. As with lead, the arsenic appears to come from the steel grit, and the levels vary with the type of grit. The total urinary arsenic concentrations, determined as part of the medical surveillance program for arsenic, cannot be effectively used to monitor occupational exposure unless seafood has not been consumed for 2-3 days prior to the testing. Preferably, the urine should be analyzed specifically for inorganic arsenic and its metabolites.[27]

Current sampling and analytical methodology for evaluating exposure during abrasive blasting entail collecting a particulate air sample outside the abrasive blast hood. Air samples collected during this HHE support the contention that these methods do not accurately represent worker exposure to inhalable lead and other elements during abrasive blasting in confined spaces. This is because large abrasive blasting grit particles enter the sampling cassette inlet from inertia (high velocity rebound) rather than through the action of the sampling pump, where an airborne contaminant is collected in an air sample of known volume. In the absence of guidelines for the analysis of samples containing large, non-inhalable particles, all dust and grit on the sample filter is digested, analyzed, and the total amount of the selected airborne contaminant (e.g., lead), is reported. Including these large, non-inhalable particles in the analysis may thus overestimate the concentration of inhalable lead (or other metals).

This evaluation is consistent with a previous NIOSH evaluation of a shipyard abrasive blasting operation that found abrasive blaster exposures to lead in excess of OSHA PELs despite the presence of only low levels in the base metal, surface coatings, and steel grit.[28] Bulk samples collected during that study found that the grit contributed the greatest amount of lead and other metals. Standard sampling methods used to assess exposure resulted in large, non-inhalable particles entering the monitoring cassette due to high initial velocity. Even the relatively small amount of lead in grit (approximately 100 micrograms per gram grit) resulted in a significant contribution to the lead in the samples; primarily from the random entrapment of large grit particles in the filter cassettes. Other sampling methods assessed in that study included placing the sampling cassette behind the worker, use of a metal shield to guard the cassette inlet, and the use of a standard nylon cyclone. Sample placement and the use of the shield did not reliably prevent large grit particles from entering the cassette, and cyclones were not useful because they frequently became inverted as the blaster worked in confined areas.[28] Even if they did perform effectively in this environment, cyclones would not be an appropriate measurement choice because they exclude all but the respirable fraction. The investigators concluded that conventional sampling and analytical techniques result in an overestimation of worker exposures to lead and other contaminants present in abrasive blasting environments.

This issue is of considerable importance from a regulatory standpoint, as administrative and engineering controls prescribed by the OSHA lead standard are triggered by full-shift personal lead exposures in excess of the action level outside the blasting hood.

Determination of respirator efficiency by calculating the WPF indicated that the abrasive blast hoods were performing well. There was considerable variability in the WPF depending on which contaminant was selected for the calculation or when the small particle fraction alone was used in the calculation. For some of the measured contaminants, analytical variability associated with the low concentrations detected may have influenced these results. A previous study that evaluated the performance of abrasive blast hoods during the use of silica in a sand blasting booth found an average WPF of 16,800 (geometric mean).[29]

CONCLUSIONS

Monitored exposures to welding fume components exceeded applicable guidelines in the Factory. However, except for one of the workers, the respiratory protection worn by Factory welders was sufficiently protective. Despite the use of forced air ventilation during welding in confined areas, one PBZ sample exceeded 50 mg/m^3, thus warranting a higher level of respiratory protection than is currently used for that activity until engineering or work practice controls are implemented. Observations of work practices in the Factory suggest that the most likely choices for local exhaust ventilation systems are movable hoods and fume extraction guns.

Measured exposures to iron, manganese, and other metals collected outside the workers abrasive blast hood in the Shot House exceeded NIOSH RELs; all measured exposures collected inside the abrasive blast hood were below NIOSH RELs, or had a reported limit of detection that was greater than the REL. The source of lead and arsenic contamination in the Shot House is likely the steel grit used as the abrasive blasting agent. Significant levels of lead or arsenic were not detected in the Factory. The safety and health program in the Shot House, and the controls in place (PPE, administrative, engineering) during abrasive blasting appear to be effectively preventing worker exposure to lead and other contaminants during abrasive blasting operations. However, the biologic monitoring program for arsenic currently uses measurement of urinary total arsenic; these values cannot be interpreted without taking into account dietary organic sources of arsenic. Evaluation of the abrasive blast hood performance found that there is a wide variability in the calculated workplace protection factor depending on the contaminant selected.

Current sampling and analytical methods do not accurately represent employee exposure to lead or other contaminants during abrasive blasting. Measurement methods that more accurately estimate the true exposure during abrasive blasting operations are needed. There are no methods currently available to reliably collect a representative sample outside the abrasive blast hood. As such, it appears that collecting a sample inside the abrasive blast hood is more representative of the workers' exposure and avoids the significant confounding factor of large, non-inhalable materials. Air sampling results obtained outside the abrasive blast hood may trigger OSHA regulatory requirements for engineering controls, respiratory protection, medical monitoring, etc. Samples collected inside a properly selected and used abrasive blasting hood should result in levels below regulatory action limits. This however, should not relieve the employer of responsibility to implement engineering and work practice controls as the primary control method.

RECOMMENDATIONS

Welding in the Factory

The following recommendations are applicable only for those areas evaluated; the ventilation configuration in one work area may not be applicable to another work area due to differences in the welding operations and process layout.

(1) Investigate and implement, where feasible, fume extraction guns for flux-cored arc welding processes, particularly during welding operations which are enclosed or semi-enclosed. Fume extraction guns can only be used with continuous wire feed welding operations such as FCAW, and are not available for stick welding operations. For fume extraction guns to be used successfully, the following concerns need to be addressed:

(A) Educate welders on the proper use of the fume extraction gun. For it to be used efficiently, welders may need to adjust their technique slightly to account for the added size and weight of the gun.

(B) Ensure the ventilation is effectively exhausting the welding fume without disturbing the shielding gas. This requires a balancing of the shielding gas flow rate and the ventilation exhaust rate. Welders should be involved and/or educated in the proper selection of exhaust rates so that they do not modify the ventilation later and potentially decrease the effectiveness of the guns.

(C) Exhaust contaminated air to the outside and practice preventive maintenance of the ventilation system. This includes periodic inspection of the welding gun nozzle to ensure the exhaust orifices are not clogged.

(2) Implement local exhaust ventilation in the Factory for confined space welding operations. While the blowers currently used may help to dilute the welding fume concentration, the addition of an exhaust system would help to reduce the amount of fume in the immediate vicinity of the work area. Mechanical exhaust ventilation might be provided by routing 4"-8" flexible tubing into the work space and connecting it to a portable local exhaust ventilation unit. This type of setup would be adaptable to a number of process configurations. The duct work (tubing) for the ventilation system should not block the welder's means of access to and from the confined work space. Duct adapters are available for use with confined spaces.[30]

(3) Consider implementation of local exhaust ventilation for welding operations throughout the Factory. Due to the nature of the work in the shipyard, it may not be possible to automate or isolate certain welding processes. Stringent shipbuilding specifications may also limit the use of process substitutions. As such, the control of choice at the shipyard may be ventilation. Considerations before implementing controls include:

(A) Ensure the local exhaust ventilation system does not obstruct movement and activities of the overhead bridge crane, particularly in the Unit Department. Possibilities include installing the LEV system on a traversing rail along the equipment lane or mounting the LEV system on the structural posts in the equipment lane. One manufacturer's literature shows an articulating arm unit which can be mounted on a carriage that travels along an extraction rail (front reach of about 14', 360 degree rotation).[31]

(B) Local exhaust ventilation systems should be accessible from a variety of welding positions. For example in the Unit Department, if the LEV system is mounted on posts in the equipment lanes, welding performed close to the middle of the department, near the walkway, may not be adequately controlled unless the articulating arms can reach welding operations 60 feet away. Since a reach that great may not be probable, LEV systems would need to be positioned at locations other than just the equipment lanes.

(4) Use welding curtains, screens, or tarps around welding operations to help prevent welder's flash hazards, particularly in the Fabrication and Web Departments. According to OSHA 29 CFR 1915.56, whenever practicable, arc welding and cutting operations shall be shielded by screens to protect nearby personnel from the arc flash. If it is impractical to place curtains or screens around the welding operations, determine if they can at least be positioned between work areas and the walkways to protect nearby personnel from welder's flash. Workers adjacent to welding operations should use long gloves and personal hoods to protect themselves against unshielded welding flashes.

(5) Continue participating in the NAVSEA Emissions Working Group to learn of new control ideas or successful ventilation efforts implemented in other shipyards which may be applicable to Avondale.

(6) Evaluate specific welding tasks and implement automation options where feasible. An example of partial automation already observed in the shipyard was that of the tripod welder which allowed the welder to maintain some distance between himself and the welding process.

(7) Until a ventilation or other controls have been implemented and comprehensively evaluated to ensure effectiveness, respiratory protection should continue to be used when welding in the Factory. Supplied air respirators offering a higher degree of protection should be used when working in confined area such as the Inner Bottom Units, even if a forced air blower is utilized.

Safety and Health Program

Avondale should ensure that Industrial Hygiene and Safety review is obtained and incorporated during the early conceptual or design phase for new or remodeled facilities and processes. Anticipating potential health and safety issues and providing for appropriate controls and safeguards during the initial planning stages of projects is an effective means of preventing future problems and avoiding costly re-design and retrofits.

Employees should be encouraged to report all potential work-related health symptoms to appropriate health care personnel. Avondale should monitor reported health complaints in a system designed to identify particular job duties, work materials, or areas which may be associated with particular health effects.

Biologic monitoring for arsenic should allow for specific determination of exposure to inorganic arsenic, preferably by speciation of the arsenic in a urine sample. Inorganic arsenic and its metabolites can be distinguished from the non-toxic organic arsenic found in seafood.

Continued collection of sputum samples as part of a medical surveillance program for occupational arsenic exposure is not of preventive medical value and is no longer required by OSHA.

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Table 1 Personal Sampling Results - Welding: Gravimetric and Elemental Avondale Shipyard Factory Building, Day Shift: HETA 97-0260 October 22, 1997					
Task Monitored	Sample #s	Minutes Sampled	Contaminants Detected	TWA Concentration mg/m^3	REL mg/m^3
Track Welding on Platen 40 at Pole D-78, Arc Gouging for 1.5 hours	3392 3362 1997	394	Total Weight (Gravimetric)	14.1	LFC
			Lead	0.004	0.1
			Arsenic	<0.003	0.002
			Manganese	0.64	1.0
			Iron	6.1	5.0
			Copper	0.07	0.1
			Chromium	0.01	0.5
Flux Core welding on mild steel. Inner Bottom Unit 26, C3	3378 3406	416	Total Weight (Gravimetric)	14.4	LFC
			Lead	0.003	0.1
			Arsenic	<0.003	0.002
			Manganese	1.53	1.0
			Iron	2.61	5.0
			Copper	0.007	0.1
			Chromium	0.005	0.5
Stick and Flux Core welding on mild steel. Platen 20, B3	3366 3395	427	Total Weight (Gravimetric)	3.15	LFC
			Lead	0.003	0.1
			Arsenic	<0.002	0.002
			Manganese	0.24	1.0
			Iron	0.98	5.0
			Copper	0.009	0.1
			Chromium	0.002	0.5
Flux Core welding on mild steel on top of Platen 20, B3, Unit 108	3404 3402	422	Total Weight (Gravimetric)	19.1	LFC
			Lead	0.004	0.1
			Arsenic	<0.002	0.002
			Manganese	2.1	1.0
			Iron	4.2	5.0
			Copper	0.01	0.1
			Chromium	0.007	0.5

Table 1 Personal Sampling Results - Welding: Gravimetric and Elemental Avondale Shipyard Factory Building, Day Shift: HETA 97-0260 October 22, 1997					
Task Monitored	Sample #s	Minutes Sampled	Contaminants Detected	TWA Concentration mg/m^3	REL mg/m^3
Flux Core Welding in Inner Bottom - confined area. Sampling conducted for duration of activity	3398	99	Total Weight (Gravimetric)	55.5	LFC
			Lead	0.01	0.1
			Arsenic	<0.005	0.002
			Manganese	7.33	1.0
			Iron	12.5	5.0
			Copper	0.01	0.1
			Chromium	0.02	0.5

NOTES:
Gravimetric = Total weight of contaminants detected on filter
mg/m3 = milligrams of contaminant per cubic meter of air
TWA = time-weighted average concentration
All samples were field blank corrected
REL = NIOSH Recommended Exposure Limit for a 10-Hour TWA
LFC = Lowest Feasible Concentration
All Welders wore ½ mask air-purifying respirators with Dust-Mist-Fume filters or organic vapor cartridges with pre-filters.

Table 2
Abrasive Blast House (Unit 265 and 106) Gravimetric Sampling Results
Inside and Outside Blast Hood, Passive: October 22-23, 1997
Avondale Shipyards: HETA 97-0260

Sample #, AB #	Time (min)	OH(A) mg/m^3	TWA OH(A)	OH(B) mg/m^3	TWA OH(B)	TWA OH(C)	Total mg	P(A) mg	P(B) mg	P(C) mg	OH(C) minus P(C)	IH mg/m^3	WPF	
													OH-A/IH	OH-C/IH
3382 AB #1	16:24-18:04 (100)	65.3	44.0 mg/m^3	1253.1	538.6 mg/m^3	582.6 mg/m^3	271.6	0.51	1.07	1.58	579 mg/m^3	0.24	183	2427.5
3163 AB #1	18:04-19:54 (110)	29.5		27.4										
3182 AB #1	20:48-21:35 (49)	33.2		227.8										
3411 AB #2	16:27-18:26 (120)	40.7	45.2 mg/m^3	678.9	602.3 mg/m^3	647.5 mg/m^3	292.7	1.74	101.5	103.3	419.3 mg/m^3	0.23	196	2817
3174 AB #2	18:27-19:58 (90)	57		240.9										
3137 AB #2	21:03-21:44 (41)	32.5		1173.6										
3388 AB #3	16:32-18:24 (112)	44.4	41.0 mg/m^3	2538.1	1352.0 mg/m^3	1393 mg/m^3	571.2	ND	19.5	19.5	1345.6 mg/m^3	0.20	205	6965
3153 AB #3	18:40-19:56 (76)	41.4		685.1										
3168 AB #3	20:28-21:30 (62)	34.5		26.9										
3386 AB #4	16:52-18:28 (96)	39.3	42.4 mg/m^3	2626.6	1572.9 mg/m^3	1615.3 mg/m^3	851.2	5.1	25.35	30.45	1573.2 mg/m^3	0.12	353	>10,000
3165 AB #4	18:28-20:04 (96)	56.3		1649.7										
3130 AB #4	20:49-22:00 (71)	27.6		44.5										

Table 2
Abrasive Blast House (Unit 265 and 106) Gravimetric Sampling Results
Inside and Outside Blast Hood, Passive: October 22-23, 1997
Avondale Shipyards: HETA 97-0260

Sample #, AB #	Time (min)	OH(A) mg/m^3	TWA OH(A)	OH(B) mg/m^3	TWA OH(B)	TWA OH(C)	Total mg	P(A) mg	P(B) mg	P(C) mg	OH(C) minus P(C)	IH mg/m^3	WPF	
													OH-A/IH	OH-C/IH
3222 AB #5	16:45-18:10 (85)	97.8	61.9 mg/m^3	1181.6	516.8 mg/m^3	578.7 mg/m^3	273.5	0.31	2.96	3.27	571.7 mg/m^3	0.07	884	8267
3179 AB #5	18:10-20:00 (110)	29.1		45.3										
3173 AB #5	20:52-21:31 (39)	76.0		397.5										
3394 AB #6	16:41-18:24 (103)	44.0	34.6 mg/m^3	1234.8	1017.1 mg/m^3	1051.7 mg/m^3	457.7	0.38	17.72	18.1	1010.1 mg/m^3	0.06	577	>10,000
3136 AB #6	18:24-20:00 (96)	29.0		1340.3										
3152 AB #6	20:22-21:19 (57)	27.0		79.3										
3127 AB #7	16:43-18:34 (111)	63.0	58.8 mg/m^3	323.6	719.5 mg/m^3	778.3 mg/m^3	273.2	1.78	364.7	366.5	NC	0.12	490	6486
3230 AB #7	20:16-21:40 (84)	53.31		1242.6										
3363 AB #8	17:01-18:27 (88)	67.7	41.9 mg/m^3	287.8	250.3 mg/m^3	292.2 mg/m^3	125.9	2.12	ND	2.12	286.3 mg/m^3	0.06	698	4870
3129 AB #8	18:27-20:00 (93)	28.4		301.2										
3133** AB #8	20:31-21:14 (43)	18.1		63.3										
3134 AB #9	16:57-18:27 (90)	74.5	47.6 mg/m^3	10,910	5860.7 mg/m^3	5908.3 mg/m^3	2245.2	0.79	80.95	81.7	5691.9 mg/m^3	<0.05	ND	>10,000
3181 AB #9	18:27-19:52 (85)	38.4		4,555										

Table 2
Abrasive Blast House (Unit 265 and 106) Gravimetric Sampling Results
Inside and Outside Blast Hood, Passive: October 22-23, 1997
Avondale Shipyards: HETA 97-0260

Sample #, AB #	Time (min)	OH(A) mg/m^3	TWA OH(A)	OH(B) mg/m^3	TWA OH(B)	TWA OH(C)	Total mg	P(A) mg	P(B) mg	P(C) mg	OH(C) minus P(C)	IH mg/m^3	WPF	
													OH-A/IH	OH-C/IH
3380 AB #9	20:28-21:29 (61)	20.7		230.3										
3370 AB #10	26:53-18:26 (92)	48.0		2150										
3377 AB #10	18:26-19:59 (93)	57.7	57.1 mg/m^3	1192.4	1753.5 mg/m^3	1810.6 mg/m^3	857.5	1.92	219	221	1344 mg/m^3	0.05	1142	>10,000
3391 AB #10	20:25-21:28 (63)	69.6		2002.8										
3161 AB #11	16:51-18:20 (99)	48.6		1363.4										
3407 AB #11	18:20-19:54 (94)	113.6	64.1 mg/m^3	260.5	635.4 mg/m^3	699.5 mg/m^3	351.1	0.75	40.31	41.1	617.5 mg/m^3	0.05	1282	>10,000
3175 AB #11	20:19-21:11 (58)	10.2		<.17										

NOTES:

A = Smaller size fraction remaining on filter after removal of the loose bulk.
B = Larger size particulate fraction (loose bulk) removed from filter and analyzed separately
C = Total (A + B)
mg/m^3 = milligrams of contaminant per cubic meter of sampled air.
TWA = time-weighted average concentration

OH = Outside Blast Hood Sample
P = "passive" sample, closed face filter, obtained outside Blast Hood
IH = Inside Blast Hood Sample
AB # = Abrasive Worker Individual Identifier Number
ND = No particulate present and sample was not analyzed.

WPF = workplace protection factor: defined as the ratio of the measured contaminant concentration outside the respirator face piece to the contaminant concentration inside the respirator face piece (OH-C/IH). The samples were taken simultaneously while the respirator was being properly worn and used during normal work activities. Two sets of WPFs were calculated: OH-A/IH (using the smaller particle fraction concentration; OH-C/IH, using the total measured concentration)

The passive samples were worn by the worker for the duration of the workshift. The filter cassette was fixed to the workers lapel and the filter side cap removed. No air was drawn through the filter.
NC = The sample set was not compared because one OH sample was lost due to pump damage

** = This sample was collected when the worker was conducting compressed air blowdown and cleanup activities.
AB# 1-5 were sampled on October 22, AB# 6-11 were sampled on October 23

Table 3
Abrasive Blast House (Unit 265 and 106) Elemental Sampling Results
Inside and Outside Blast Hood, Passive
Avondale Shipyards: HETA 97-0260
October 22-23, 1997

Element	OH(A), (mg/m^3)	OH(B), (mg/m^3)	OH(C), (mg/m^3)	P(A), (µg)	P(B), (µg)	P(C), (µg)	OH(C) minus P(C)	IH (µg/m^3)	WPF		NIOSH REL
									OH(A)/IH	OH(C)/IH	
AB #1											
Lead	0.007	0.03	0.037	<0.2	<0.5	<0.5	0.037 mg/m^3	<0.5		ND	0.1 mg/m^3
Arsenic	<0.005	<0.1	<0.1	<0.9	<3.0	<3.0	<0.1 mg/m^3	<2.0		ND	2 µg/m^3 (C)
Manganese	0.21	1.49	1.7	1.4	1.6	3.0	1.7 mg/m^3	1.0	210	1700	1.0 mg/m^3
Iron	18.4	448.3	466.7	99	1000	1099	464.4 mg/m^3	84.7	217	5510	5.0 mg/m^3
Copper	0.04	0.89	0.93	0.23	0.31	0.54	0.92 mg/m^3	0.17	235	5470	1.0 mg/m^3
Chromium	0.016	0.29	0.31	<0.2	<0.5	<0.5	0.31 mg/m^3	(0.7)		ND	0.5 mg/m^3
AB #2											
Lead	0.007	0.04	0.047	(0.2)	5.2	5.2	0.035 mg/m^3	<0.7		ND	0.1 mg/m^3
Arsenic	(0.005)	(0.02)	(0.02)	<0.9	<3	<3	(0.02) mg/m^3	<3.0		ND	2 µg/m^3 (C)
Manganese	0.24	2.3	2.54	14	150	164	2.18 mg/m^3	0.9	266	2822	1.0 mg/m^3
Iron	18.6	431.6	450.2	2000	100,000	102,000	224.4 mg/m^3	69.1	269	6515	5.0 mg/m^3
Copper	0.05	0.54	0.59	2.3	70	72.3	0.43 mg/m^3	0.16	312	3688	1.0 mg/m^3
Chromium	0.01	0.23	0.24	1.2	30	31.2	O.17 mg/m^3	(0.7)		ND	0.5 mg/m^3
AB #3											
Lead	0.009	0.06	0.069	<0.08	<0.2	<0.2	0.069 mg/m^3	<0.5		ND	0.1 mg/m^3
Arsenic	(0.007)	<0.1	(0.007)	<0.9	<3	<3	(0.007) mg/m^3	<2.2		ND	2 µg/m^3 (C)
Manganese	0.20	3.16	3.36	6.0	30	36	3.27 mg/m^3	0.6	333	5600	1.0 mg/m^3

Table 3
Abrasive Blast House (Unit 265 and 106) Elemental Sampling Results
Inside and Outside Blast Hood, Passive
Avondale Shipyards: HETA 97-0260
October 22-23, 1997

Element	OH(A), (mg/m^3)	OH(B), (mg/m^3)	OH(C), (mg/m^3)	P(A), (µg)	P(B), (µg)	P(C), (µg)	OH(C) minus P(C)	IH (µg/m^3)	WPF OH(A)/IH	WPF OH(C)/IH	NIOSH REL
Iron	16.4	1107.1	1123.5	750	14000	14750	1087.5 mg/m^3	54	304	<10,000	5.0 mg/m^3
Copper	0.05	1.2	1.25	1.2	9.8	11.0	1.22 mg/m^3	0.20	250	6250	1.0 mg/m^3
Chromium	0.02	0.06	0.62	(0.3)	4.2	4.2	0.61 mg/m^3	(0.7)		ND	0.5 mg/m^3
<u>AB #4</u>											
Lead	0.01	0.29	0.30	(0.5)	(0.1)	(0.5)	0.3 mg/m^3	<0.4		ND	0.1 mg/m^3
Arsenic	<0.005	0.03	0.03	<0.9	<3.0	<3.0	0.03 mg/m^3	<1.9		ND	2 µg/m^3 (C)
Manganese	0.21	8.6	8.81	31	43	74	8.67 mg/m^3	0.5	420	>10,000	1.0 mg/m^3
Iron	15.5	689.2	704.7	2500	24,000	26,500	653.9 mg/m^3	39.5	392	>10,000	5.0 mg/m^3
Copper	0.05	1.7	1.75	3.7	15	18.7	1.71 mg/m^3	0.12	416	>10,000	1.0 mg/m^3
Chromium	0.02	0.6	0.62	2.2	3.6	5.8	0.61 mg/m^3	(0.6)		ND	0.5 mg/m^3
<u>AB #5</u>											
Lead	0.01	0.04	0.05	(0.06)	<0.08	(0.06)	0.05 mg/m^3	<0.7		ND	0.1 mg/m^3
Arsenic	(0.007)	(0.01)	(0.01)	<0.9	<3	<3	(0.01) mg/m^3	<0.21		ND	2 µg/m^3 (C)
Manganese	0.33	2.18	2.51	1.2	0.83	2.03	2.51 mg/m^3	0.2	1650	>10,000	1.0 mg/m^3
Iron	29.2	312.2	341.4	69	3000	3069	333.6 mg/m^3	20.4	1431	>10,000	5.0 mg/m^3
Copper	0.09	0.63	0.72	0.19	0.84	1.03	0.72 mg/m^3	(0.02)		ND	1.0 mg/m^3
Chromium	0.02	0.24	0.26	<0.2	<0.5	<0.5	0.26 mg/m^3	(0.5)		ND	

Table 3
Abrasive Blast House (Unit 265 and 106) Elemental Sampling Results
Inside and Outside Blast Hood, Passive
Avondale Shipyards: HETA 97-0260
October 22-23, 1997

Element	OH(A), (mg/m^3)	OH(B), (mg/m^3)	OH(C), (mg/m^3)	P(A), (µg)	P(B), (µg)	P(C), (µg)	OH(C) minus P(C)	IH (µg/m^3)	WPF		NIOSH REL
									OH(A)/IH	OH(C)/IH	
AB #6											
Lead	0.006	0.02	0.026	<0.2	<0.8	<0.8	0.026 mg/m^3	<1.0		ND	0.1 mg/m^3
Arsenic	(0.005)	(0.09)	(0.09)	<0.9	<3	<3	(0.09) mg/m^3	(3.8)		ND	2 µg/m^3 (C)
Manganese	0.19	2.7	2.89	3.0	38	41	2.80 mg/m^3	0.5	380	5780	1.0 mg/m^3
Iron	15.2	865.1	880.3	1500	17,000	18,500	837.8 mg/m^3	33.3	456	>10,000	5.0 mg/m^3
Copper	0.03	0.82	0.85	1.4	15	16.4	0.81 mg/m^3	(0.04)		ND	1.0 mg/m^3
Chromium	0.02	0.47	0.49	<0.2	14	14	0.46 mg/m^3	<0.4		ND	0.5 mg/m^3
AB #7											
Lead	0.006	0.02	0.026	(0.2)	3.5	3.5	NC	<0.8		ND	0.1 mg/m^3
Arsenic	(0.005)	0.03	0.03	<0.9	(20)	(20)	NC	<1.9		ND	2 µg/m^3 (C)
Manganese	0.4	3.4	3.8	100	720	820	NC	0.8	500	4750	1.0 mg/m^3
Iron	28.7	486.7	515.4	17,000	360,000	377,000	NC	50.5	568	>10,000	5.0 mg/m^3
Copper	0.07	0.6	0.67	12	310	322	NC	(0.04)		ND	1.0 mg/m^3
Chromium	0.02	0.3	0.32	4.8	160	164.8	NC	<0.4		ND	0.5 mg/m^3
AB #8											
Lead	0.002	0.008	0.01	0.12	NA	0.12	0.009 mg/m^3	<0.6		ND	0.1 mg/m^3
Arsenic	(0.002)	<0.02	(0.002)	<0.9	NA	<0.9	ND mg/m^3	<2.6		ND	2 µg/m^3 (C)
Manganese	0.22	1.01	1.23	5.7	NA	5.7	1.22 mg/m^3	0.6	367	2050	1.0 mg/m^3

Table 3
Abrasive Blast House (Unit 265 and 106) Elemental Sampling Results
Inside and Outside Blast Hood, Passive
Avondale Shipyards: HETA 97-0260
October 22-23, 1997

Element	OH(A), (mg/m^3)	OH(B), (mg/m^3)	OH(C), (mg/m^3)	P(A), (µg)	P(B), (µg)	P(C), (µg)	OH(C) minus P(C)	IH (µg/m^3)	WPF		NIOSH REL
									OH(A)/IH	OH(C)/IH	
Iron	18	172.3	190.3	420	NA	420	189.3 mg/m^3	41.1	438	4630	5.0 mg/m^3
Copper	0.06	0.23	0.29	0.91	NA	0.91	0.29 mg/m^3	(0.03)		ND	1.0 mg/m^3
Chromium	0.02	0.11	0.13	(0.2)	NA	(0.2)	0.13 mg/m^3	<0.6		ND	0.5 mg/m^3
AB #9											
Lead	0.001	0.07	0.071	(0.3)	0.81	0.81	0.07 mg/m^3	<0.5		ND	0.1 mg/m^3
Arsenic	(0.007)	<0.03	(0.007)	<0.9	(3)	(3)	ND mg/m^3	<2.4		ND	2 µg/m^3 (C)
Manganese	0.28	6.4	6.68	6.0	280	286	5.9 mg/m^3	<0.1		ND	1.0 mg/m^3
Iron	18.5	1926	1944.5	1100	82,000	83,100	1725.8 mg/m^3	5	3700	>10,000	5.0 mg/m^3
Copper	0.04	2.4	2.44	1.6	75	76.6	2.24 mg/m^3	<0.08		ND	1.0 mg/m^3
Chromium	0.02	1.23	1.25	(0.4)	50	50	1.12 mg/m^3	<0.05		ND	0.5 mg/m^3
AB #10											
Lead	(0.001)	0.08	0.08	<0.2	(100)	(100)	0.08 mg/m^3	<0.5		ND	0.1 mg/m^3
Arsenic	(0.005)	0.05	0.05	<0.9	<3	<3	0.05 mg/m^3	<0.21		ND	2 µg/m^3 (C)
Manganese	0.36	8.27	8.63	18	490	508	7.56 mg/m^3	0.4	900	>10,000	1.0 mg/m^3
Iron	21.5	1201.3	1222.8	1100	210,000	211,000	777.28 mg/m^3	30.9	696	>10,000	5.0 mg/m^3
Copper	0.05	1.55	1.6	1.5	170	171.5	1.24 mg/m^3	(0.05)		ND	1.0 mg/m^3
Chromium	0.02	0.68	0.7	0.88	100	100.88	O.49 mg/m^3	(0.05)		ND	0.5 mg/m^3

Table 3 Abrasive Blast House (Unit 265 and 106) Elemental Sampling Results Inside and Outside Blast Hood, Passive Avondale Shipyards: HETA 97-0260 October 22-23, 1997											
Element	OH(A), (mg/m^3)	OH(B), (mg/m^3)	OH(C), (mg/m^3)	P(A), (µg)	P(B), (µg)	P(C), (µg)	OH(C) minus P(C)	IH ($\mu g/m^3$)	WPF		NIOSH REL
									OH(A)/IH	OH(C)/IH	
AB #11											
Lead	0.001	0.03	0.031	(0.2)	(0.2)	(0.2)	ND	<0.5		ND	0.1 mg/m^3
Arsenic	0.008	0.04	0.048	<0.9	<0.3	<0.9	ND	<2.3		ND	2 $\mu g/m^3$ (C)
Manganese	0.4	5.14	5.54	8.5	88	96.5	5.35 mg/m^3	0.2	2000	>10,000	1.0 mg/m^3
Iron	29.2	463.8	493	1000	40,000	41,000	411.3 mg/m^3	13.0	2246	>10,000	5.0 mg/m^3
Copper	0.07	0.77	0.84	1.0	22	23	0.79 mg/m^3	<0.08		ND	1.0 mg/m^3
Chromium	0.03	0.38	0.41	(0.3)	15	15	0.38 mg/m^3	<0.5		ND	0.5 mg/m^3

Notes:

All Sample #s and times are the same as those described in Table 1 for the corresponding abrasive blaster individual identifier number. All reported values are time-weighted average concentrations in milligrams per cubic meter (mg/m^3) except for the passive samples (mass only) and IH sample (micrograms per cubic meter [$\mu g/m^3$]). All employees wore a half-mask air-purifying respirator with HEPA filter in addition to the blast hood.

< = less than
ND = Not determined
() = values in parentheses indicate the contaminant concentration was between the analytical limit of detection (LOD) and the limit of quantification (LOQ).
NA = Sample was not analyzed
A = Filter Analysis
B = Larger size particulate fraction (loose bulk) removed from filter and analyzed separately
C = Total (A + B)
AB # = Abrasive Worker Individual Identifier Number

OH = Outside Blast Hood Sample
P = "passive" sample, closed face filter, obtained outside Blast Hood
IH = Inside Blast Hood Sample

OH(C) minus P(C) = the concentration determined by subtracting the contaminant mass detected on the passive filter from the total contaminant mass detected on the outside the blast hood sample.

WPF = workplace protection factor: defined as the ratio of the measured contaminant concentration outside the respirator face piece to the contaminant concentration inside the respirator face piece (OH-C/IH and OH=A/IH). The samples were taken simultaneously while the respirator was being properly worn and used during normal work activities.

NC = The sample set was not compared because one OH sample was lost due to pump damage.

Table 4 Avondale Shipyards: HETA 97-0260 Paired Bulk Sample Results - Steel Grit from Shot House. All Results in µg/g												
Description	As		Pb		Cr		Cu		Mn		Fe	
	ACS	DC	ACS	DC	ACS	DC	ACS	DC	ACS	DC	ACS	DC
1A/1B: South Pot, Recycle Grit	**74.1**	**43**	**4.5**	**3**	**529.3**	**470**	**942.5**	**680**	**3529**	**2300**	**949K**	**10^6**
2A/2B: South Side, Coarse Reject	**49.1**	**40**	**65.8**	**29**	**519**	**640**	**1518**	**950**	**6909**	**3400**	**683K**	**800K**
3A/3B: South Side, Fine Reject	**30.2**	**16**	**223.4**	**190**	**408.9**	**320**	**1035**	**910**	**6486**	**5600**	**385K**	**360K**
4A/4B: North Side, Recycle Grit	**41.3**	**39**	**4.3**	**1.4**	**264**	**270**	**836**	**770**	**1104**	**2100**	**953K**	**990K**
5A/5B: North Side, Coarse Reject	**32.1**	**41**	**25.5**	**7.4**	**418.6**	**290**	**909.5**	**790**	**4607**	**2599**	**743K**	**870K**
6A/6B: North Side, Fine Reject	**16.1**	**12**	**35.2**	**71**	**463.5**	**270**	**1155**	**640**	**9703**	**7200**	**526K**	**320K**
7A/7B: Inside Shot House Floor	**41.7**	**46**	**6.5**	**1.5**	**464.6**	**240**	**791.5**	**810**	**2174**	**1700**	**958K**	**10^6**
8A/8B: Virgin Shot - G40 Steel Grit	**31.9**	**30**	**5.9**	**ND**	**149.1**	**ND**	**698.2**	**430**	**912**	**1200**	**962K**	**870K**

ACS = NIOSH Analytical Chemistry Services (Analysis by Inductively Coupled Plasma Emission Spectroscopy)

DC = Data Chem (Analysis by Atomic Absorption Spectroscopy)

µg/g = microgram of contaminant per gram of sample, equivalent to part per million (ppm).

No cadmium detected in either sample set

As = arsenic

Pb = lead

Cr = Chromium

Cu = Copper

Mn = Manganese

Fe = Iron

APPENDIX A: SAMPLING AND ANALYTICAL METHODOLOGY

Processes selected for monitoring were based on an assessment of employee work activities and controls utilized. Activities of concern noted by the HHE requesters were also targeted for sampling. The monitoring was conducted utilizing established analytical protocols (NIOSH analytical methods).[1] Calibrated air sampling pumps were attached to selected workers and connected, via tubing, to sample collection media placed in the employees' breathing zone. A primary standard was used to calibrate the air sampling pumps. Monitoring was conducted throughout the employees' work-shift. After sample collection, the pumps were post-calibrated and the average of the pre- and post-calibration flow rates were used to determine the sample volume. All air samples were submitted to the NIOSH contract laboratory (Data Chem, Salt Lake City, Utah) for analysis. Field blanks were submitted with the samples and all reported results were blank corrected. Specific sampling and analytical methods used during this survey were as follows:

Welding Fume

Personal exposures to airborne welding fume were monitored using Gilian HFS 513A or Gil-Air sampling pumps. Flow rates of approximately 2 liters per minute (l/m) were used to obtain the samples. The samples were collected on tared 37 millimeter (mm),5 micrometer (µm) pore size, poly-vinyl chloride (PVC) filters in the closed-face mode, and analyzed gravimetrically to determine the total welding fume concentration according to NIOSH Method 0500. An element specific analysis was also conducted on the samples, according to NIOSH Method 7300, to differentiate and quantify the following metal species: lead, iron, chromium, arsenic, manganese, and copper. With this technique, the sample filters are microwave digested in an acid mixture, and analyzed with a regular inductively coupled plasma emission spectrometer (ICAP). Additionally, all samples found to be nondetected for lead using the regular ICAP were reanalyzed using a trace ICAP. These reanalyses were conducted to verify that the nondetected values for lead were not the result of the dilutions necessary to overcome the high iron concentrations present on the samples.

Abrasive Blasting

Personal breathing zone (PBZ) monitoring during abrasive blasting activities was conducted to evaluate exposure to total particulate and the following metal species: lead, iron, chromium, arsenic, manganese, copper, using the same methods as that described for welding fume. For each abrasive blaster monitored, samples were collected in three locations: inside the blast hood, outside the blast hood, and a “passive” sample outside the blast hood.

The inside the blast hood samples were obtained by connecting the air sampling pump to the worker and attaching the filter to the inside of the blast hood using a Helmet Sampling Adaptor (SKC, Inc., Cat.# 225-600) to position the sampling cassette adjacent the workers’ breathing zone. The pump was activated just prior to the worker donning the blast hood and entering the Shot House. Sampling was conducted for the duration of the work shift. The outside the blast hood samples were collected by attaching the filter cassette to the abrasive blast shroud. Because of the anticipated high loading on the filters, the cassettes were changed out every 1 - 1.5 hours (whenever the worker exited the Shot House). Time-weighted average concentrations were calculated using the following formula:

$$\text{TWA (milligrams/cubic meter)} = \frac{C_1T_1 + C_2T_2 + C_nT_n}{T_1 + T_2 + T_n}$$

Where: C_1T_1 = concentration measured during sampling period T

The passive samples were collected by attaching a 4 inch length of Tygon tubing to a filter cassette containing a tared 37 mm, 5 µm pore size poly vinyl filter. The tubing and cassette was then secured to the outside of the abrasive blast shroud and the inlet cap removed (closed face mode). The filter cassette was worn by the worker for the duration of the work shift.

On both the passive and outside the hood samples, the larger size fraction (loose grit) was removed from the filter and analyzed (gravimetrically and elementally) separately. Although a rigorous definition and size range for this larger particulate size fraction was not determined, the larger particles removed and analyzed separately are believed to consist primarily of rebound or inertia driven shot and not in a size range considered to present an inhalation hazard. For each filter portion analyzed from the outside the hood sample, TWA concentrations were calculated. The two measurements were then combined to calculate the total concentration. Because no air was drawn through the passive monitor, only the total weight (milligrams) was reported.

Bulk Samples

Eight steel grit bulk samples in duplicate were collected from the Shot House in wide-mouth polyethylene containers to determine the concentration of the following elements: lead, iron, arsenic, cadmium, chromium, copper, and manganese. One sample from each pair was shipped to the NIOSH contract laboratory (DataChem, Salt Lake City, Utah) and the companion sample shipped to the NIOSH laboratory (ACS) for analysis. The purpose of the paired sampling was to address potential analytical problems associated with quantifying low concentrations of lead in a sample that is predominantly iron using ICAP as the analytical method. In addition to the steel grit samples, a bulk sample of the mild steel used in the factory, and both components of a 2-part epoxy resin used as a pre-construction primer prior to welding and abrasive blasting were submitted to ACS for elemental analysis. At the NIOSH contract laboratory, an aliquot from each sample was digested and analyzed by graphite furnace atomic absorption spectrometry (AAS). Because of high iron concentrations, some samples required dilutions up to 1000X. At ACS, an aliquot of each sample was analyzed by ICAP according to NIOSH Method #7300. To determine recovery data, Standard Reference Material 364 (high carbon steel) from the National Institute for Standards and Technology (NIST) was found to be the best available match to the samples. The air samples were placed on hold until the results of the bulk sampling were available.

References

1. NIOSH [1994]. NIOSH manual of analytical methods, 4th ed. Eller, RM, ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94-113.

APPENDIX B: CONTROL OF WELDING FUME

To reduce the hazard of welding fume exposures, the following hierarchy of controls should be considered: automation, substitution, isolation, ventilation.

- Partial or complete automation so the welder is less exposed to welding fumes.

- Implement process changes to limit hazards. For example, determine if different joining process other than welding can be used, if lower fume-producing welding processes, such as submerged arc welding or gas tungsten arc welding (GTAW or TIG) are feasible; or if low-fume electrodes can be substituted for the electrodes currently used.

- Isolate or enclose the welding process to limit the hazard to workers.

- Utilize ventilation to remove the fumes and gases from the welder's breathing zone.

A number of ventilation systems are commercially available to help control fume emissions during welding operations. Local exhaust ventilation (LEV) controls capture the air contaminants directly at the point of generation and are generally positioned no more than 12 inches away from the source. LEV systems are more effective than general ventilation systems since the air contaminants can be captured and removed before they can reach the welder's breathing zone. However, the effectiveness of the LEV system is often dependent on how the welder positions the hood; if the hood is placed too far from the welding operation it may not adequately capture the air contaminants, depending on the capture velocity. LEV systems used during industrial welding operations can include: fixed movable hoods, portable movable hoods, fume extraction guns, and, to some extent, canopy hoods.

Movable Hoods

OSHA 29 CFR 1910.252 recommends that "(movable hoods) should be placed as near as practicable to the work being welded and provided with a rate of airflow sufficient to maintain a velocity in the direction of the hood of 100 fpm in the zone of welding when the hood is at its most remote distance from the point of welding." To maintain a capture velocity of 100 fpm, OSHA provides the following values when using a 3" wide, flanged hood.

OSHA GUIDELINES FOR MOVABLE HOOD AIRFLOW RATES

Distance from Arc to Hood (in)	Airflow (cfm)	Duct Diameter (in)
4-6	150	3
6-8	275	3.5
8-10	425	4.5
10-12	600	5.5

The ACGIH Ventilation Manual also provides guidelines on the use of movable exhaust hoods for welding operations.[1] The airflow rates suggested by ACGIH are more conservative than those recommended by OSHA.

ACGIH GUIDELINES FOR MOVABLE HOOD AIRFLOW RATES

Distance from Arc to Hood (in)	Plain Duct Airflow (cfm)	Flange or Cone Hood Airflow (cfm)
up to 6	335	250
6-9	755	560
9-12	1335	1000

Fume Extraction Guns

Fume extraction guns are high vacuum, low volume controls. Two types of fume extraction guns are available. One type of gun incorporates the ventilation directly into the gun design. Lines for the shielding gas and exhausted air are encased in a large, single line leading from the gun. The second type of gun uses a conventional, nonventilated model with a suction attachment connected to the gun nozzle. On this model, the shielding gas and exhausted air lines remained separate. The type of gun used often depends on the welder's personal preference. Welders who find the all-in-one fume extraction gun bulky and cumbersome may prefer to use a conventional gun with the suction attachment. One manufacturer gives the following comparison of airflow rates for fume extraction guns and suction devices.[2]

APPROXIMATE AIRFLOW RATES FOR LEV SYSTEMS

Suction Device	Approximate Airflow Requirement (cfm)
Fume Extraction Gun	20-60
Small Suction Hood	40-80
Large Suction Hood	80-160

Although local exhaust ventilation can be very efficient at reducing worker welding fume exposures, there are many impediments to the successful implementation of this type of ventilation control in the shipbuilding industry:

(1) Controls must be usable in confined or enclosed spaces, or in awkward positions.
(2) Controls must be usable by a mobile workforce and may require extensive reaches.
(3) Controls must be able to be moved out of the way of overhead cranes and hoists when necessary.
(4) Duct work for controls must be tough enough to endure misuse and abuse.
(5) Controls must be able to effectively filter exhaust air before releasing it back into the welding area, or must exhaust air to the outside (preferrable).
(6) Controls must be flexible enough to adjust to changes in unit size and configuration, or changes in the process layout.

There can be additional drawbacks to using the various types of local exhaust ventilated controls. For example, welders may resist using fume extraction guns if they consider them to be too cumbersome or if they believe the ventilation is exhausting the shielding gas in addition to the fumes. Movable hoods are only effective if welders continually position the hood close to the point of fume generation. Portable ventilated units may be too large to maneuver through the work in progress on the Factory floor.

If local exhaust ventilation controls cannot be implemented, general exhaust ventilation (GEV) controls should be considered. A drawback to a GEV system is that, although it may help to reduce overall fume levels in the facility, it may not have a significant impact on reducing the exposure levels of the welder. OSHA 29CFR1910.252 recommends a minimum exhaust ventilation rate of 2000 cfm per welder when welding in a space of less than 10,000 ft^3 per welder, or when in a room with a ceiling height of less than 16 ft, or when in confined spaces or where the welding space contains structural barriers to the extent that they significantly obstruct cross ventilation. The ACGIH Ventilation Manual suggests the following general ventilation airflow rates: (1) for open areas where welding fume can rise away from the breathing zone the airflow required (cfm) = 800 x lb/hour of rod/wire used; (2) for enclosed areas or positions where fume does not readily escape the breathing zone the airflow required (cfm) = 1600 x lb/hour of rod/wire used. Examples of general exhaust ventilation controls include: suspended air filtration units and roof ventilators.

Other Welding Fume Controls

In addition to engineering controls, other factors such as work practices, personal protective equipment, and administrative controls should be investigated to help reduce worker exposures to welding fumes. Examples of work practices that may help to lower worker fume exposures include: educating welders to keep their heads out of the weld plume and to remain aware of air currents to ensure welding is performed upwind of the fumes as much as possible. Examples of personal protective equipment include: proper use of respirators, use of welding glasses/goggles/hoods by welders and workers in the vicinity, and availability of welding screens to place around weld operations. Examples of administrative controls include: job rotation to limit welders' exposures, training and education of welders on hazards and controls associated with their jobs, ensuring welders use ventilation and other control measures supplied to them.

References

1. ACGIH [1992]. Industrial ventilation: a manual of recommended practice. 21st Ed. Cincinnati, Ohio. American Conference of Governmental Industrial Hygienists.

2. Lincoln Electric [1994]. Lincoln Environmental Systems. High-Vacuum Solutions. Fume X-Tractor™ Products. Product Literature, E13.10. Cleveland, OH

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