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Astoria Metal Corporation
Hunters Point Naval Shipyard
San Francisco, California

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PREFACE

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (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 and 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.

HETAB 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 NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was written by James D. McGlothlin of the Engineering Control and Technology Branch, Division of Physical Sciences and Engineering (DPSE), Dino Mattorano, Josh Harney, and Daniel Habes of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Dr. McGlothlin is now an Associate Professor of Industrial Hygiene and Ergonomics at Purdue University. Field assistance was provided by Calvin Cook and Kevin Roegner, DSHEFS. Ergonomic technical support was provided by Steve Wurzelbacher. Analytical support was provided by Data Chem Laboratories, Salt Lake City, Utah. Desktop publishing was performed by Ellen Blythe and Nichole Herbert. Review and preparation for printing were performed by Penny Arthur.

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Highlights of the NIOSH Health Hazard Evaluation

Airborne Exposures to Metals and Ergonomic Hazards

This NIOSH Health Hazard Evaluation (HHE) was jointly requested by Astoria Metal Corporation (AMC) management and the International Brotherhood of Boilermakers. It was conducted on April 1–3, 1998, at Dry Dock #4 and covered ergonomic issues like welding, torch cutting, grinding, and office work. It also covered airborne exposures to metals like lead, cadmium, nickel, and copper.

What NIOSH Did

- We took breathing zone air samples on workers welding, torch cutting, and grinding.
- We looked at which jobs involved risk factors for injury.
- We adjusted office workstations to fit the user's body better.
- We reviewed injury and illness records and the respiratory protection program.
- We looked at other potential safety hazards such as trips and falls, falling objects, and confined spaces.

What NIOSH Found

- Overhead welding and cutting jobs have the greatest risk for causing arm and shoulder problems.
- Workers already use good practices to avoid arm and shoulder problems in the ship breaking and barge repair tasks.
- Workers used respirators, but some were still over–exposed to metals such as lead, nickel, cadmium, copper, and manganese.
- Respirators may not protect the workers enough from lead and cadmium.
- Torch cutting jobs may lead to injury from falling metal pieces and flying objects.
- There are permit–required confined spaces at AMC, but there is no written program for safe confined space entry.

What Astoria Managers Can Do

- Lower exposures to airborne metals by using ventilation.
- If exposures can't be lowered enough with ventilation, have workers inside ships and in the process area use full face–piece respirators instead of half–faced.
- Start an ergonomics program.
- Tell workers about the dangers of falling metal pieces, flying metal pieces, and shifting loads.
- When buying new office equipment, get items that can be personally adjusted.
- Train workers to recognize awkward postures and other injury risk factors.
- Make the respiratory protection, lead exposure control, hearing conservation, and confined space entry plans comply with the OSHA standards.
- Arrange wash areas to separate dirty work clothes from clean street clothes.

What Astoria Employees Can Do

- Shave facial hair so that respirators can properly protect you.
- Do not eat, drink, or smoke in contaminated areas.
- Wear safety glasses.
- Avoid awkward or uncomfortable positions when welding and cutting.
- Relax your muscles once in a while when working in awkward postures.
- Use good work practices when cutting metal to prevent injuries.
- Join in all medical monitoring and safety training programs.

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National Institute for Occupational Safety and Health
NIOSH

Health Hazard Evaluation Report 97–0196–2755

Astoria Metal Corporation
Hunters Point Naval Shipyard
San Francisco, California
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SUMMARY

On May 7, 1997, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at Astoria Metal Corporation (AMC) located at Hunters Point Naval Shipyard in San Francisco, California. The request, which was submitted jointly by AMC management and the International Brotherhood of Boilermakers, raised concerns about repetitive motion injuries and metal exposures during welding, torch cutting, grinding, and abrasive blasting operations. Due to an ongoing Occupational Safety and Health Administration (OSHA) investigation, NIOSH did not conduct a site visit until April 1998.

On April 1, 1998, NIOSH researchers conducted an industrial hygiene and ergonomic evaluation on ships being repaired or dismantled on Dry Dock #4, to identify specific work areas and job tasks and to devise an air sampling and ergonomic evaluation plan. On April 2 and 3, 1998, personal breathing zone (PBZ) air samples and bulk paint chip samples were collected for metals analysis. NIOSH investigators also reviewed the lead and respiratory protection programs, and the OSHA 200 Log and Summary of Occupational Illnesses and Injuries. An ergonomic evaluation was conducted on selected employees performing welding tasks on Dry Dock #4, and on three office workers performing administrative duties that involved the use of personal computers.

PBZ air samples were collected from AMC workers performing job tasks involving welding, grinding, and torch cutting. In the process area, three workers were monitored while torch cutting (with oxygen and propane) large metal structures (gimbal assembly) removed from the superstructure of the Glomar Explorer. In the dry dock, five workers were monitored while retrofitting and repairing two barges; two workers were underneath the barges and three were inside the barge tanks. Work activities included stick and metal inert gas (MIG) welding of new materials onto the barge. Also in the dry dock, two workers onboard the U.S.S. Ashtabula were monitored while torch cutting and removing non–ferrous materials such as brass, copper, and aluminum from the engine room.

PBZ air sample results (8–hr, time–weighted averages [TWAs]) are separated into four work areas: the U.S.S. Ashtabula, the process area, inside the barge tank, and under the barge. On the U.S.S. Ashtabula, all four PBZ air sample lead concentrations exceeded the NIOSH recommended exposure limit (REL), OSHA permissible exposure limit (PEL), and the American Conference of Governmental Industrial Hygienists (ACGIH®) threshold limit value (TLV®) of 50 micrograms per cubic meter ($\mu g/m^3$), with lead concentrations ranging from 253 to 435 $\mu g/m^3$. Cadmium concentrations ranged from 10 to 61 $\mu g/m^3$: all four PBZ air sample concentrations exceeded the PEL

of 5 µg/m^3 and TLV of 10 µg/m^3. NIOSH considers cadmium to be a potential occupational carcinogen, and recommends that exposures be reduced to the lowest feasible levels. The highest lead and cadmium concentrations were collected from the worker torch cutting and removing non–ferrous materials. Nickel concentrations ranged from 14 to 55 µg/m^3, with three of four PBZ air sample concentrations exceeding the REL of 15 µg/m^3. Copper concentrations ranged from 168 to 362 µg/m^3, with all four PBZ air sample concentrations exceeding the REL and the PEL of 100 µg/m^3. The highest nickel and copper concentrations were collected from the firewatcher.

In the process area, lead concentrations ranged from 41 to 399 µg/m^3; four of five PBZ air sample concentrations exceeded the REL, PEL, and TLV of 50 µg/m^3. Cadmium concentrations ranged from less than 0.1 µg/m^3 to 0.4 µg/m^3; all below relevant evaluation criteria. Nickel concentrations ranged from 1 to 43 µg/m^3; three of five PBZ air samples exceeded the REL of 15 µg/m^3. Copper concentrations range from 6 to 63 µg/m^3; all five PBZ air sample concentrations were below the REL and the PEL.

In the barge tank, lead concentrations ranged from 79 to 356 µg/m^3; all five PBZ air sample concentrations exceeded the REL, PEL, and TLV. Nickel concentrations ranged from less than 0.6 to 3 µg/m^3; all PBZ air sample concentrations were below relevant evaluation criteria. Manganese concentrations ranged from 82 to 873 µg/m^3; four of five PBZ air sample concentrations exceeded the TLV of 200 µg/m^3. Copper concentrations ranged from 11 to 19 µg/m^3; all five PBZ air sample concentrations were below relevant evaluation criteria.

Under the barge, lead concentrations ranged from less than 0.6 µg/m^3 to 2.5 µg/m^3; all four PBZ air sample concentrations were below relevant evaluation criteria. All nickel concentrations were below the minimum detectable concentrations (MDC) of 0.6 µg/m^3 and below relevant evaluation criteria. Manganese concentrations ranged from 46 to 75 µg/m^3; all PBZ air sample concentrations were below relevant evaluation criteria. Copper concentrations ranged from 2 to 5 µg/m^3 and were below all relevant evaluation criteria.

Workers performing tasks that involved welding, grinding, or torch cutting wore NIOSH–approved half–face, air–purifying respirators equipped with organic vapor and high efficiency particulate air (HEPA) filters. NIOSH has given these respirators an assigned protection factor (APF) of 10.[1] Therefore, the maximum use concentration (MUC) for these respirators for lead is 500 µg/m^3 as an 8–hr TWA (OSHA PEL of 50 µg/m^3 x APF of 10 = 500 µg/m^3). The MUC for cadmium is 50 µg/m^3 as an 8–hr TWA. Based on this information, if the respirators are properly fitted to the workers and used in conjunction with a comprehensive respiratory protection program, personal exposures to lead, nickel, copper, and manganese would be expected to be below the occupational exposure limit. However, two of four PBZ air sample concentrations collected from workers on the ship exceeded the MUC of 50 µg/m^3 for cadmium for these respirators. It is important to note that, although all lead PBZ air sample concentrations (8–hr TWA) were below the MUC of 500 µg/m^3, one worker on the ship and one in the process area had partial–shift TWAs greater than the MUC. Respirators should not be relied upon as the primary means of limiting exposure. They should only be used after engineering and/or administrative controls have been implemented.

Overhead welding, cutting tasks, and working in confined spaces with awkward postures for prolonged periods of time posed significant biomechanical risks for musculoskeletal disorders among workers in the shipbreaking and barge repair jobs. However, the use of good work practices (e.g. frequent micro–breaks and reduced reach distances during welding, cutting, and grinding operations) observed during the NIOSH evaluation, reduced this risk. Evaluation of the office work environment revealed non–adjustable office furniture and employees reporting some musculoskeletal discomfort. However, simple ergonomic fixes, such as adjusting the height of the computer monitors and providing foot rests for a more comfortable posture in the seated workstations, seemed to reduce some of their reported musculoskeletal discomfort. A comprehensive ergonomics program encompassed within the shipyard safety program should be established. Specific recommendations to accomplish these goals are contained in the recommendations section.

Based on the NIOSH evaluation conducted on April 1–3, 1998, a respiratory hazard to lead and cadmium existed during welding and cutting tasks. The potential for musculoskeletal disorders existed for employees performing welding, cutting, and material handling tasks at this shipyard. In addition, safety hazards from torch cutting activities were identified. Recommendations are included in the body of this report to protect workers from hazardous airborne metal exposure and from biomechanical hazards.

Keywords: SIC 3731, 4499 (Ship Breaking, Ship Repair, Dismantling Ships), Metals exposure, lead, cadmium, nickel, respiratory hazards, musculoskeletal disorders, welders, cutters, ergonomics.

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INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) received a request on May 7, 1997, for a health hazard evaluation (HHE) at Astoria Metal Corporation (AMC) located at Hunters Point Naval Shipyard in San Francisco, California. The request, which was submitted jointly by AMC management and the International Brotherhood of Boilermakers, raised concerns about repetitive motion injuries and metal exposures during welding, torch cutting, grinding, and abrasive blasting operations.

Due to an ongoing Occupational Safety and Health Administration (OSHA) investigation, NIOSH did not conduct a site visit until April 1998. On April 1, 1998, the NIOSH evaluation began with an opening conference and a walk–through inspection of Dry Dock #4 to identify specific work areas and job tasks for inclusion in the evaluation and to devise an air sampling plan. On April 2 and 3, 1998, personal breathing zone (PBZ) air samples and bulk paint chip samples were collected for metal analysis. NIOSH investigators also reviewed the lead and respiratory protection programs, and the OSHA 200 Log and Summary of Occupational Illnesses and Injuries.

The ergonomic evaluation was conducted in parallel with the industrial hygiene air sampling evaluation. Workers were videotaped performing welding, cutting, and material handling tasks on ships in Dry Dock #4 of the shipyard. A questionnaire and checklist were administered to determine work risk factors for shipyard office workers. Informal interviews were also conducted with all workers videotaped or who completed questionnaires to determine causes, if any, of musculoskeletal disorders.

BACKGROUND

AMC is one of three active shipbreaking (scrapping, demolition, and dismantling) facilities in the country; the others are located in Texas and Maryland. AMC was originally established for the purpose of dismantling surplus Navy vessels. Over the last few years, the company has expanded into major repair and conversion projects. These projects have been performed for both commercial companies and federal agencies on various vessels including barges, cargo carriers, aircraft carriers, and exploration vessels.

AMC usually operates one 8–hour work shift (7:30 a.m. to 4:00 p.m.) with a total of 25 workers. Depending on demand, in some cases 10– to 12–hour work shifts are conducted. Most AMC work activities are performed in a dry dock or in the process area adjacent to a dry dock. It is important to note that the work force evaluated by NIOSH is less than half of AMC's historically normal work force of 60 workers. The decrease was due in part to a lull in the U.S. ship scrapping industry and the decrease in scrap metal prices.

Hard hats, safety glasses, and safety shoes are required throughout the facility. Foam ear plugs are available for workers to wear at their own discretion. Workers performing any job tasks involving welding, grinding, or torch cutting are required to wear NIOSH–approved half–face air–purifying respirators equipped with organic vapor and high efficiency particulate air (HEPA) filters. Each worker is reportedly fit–tested (qualitatively) and assigned a respirator. Workers are responsible for care, maintenance, and repair of respirators. Replacement respirator filters are available at the tool shed for workers to change at their own discretion. Smoking is prohibited at AMC except in designated areas near the lunch room. AMC provides and launders cloth coveralls for all workers. Disposable Tyvek® coveralls are available as well.

METHODS

Metals

On April 2 and 3, 1998, PBZ air samples were collected from all AMC workers involved with welding, grinding, and torch cutting. In most cases, sample filter cassettes were changed during lunch to prevent particulate overloading. On three separate individuals, sample filter cassettes were changed a second time (total of three consecutive samples per individual) for the same reason. A total of 36 air samples from 10 AMC workers were collected for metals analysis. PBZ air samples were collected on the lapel outside of the welding helmet or face shield because workers wore respirators underneath. Three paint chip samples were collected from scrap metal that workers were torch cutting in the process area. This scrap metal was previously removed from the Glomar Explorer superstructure.

Air samples for metals were collected on 37–millimeter (mm), 0.8 micrometer (µm) pore size cellulose ester membrane filters in cassette holders. The filters were attached via flexible Tygon® tubing to personal sampling pumps and the sampling trains were calibrated at a flow rate of 2 liters per minute (Lpm). The samples were analyzed for 28 elements using NIOSH analytical method 7300.[2] A Thermo Jarrell Ash ICAP–61E inductively coupled plasma (ICP) emission spectrometer controlled by a Digital DEC Station 466D2LP personal computer was used for all measurements. The analytical limits of detection (LOD) for cadmium, copper, manganese, nickel, and lead were 0.08, 0.08, 0.01, 0.5, and 0.5 micrograms per filter (µg/filter), respectively. This equates to minimum detectable concentrations (MDC) of 0.1, 0.1, 0.01, 0.6, and 0.6 micrograms per cubic meter of air ($\mu g/m^3$), respectively, using a maximum sample volume of 800 liters. The analytical limit of quantitation (LOQ) for cadmium, copper, manganese, nickel, and lead were 0.3, 0.3, 0.04, 1.0, and 2.0 µg/filter, respectively. This equates to minimum quantifiable concentrations (MQC) of 0.37, 0.37, 0.05, 1.25, and 2.5 $\mu g/m^3$, respectively, using a maximum sample volume of 800 liters.

Paint chip samples were collected in a labeled glass vial and shipped to a contract laboratory for metals analysis. All layers of paint, including the primer, were removed from each sample location. Samples were weighed out in 0.1 gram (g) portions and analyzed using NIOSH method 7300 as described above. The analytical LODs for cadmium, copper, manganese, nickel, and lead were 0.8, 0.8, 0.1, 5.0, and 5.0 micrograms per gram (µg/g), respectively. The LOQs for cadmium, copper, manganese, nickel, and lead were 3.0, 3.0, 0.4, 10, and 20 µg/g.

Ergonomics

The ergonomics evaluation of the Astoria facility consisted of a walk–through survey, videotaping of selected jobs for subsequent "job analysis," structured questionnaire and checklist evaluations of office workers (Figures 1–3), and informal interviews with all employees either videotaped, completing questionnaires, or completing checklists. The purpose of videotaping jobs for subsequent job analysis is to quantitatively evaluate the job for occupational risk factors for work–related musculoskeletal disorders (WMSDs). These WMSDs risk factors include repetition, excessive force, awkward posture, contact stress, low temperature, and vibration.[3,4]

Job analysis was broken down into two phases. Phase I included analyzing the job at regular speed to determine job cycle time, and in "slow–motion" and "stop–action" to sequence job steps and perform biomechanical evaluations of working postures. Methods included time and motion study techniques,[5] and work methods analysis to determine the work content of the job.[6]

The second phase of job analysis included using the revised NIOSH lifting equation,[7] and the MVTA system (Multi–Media Video Task Analysis) developed by researchers from the University of Wisconsin–Madison.[8] The MVTA system consists of custom multi–media software that enables interactive computer control of videotaped task records that can be synchronized with any sampled analog data. Task elements are marked by break points in the video record that are based on the observed events listed below. The video record can then be reviewed at any speed or direction and the task elements revised as needed. The custom software then enables the time frequency of each element to be calculated. Finally, workers performing the two–handed welding task were compared to population norms using the University of Michigan 2D Static Strength Model.

Shipbreaking and Ship Repair

Four main Astoria work tasks were identified for ergonomic task analysis. These included: welding, cutting, asphalt removal, and grinding. Cycles of each task were then videotaped and evaluated using the MVTA system. To perform a frequency analysis with the MVTA system, the main work tasks were differentiated into task elements as follows:

Welding Task

1. *Weld:* application of arc time of welding unit to a surface.
2. *Examine:* inspection of welding surface without arc time.
3. *Re–position:* change in posture or position, during which there is no welding performed.
4. *Rest:* absence of arc time or other gross movement without performance of the above elements.
5. *Other:* selection of weld sticks, manipulation of weld cable, etc.

Cutting Task

1. *Cut:* application of arc time of cutting unit to a surface.
2. *Examine:* inspection of cutting surface without arc time.
3. *Re–position:* change in posture or position, during which there is no cutting performed.
4. *Rest:* absence of arc time or other gross movement without performance of the above elements.
5. *Other:* manipulation of cutting unit, etc.

Asphalt Removal Task

1. *Pound:* application of vertical force to asphalt with metal rod.
2. *Scrape:* application of horizontal force to asphalt with metal rod.
3. *Lift:* raising a chunk of asphalt.
4. *Examine:* inspection of asphalt surface, during which above elements are not performed.
5. *Re–position:* change in posture or position, during which none of the above elements are performed.
6. *Rest:* absence of gross movement without performance of the above elements.
7. *Other:* sweeping, heavy equipment operation, etc.

Grinding Task

1. *Grind:* application of grinder pad to a surface.
2. *Examine:* inspection of grinding surface without grinder operation.
3. *Re–position:* change in posture or position, during which there is no grinding performed.
4. *Rest:* absence of other gross movement, without performance of the above elements.
5. *Other:* changing grinding pad, grinder maintenance, etc.

Office Evaluation–Ergonomics

Three office workers were evaluated for musculoskeletal discomfort at AMC during the NIOSH evaluation. Symptoms survey forms, (Figures 1 and 2), were used to gather information from these employees regarding any pain or discomfort they had in the past year that may be associated with their work. In addition, a computer workstation checklist (Figure 3), was used to link the physical workstation layout to the musculoskeletal discomfort symptoms reported by the office workers. Informal interviews of these office workers about their primary office tasks were conducted to complete the ergonomic evaluation.

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 increases 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),[9] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[10] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[11] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm.[12] Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PEL's and STEL's. An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

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.

Lead

People have used lead since ancient times because of its useful properties, and it was the ancient Romans and Greeks who first discovered its toxic effects. Workplace exposure to lead occurs by inhalation of dust and fume and ingestion of lead–contaminated dust on surfaces. Once absorbed, lead accumulates in the soft tissues and bones. Lead is stored in the bones for decades, and health effects may occur long after the initial exposure as the bones release lead into the body.

Occupational exposure to lead occurs via inhalation of dust and fume, and ingestion from contact with lead–contaminated hands, food, cigarettes, and clothing. Symptoms of lead poisoning include weakness, excessive tiredness, irritability, constipation, anorexia, abdominal discomfort (colic), fine tremors, and "wrist drop."[13,14,15] Overexposure to lead may also result in damage to the kidneys, anemia, high blood pressure, infertility and reduced sex drive in both sexes, and impotence. An individual's blood lead level (BLL) is a good indication of recent exposure to, and current absorption of lead.[16]

The overall geometric mean BLL for the U.S. adult population (ages 20–74) declined significantly between 1976 and 1991, from 13 to 3 micrograms per deciliter (µg/dL) of blood—this decline is most likely due primarily to the reduction of lead in gasoline. More than 90% of adults in the U.S. now have a BLL of <10 µg/dL, and more than 98% have a BLL of < 15 µg/dL.[17]

Under the OSHA general industry lead standard (29 CFR 1910.1025), the PEL for airborne exposure to lead is 50 µg/m^3 as an 8–hr TWA and medical removal is required if an employee's average BLL is 50 µg/dL.[18] Medically removed workers cannot return to jobs involving lead exposure until their BLL is below 40 µg/dL. The OSHA standard requires adjusting the PEL for work shifts longer than 8 hours. NIOSH has concluded that the OSHA standard should prevent the most severe symptoms of lead poisoning, but that it does not protect workers and their children from all of the adverse effects of lead.[19] The ACGIH TLV for lead is 50 µg/m^3 (8–hour TWA), with worker BLLs to be controlled to ≤30 µg/dL.[15] A national health goal for the year 2000 is to eliminate all occupational exposures which result in BLLs greater than 25 µg/dL.[20] The NIOSH REL for inorganic lead is 50 µg/m^3 (8–hour TWA).[21] NIOSH supports the Public Health Service (PHS) goal and recommends that to minimize the risk of adverse health effects, employers and workers should continually strive to reduce workplace lead exposures.

Health studies indicate that the OSHA lead standards noted above are not protective for all the known health effects of lead. Studies of adults have found neurological symptoms with BLLs of 40 to 60 µg/dL, decreased fertility in men at BLLs as low as 40 µg/dL, and increases in blood pressure with no apparent threshold to BLLs of less than 10 µg/dL. Fetal exposure to lead is associated with reduced gestational age, birth weight, and early mental development with maternal BLLs as low as 10 to 15 µg/dL.

In homes with a family member occupationally exposed to lead, care must be taken to prevent "take home" of lead. Lead may be carried into the home on clothing, skin, hair, or from vehicles. High BLLs in resident children, and elevated concentrations of lead in house dust, have been found in the homes of lead–exposed workers.[22] According to the Centers for Disease Control and Prevention (CDC), children of persons who work in areas of high lead exposure should receive a BLL test.[23]

Cadmium

Exposure to cadmium produces a wide variety of effects involving many organs and systems. Although acute health effects from overexposure to cadmium have been reported, currently, in most occupational settings, chronic effects are of greater concern.

Cadmium poisoning has been reported from acute overexposure to cadmium oxide fumes; the principal symptom is respiratory distress due to chemical pneumonitis and edema.[15] In one situation with a very high level of exposure (40–50 mg/m^3 for 1 hour), death was reported.[15]

Long–term occupational exposure to cadmium is most strongly associated with an increased occurrence of lung cancer, kidney damage, and chronic obstructive lung disease.[24] The total amount of cadmium exposure affects the risk of developing disease. This risk increases as the number of years and the level of cadmium exposure increase.

The kidney is thought to be the organ most sensitive to the toxic effects of cadmium. Kidney damage caused by cadmium exposure occurs when cadmium accumulates in the kidneys. The damage can progress over time and is irreversible. Chronic lung injury develops in workers in relation to the time and level of exposure. Effects on the lung occur quite slowly. The exposure level at which these effects occur is unknown. The level of exposure linked with lung damage, however, is thought to be above that which causes kidney damage.

NIOSH considers cadmium to be a potential human carcinogen.[9,25] Two types of cancer have been of concern–lung and prostate cancer. Although the evidence linking overexposure to cadmium with lung cancer is strong, the evidence linking cadmium exposure with prostate cancer is weaker.[26] NIOSH recommends that exposures to potential human carcinogens be reduced to the lowest feasible concentrations.[27] The ACGIH TLV and OSHA PEL for cadmium are 10 and 5 µg/m^3 respectively, as an 8–hr TWA.

Nickel

Nickel is one of the most common causes of allergic contact dermatitis ("nickel–itch").[28] The condition has been seen in various occupations including hairdressers, nickel platers, and jewelers. Once a worker is sensitized to nickel, the sensitivity persists after the exposure is removed.[15] The major route of exposure to nickel and nickel compounds is through inhalation.[29] Inhalation exposures have been associated with cancer of the lung and of the nasal sinuses in workers employed in nickel refineries and smelters.[30] Although not common, other health effects of nickel inhalation exposures include nasal irritation, damage to the nasal mucosa, perforation of the nasal septum, loss of smell, pneumoconiosis, and allergic asthma.

The NIOSH REL and OSHA PEL for nickel metal as an 8– to 10–hr TWA are 15 µg/m^3 and 1,000 µg/m^3, respectively.[9,10] NIOSH considers nickel to be a potential occupational carcinogen and therefore, recommends that exposures be reduced to the lowest feasible concentration. ACGIH TLVs for insoluble nickel, i.e., nickel oxide, and nickel subsulfide (forms found in welding fume) are 200 and 100 µg/m^3, respectively. Both forms of nickel have an A1 designation, confirmed human carcinogen.[10]

Welding Fume

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 toxic metals involved. Welding fumes are a product of 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.[31] The flux coating (or core) of the electrode/wire may contain up to 30 organic and inorganic compounds. The primary responsibility of the flux is to release a shielding gas to insulate the weld puddle from air, thereby protecting against oxidation.[32] The size of welding fume particulate is highly variable and ranges from less than 1–µm diameter (not visible) to 50–µm diameter (seen as smoke).[33]

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.[33,34,35] 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. In addition to the generation of fumes, many other potential health hazards exist for welders. Welding operations can produce toxic gases, such as ozone, carbon monoxide (CO), nitrogen dioxide (NO_2), and phosgene (formed from chlorinated solvent decomposition).[33,34,35] Welders can also be exposed to ultraviolet light from the welding arc.

Epidemiological studies and case reports of workers exposed to welding emissions have shown an excessive incidence of acute and chronic respiratory diseases.[34] These illnesses include metal fume fever (primarily from zinc, copper, and manganese oxides), pneumonitis, and pulmonary edema. The major concern, however, is the excessive incidence of lung cancer among welders. Epidemiological evidence indicates that welders generally have a 40% increase in relative risk of developing lung cancer as a result of their work.[34]

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 and meeting the exposure limit for each welding fume constituent.[27] A PEL for total welding fumes has not been established by OSHA; however, individual PELs have been set for welding fume constituents. ACGIH has established a TLV of 5 mg/m^3 TWA for welding fumes. 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." The ACGIH also recommends that arc welding fumes be tested frequently to determine whether exposure levels are exceeded for individual constituents.[10]

Manganese

Health effects of excessive occupational manganese exposure are primarily neurological and respiratory (including irritation, pneumonitis, and chronic bronchitis). Metal fume fever has also been reported with exposure to manganese fume. Most notably, occupational exposure to manganese dust is known to cause *manganism*, a Parkinsonian–like syndrome with well recognized characteristics. This condition has also been referred to as manganese poisoning and chronic manganese toxicity.

The NIOSH REL for manganese compounds and fumes is an 8–hr TWA of 1,000 µg/m^3, with a STEL of 3,000 µg/m^3 based on central nervous system effects and pneumonitis.[9,36] The OSHA PEL for manganese dust/fume is a ceiling criteria of 5,000 µg/m^3.[11] In 1996, ACGIH lowered the TLV for manganese fume from 1,000 µg/m^3 to 200 µg/m^3 to address adverse pulmonary effects, central nervous system (CNS) effects, and male infertility.[37]

Copper

In humans, inhalation of copper fume has resulted in irritation of the upper respiratory tract, metallic or sweet taste, and discoloration of the skin and hair. Copper fume exposure is associated with metal fume fever, an acute 24– to 48–hour illness characterized by influenza–like symptoms including fever, chills, sweating, weakness, headaches, muscle aches, and dryness of mouth and throat. The NIOSH REL and OSHA PEL for copper fume is an 8–hr TWA of 100 µg/m^3.[11] The ACGIH TLV for copper fume is 200 µg/m^3 as an 8–hr TWA.[10]

RESULTS/DISCUSSION

Workers participating in the NIOSH investigation worked in the process area or in Dry Dock #4 (on the barges or on the U.S.S. Ashtabula). PBZ air samples were collected from AMC workers performing job tasks involving welding, grinding, and torch cutting. In the process area, three workers were monitored while torch cutting (with oxygen and propane) large metal structures (gimbal assembly) removed from the superstructure of the Glomar Explorer. In the dry dock, five workers were monitored while retrofitting and repairing two barges; two workers were underneath the barges and three were inside the barge tanks. Work activities included stick and metal inert gas (MIG) welding of new materials onto the barge. Also in the dry dock, two workers onboard the U.S.S. Ashtabula were monitored while torch cutting and removing non–ferrous materials such as brass, copper, and aluminum from the engine room. One worker performed torch cutting and the other was the firewatcher. NIOSH investigators did not observe work tasks inside the ship because of ongoing asbestos abatement activities.

Metals

Personal Breathing Zone (PBZ) Air Samples

PBZ air sample results are separated into four work areas: the U.S.S. Ashtabula, the process area, inside the barge tank, and under the barge. Results are summarized in Tables 1– 4. Only the results for the metals with the greatest toxicological significance and found at the highest concentrations are presented. Air sample results presented below are 8–hr TWAs. It should be noted that on the second day of monitoring, it rained periodically and work activities were slower than the previous day, especially for those working outside (i.e., in the process area).

On the U.S.S. Ashtabula, (Table 1) 8–hr. TWA lead concentrations ranged from 253 to 435 µg/m^3; all four PBZ air sample concentrations exceeded the NIOSH REL, OSHA PEL and ACGIH TLV of 50 µg/m^3. Cadmium concentrations ranged from 10 to 61 µg/m^3; all four 8–hr. TWA PBZ air sample concentrations exceeded the PEL of 5 µg/m^3 and the TLV of 10 µg/m. The highest lead and cadmium concentrations were collected from the worker torch cutting and removing non–ferrous materials. Nickel 8–hr. TWA concentrations ranged from 14 to 55 µg/m^3; three of four PBZ air sample concentrations exceeded the REL of 15 µg/m^3. Copper 8–hr. TWA concentrations ranged from 168 to 362 µg/m^3; all four PBZ air sample concentrations exceeded the REL and the PEL of 100 µg/m^3. The highest nickel and copper concentrations were collected from the firewatcher.

In the process area (Table 2), 8–hr. TWA lead concentrations ranged from 41 to 399 µg/m^3; four of five PBZ air sample concentrations exceeded the REL, PEL, and TLV of 50 µg/m^3. Cadmium concentrations ranged from 'trace' to 'not detected;' all below relevant evaluation criteria. Nickel concentrations ranged from 1 to 43 µg/m^3; three of five PBZ air samples exceeded the REL of 15 µg/m^3. Copper concentrations range from 6 to 63 µg/m^3; all five PBZ air sample concentrations were below the REL and the PEL.

Inside the barge tank (Table 3), 8–hr. TWA lead concentrations ranged from 79 to 356 µg/m^3; all five PBZ air sample concentrations exceeded the PEL and TLV of 50 µg/m^3. Nickel concentrations ranged from less than 0.6 to 3 µg/m^3; all PBZ air sample concentrations were below relevant evaluation criteria. Manganese concentrations ranged from 82 to 873 µg/m^3; four of five PBZ air sample concentrations exceeded the TLV of 200 µg/m^3. Copper concentrations ranged from 11 to 19 µg/m^3; all five PBZ air sample concentrations were below relevant evaluation criteria.

Under the barge (Table 4), 8–hr. TWA lead concentrations ranged from "trace" to "not detected"; all four PBZ air sample concentrations were below relevant evaluation criteria. All nickel concentrations were below the MDC of 0.6 µg/m^3 and the relevant evaluation criteria. Manganese concentrations ranged from 46 to 75 µg/m^3; all PBZ air sample concentrations were below relevant evaluation criteria. Copper concentrations ranged from 2 to 5 µg/m^3 and were below all relevant evaluation criteria.

Workers performing jobs that involved welding, grinding, or torch cutting wore NIOSH–approved half–face, air–purifying respirators equipped with organic vapor and HEPA filters. NIOSH has given these respirators an assigned protection factor (APF) of 10.[1] Therefore, the maximum use concentration (MUC) for these respirators for lead is 500 µg/m^3 as an 8–hr TWA (NIOSH REL and OSHA PEL of 50 µg/m^3 x APF of 10 = 500 µg/m^3). The MUC for cadmium is 50 µg/m^3 as an 8–hr TWA. Based on this information, if the respirators are properly fitted to the workers and used in conjunction with a comprehensive respiratory protection program, personal exposures to lead, nickel, copper, and manganese would be expected to be below the occupational exposure limit. However, two of four PBZ air sample concentrations collected from workers on the ship exceeded the MUC of 50 µg/m^3 for cadmium for these respirators. It is important to note that, although all lead PBZ air sample concentrations (8–hr TWA) were below the MUC of 500 µg/m^3, one worker on the ship and one in the process area had partial–shift TWAs greater than the MUC. Additionally, deficiencies in the respiratory protection and lead control programs were identified during the NIOSH site visit as described in the "observations" section.

Bulk Paint Chip Samples

The paint chip analytical results are presented in Table 5. All three paint chip samples were collected from scrap metal removed from the Glomar Explorer. The analysis revealed that paint chip samples contained metals that were identified in the PBZ air samples, including lead. The bulk samples contained from 0.08% to 9.5% lead by weight.

Paint chip samples were not collected from the ship because a private contracting firm had already performed this task. According to AMC, the paint chip samples contained from 0.12% lead by weight on the outer bulkheads–main deck to 15% lead by weight on the inner and outer bulkheads, and on the deck of the engine room. Results for other metals were not reported.

Bulk paint chip samples were not collected from the barges because most job tasks involved stick or MIG welding of new material onto the barge surface. Prior to the NIOSH site visit, paint was removed from the barge surfaces via abrasive blasting. According to AMC, paint on the barge did not contain lead.

Observations

Lead Control Program

Review of the lead control program revealed its strengths and weaknesses. Strengths included a well written lead control document that contained all of the following essential components of an effective program: a description of lead, health hazards associated with lead exposure, occupational exposure limits, medical surveillance, exposure control requirements (i.e., personal protective equipment [PPE], engineering controls, and administrative controls), housekeeping, personal hygiene, training, workplace monitoring, and a description of the responsibility of management and employees with regards to the lead control program. Other strengths of the program included good training materials and weekly safety meetings.

Weaknesses of the program are the lack of enforcement and deficiencies with the wash facility layout. On various occasions, workers were observed smoking in the dry dock on the barges and in the process areas where smoking is prohibited. Other weakness of the lead control program included no soap in the sink area, the lack of warning signs indicating lead work areas, and the absence of a written medical removal plan for workers if average BLLs are greater than or equal to 50 µg/dL. Observations of the wash facility revealed that workers did not shower before leaving the work site on the first day of exposure monitoring. This is probably due in part to the facility layout. The sink, shower, and clean/change rooms are located in one building. There is also a smaller building (without doors) adjacent to wash facility where workers remove the reusable coveralls and place them in a rubber container. The problem with the layout is that the only storage lockers are in the clean/change room. Subsequently, work clothes and boots are stored in the clean room which may result in the contamination of the clean/change room and increase workers overall exposure to lead and other metals. Furthermore, contaminated street clothes may be worn home by workers, possibly exposing family members to metals.

Respiratory Protection Program

Review of the respiratory protection program revealed its strengths and weaknesses. Strengths included good training materials and medical evaluations. Weaknesses included the lack of a written program, improper respirator storage, and the lack of respirator cleaning and maintenance. During the site visit, NIOSH investigators found respirators lying on the ground or hanging from equipment with no protective containers. Inspections of these respirators revealed dirt inside the facepieces. To clean the respirators, towelettes (alcohol) were available at the tool shed. Several workers who were not clean shaven were observed wearing respirators.

Finally, NIOSH investigators observed one respirator that was modified by the wearer.

Confined Space

Workers were required to enter the barge tanks through small access portals to weld newly installed materials. The barge tanks were ventilated through the same access portal via a blower (located on the barge) and flexible duct work. Reportedly, measurements of lower explosion limits of vapors and gases, and of oxygen and carbon monoxide levels are made prior to workers entering the tanks.

During the site visit, several noteworthy observations were made. Entrance into the barge tanks was limited not only because the access portal was only two feet in diameter, but because the ventilation duct work was also routed through the same portal. The interior floors of the tanks were slippery because of water and mud and the large metal support beams in the tanks made it even more difficult for workers to move around. Maneuverability was further compromised because the tanks were poorly lighted. As defined by OSHA and NIOSH, the tanks are considered either permit–required or Class B confined spaces, respectively. Please refer to Appendix A for confined space definitions and classifications. At the time of the NIOSH site visit, AMC did not have a comprehensive confined space program.

Blood Lead Records Review

NIOSH investigators reviewed workers' blood lead records. A trend was found in the five workers who have been employed by AMC since 1996. The earliest BLLs were collected in September 1996, in which the BLLs ranged from 6 to 29 µg/dL. At the end of January 1997, the BLLs peaked (range: 13 to 56 µg/dL) and then steadily decreased through August 1997 (range: 2 to 17 µg/dL), the last BLLs collected that year. It was reported that work on the Glomar Explorer and the U.S.S. Ashtabula started around December 1996, and January 1997. From the results of the paint chip analysis and the PBZ air samples described above, the increase in BLLs was likely a result of work beginning on the USS Ashtabula and Glomar Explorer. The decrease in BLLs may be attributed to changes made in the lead control and respiratory protection programs in May 1997. That was the time the current safety officer was hired. One significant change made at that time was requiring workers in close proximity to welding and torch cutting activities to wear respiratory protection.

Review of the most recent blood lead tests, collected in May 1998, revealed that six of seven workers' BLLs increased a minimum of 5 µg/dL and a maximum of 36 µg/dL since the previous blood lead tests collected in August 1997. One workers' BLL remained the same, 10 µg/dL. The increases in BLLs are likely due to the deficiencies in the respiratory protection and lead control programs identified by NIOSH during this investigation. It is important to note that one worker's BLL decreased a total of 23 µg/dL (from 25 to 2 µg/dL) from July 1997 to August 1997 (42 days). A change of this magnitude is questionable for two reasons. First, the biological half life of lead in the blood is approximately 40–45 days.[38] This means that 40–45 days after the July 1997, blood lead test, the worker's BLL is expected to be approximately 50% less than the initial blood lead test if there was no further exposure. In this instance, the workers BLL decreased 92%. Second, the worker's blood lead test collected August 1997, was reported at 2 µg/dL. This BLL is very low even with respect to the U.S. adult population which has an overall geometric mean BLL of 3 µg/dL. Workers chronically exposed to lead are expected to have higher BLLs than workers not exposed to lead. Furthermore, the worker's BLLs over the last two years ranged from 15 to 56 µg/dL. When questionable results like this are obtained, the worker should be retested as soon as possible after the initial test.

OSHA 200 Logs Review

Review of the OSHA 200 logs for 1996 and 1997 revealed reports of several eye injuries, mostly foreign bodies in the eye. Most workers wore safety glasses or face shields while grinding or torch cutting during this investigation. However, NIOSH investigators observed several workers who were not torch cutting or grinding, but working in close proximity to these activities, who were not wearing eye protection.

Fall and Trip Hazards

During the site visit, NIOSH investigators identified fall and trip hazards on the barges. On top of the barges, workers were observed performing activities near the edge. AMC installed small sections of railing around the barge edges where most work activities were conducted. However, workers were also observed performing activities near edges where railing had not been installed and fall protection was not used. Workers did not use fall protection when climbing in or out of the barge tank which was approximately 20 feet high. Ascending out of the barge tank was more difficult because the workers' boots were muddy from walking inside the tanks.

Other Observations

Welders wore the appropriate welding helmets. Torch cutters wore a variety of different types of eye protection including tinted and clear face shields, tinted goggles, and recreational sun glasses. The tinted face shields and goggles provided adequate protection against exposures including radiation, however, the others did not.

In the process area, NIOSH investigators noticed a gaseous odor while observing work activities. Further observations revealed that a propane–containing compressed gas line (used for torch cutting) was leaking. Upon finding this leak, an AMC worker immediately fixed the problem.

During the walk–through survey, NIOSH investigators identified two areas in the dry dock where workers may be exposed to excessive noise levels: the blower used to ventilate the barge tanks and the area under the barge. Area measurements were collected with a sound level meter. Noise measurements collected within 30 feet of the blower ranged from 82 to 95 A–weighted decibels (dBA). No workers worked within 15 feet of the blower. Under the barge, noise measurements collected around the leaky compressed air hose (used for air arc gouging) ranged from 85 to 100 dBA. Workers under the barge performed activities within 5 feet of the leaky hose; however, foam earplugs were worn for protection. These measurements indicate there is potential for noise exposures in excess of the NIOSH REL of 85 dBA as an 8–hr TWA. Currently, AMC does not have a hearing conservation program.

Ergonomics

Epidemiologic Studies

Over the years, several case reports have cited certain occupational and nonoccupational risk factors which give rise to musculoskeletal injuries.[39,40,41,42] However, only recently have epidemiologic studies (cross–sectional and case–control retrospective studies) been conducted that have examined the association between job risk factors (such as repetition, awkward postures, and force) and excess musculoskeletal morbidity.[43,44,45,46,47,48] The conclusions from these studies have revealed strong associations between ergonomic risk factors and disease outcome.

Upper Limbs

Work related musculoskeletal disorders (WMSD) of the upper limbs have been associated with job tasks that include the following: (1) repetitive movements of the upper limbs, (2) forceful grasping or pinching of tools or other objects by the hands, (3) awkward positions of the hand, wrist, forearm, elbow, upper arm, shoulder, neck, and head, (4) direct pressure over the skin and muscle tissue, and (5) use of vibrating hand–held tools. Occupational groups at risk for developing WMSDs of the upper limb continue to be identified, especially in many industrial occupations where repetitive movement is a common part of many tasks.

Engineering controls are the preferred method to reduce the risk of WMSDs; however, administrative controls such as work enlargement (either increasing the number of sub–tasks within a specific work activity to decrease repetitiveness or to increase the number and/or length of rest periods within a particular work activity), job rotation, etc., can be used as an interim measure. Surveillance of WMSDs (including the use of health–care–provider reports) can aid in identifying high–risk workplaces, occupations, and industries, and in directing appropriate preventive measures.[49]

Low Back Injuries

Occupational risk factors for low back injuries include manual handling tasks,[50] twisting,[51] bending, falling,[52] reaching,[53] lifting excessive weight,[54,55] prolonged sitting, and vibration.[56] Some nonoccupational risk factors for low back injury include obesity,[57] genetic factors,[58] and job satisfaction.[59,60] Multiple approaches such as job redesign, worker placement, and training may be the best methods for controlling back injuries and pain.[61]

Interaction Between Upper Limb Posture and Air Contaminant Exposure

Several studies have indicated that shipyard welders have a high incidence of shoulder pain, and that muscle pain and fatigue are greatest when welding is performed in overhead positions.[62,63,64] Research has suggested that these symptoms are due most to static loading of the supraspinatus shoulder muscle.[65] These effects have also been found to be reduced by welder experience and weld position.[66] Specifically, fatigue is reduced in positions where the horizontal distance from the welder's face to the weld arc is minimized and the weld is performed in the flat position while standing or sitting. However, investigators have also suggested that posture affects exposure to welding fumes and that the positions required to minimize exposure are opposite of those required to reduce static loading and fatigue. Specifically, to reduce exposure, the horizontal distance from a welder's face to the weld arc should be maximized while the vertical distance above the arc should be minimized.[67,68,69] This is due to the nature of the weld plume, which rises and widens quickly. Thus, it appears that welding ergonomics and welding fume exposure reduction require a compromise when deciding how best to preserve the health of the welder. Fume extraction may offer a solution.

Table 6 shows worker task analyses for the welding, cutting, asphalt removal, and grinding jobs analyzed using the MVTA system. The table shows the time in seconds spent completing each element of the particular task. Included are the mean element duration with standard deviation, and "% of task duration." "% task duration" was calculated by dividing the total element duration by the total task time.

Welding Job

The MVTA indicated that the cycle times for welding averaged 56 seconds (range 12 to 82 seconds). Of this time, the welding task element lasted an average of 35 seconds or about 63% of the basic job cycle. The time for resting was about 8 seconds or about 7% of the work cycle. The variability in time depended on the complexity of the welding task and the work practices of the welder. Figure 4 shows a typical welding position for welding plate on the hull of a barge. Static loading from holding the welding stick at or above shoulder height with one hand and welding leads with the other hand can lead to muscle fatigue and discomfort to the shoulder region.

It was estimated that the welding gun and welding leads weighed 25 lbs. Evaluation of static loading on the shoulder using the Michigan 2D Static Strength Model[70,71] indicated that 98% of males and 75% of females could perform this job without overexertion to the shoulders if the welding tool was held with both hands (see Table 7). However, when the welder used only one hand, it was determined that only 73% of males and 4% of females could perform this job without overexertion to the shoulders (see Table 8). Using two hands to hold the tool reduces biomechanical loading on the shoulders by distributing the load evenly over the supporting limbs while welding on overhead surfaces. While the University of Michigan model shows that the majority of workers can perform this task holding the welder with two hands, it is important to note that the risks for musculoskeletal disorders are potentially more serious when combinations of work risk factors are present (e.g. static loading and awkward postures) as they are found among workers welding above their heads.

Grinding

The average grinding element was approximately 23 seconds (range: 11 to 36 seconds), or 39% of the total work cycle. Repositioning either the grinder or the worker's body averaged 24 seconds. Resting was about 7 seconds or about 6% of the work cycle during the NIOSH survey. The grinding information collected was for work performed on a horizontal surface located at the feet of the worker. Grinding performed on a vertical or overhead surface would be much more stressful using the large grinders (approximately 35 lbs) observed during the survey. When vertical or overhead work is performed, it is recommended that lighter–weight grinders be used to reduce fatigue and musculoskeletal stress on the worker.

Asphalt Removal

The longest work elements during asphalt removal were the pounding and scrapping tasks (see Figures 5 and 6). The pounding task averaged 20 seconds (range: 4 to 51 seconds) or approximately 46% of the work cycle. The shortest element was resting, which averaged 5 seconds or approximately 5% of the work cycle. Carrying asphalt pieces to the wheel barrow was minimized by positioning the wheel barrow near the asphalt break work area. Using the NIOSH lifting equation, it was determined that the asphalt workers evaluated did not exceed the NIOSH lifting limits while performing their lifting tasks. Workers accomplished this by holding the asphalt pieces close to the body while lifting and by breaking the asphalt into pieces weighing less than 40 pounds.

Torch Cutting

There were five basic work elements for cutting tasks (Table 6): (1) metal cutting with a torch, (2) examining the metal cut, (3) repositioning the torch to continue the cut or start a new cut, (4) rest, and (5) other tasks such as moving the torch leads and adjusting the torch cutting lead. The average cutting time was approximately 27 seconds which was about 68% of the basic work cycle. The cutting time ranged from 4 seconds to 62 seconds. Resting averaged about 7 seconds or about 5% of the total work cycle. Stabilizing the piece being cut to prevent it from falling on the worker(s) was critical. Figures 7 and 8 show the potential hazards associated with torch cutting. Large metal pieces that are cut can fall to the ground and cause smaller metal pieces to become airborne which can result injury.

Office Work

Two of three office workers indicated that they had musculoskeletal discomfort associated with their job. The computer checklist noted that none of the three workers had chairs that were easily adjustable to accommodate their comfort needs.

Office worker #1 indicated neck and shoulder tension (trapezius muscles), as well as lower back pain associated with the job. Information gained from the computer workstation checklist indicated that this worker's office chair was more appropriate for occasional (executive style) sitting rather than long–term (secretarial style) sitting. This worker tried to adjust his posture to fit the executive style chair by putting a lumbar pillow in the back of the chair. Also, the worker needed to sit forward in the chair because the back of the chair could not be locked in the upright position. The shoulder tension reported by worker #1 also may have been due to the extended reaches to operate the computer mouse and to arrange documents on the desk that were being transcribed into the computer. The extended reach (over 20" from the midline of the worker's torso) to operate the mouse and access documents was due, in part, to file boxes located under the computer workstation leaving little room for the worker's legs.

Office worker #2 did not report any musculoskeletal symptoms. However, it was noted in the computer workstation checklist that this worker could benefit from a foot rest. When the chair was set to the proper height to reach the computer keyboard and see the computer screen, this worker's feet could not reach the floor. Because this position puts pressure on the back of the legs, the worker usually sat forward in the chair, not using the backrest. Alternative postures observed to accommodate the deficiencies of the chair was folding one leg under the chair and resting the other foot on the base supports.

Office worker #3 reported right shoulder blade (scapula) pain, left shoulder (deltoid) pain, and left elbow/forearm numbness and tingling. This worker noted that the symptoms in the forearm and elbow were transient and probably related to arthritis, but that the shoulder pain was related to the job. This worker said that the left shoulder pain was from lifting boxes, while the right shoulder blade pain was from excessive reaching to use the computer mouse or to manipulate documents near the computer. Documentation from the computer workstation checklist showed that there were no obstructions such as file boxes under the computer workstation that would require excessive reaching. However, like the other two computer workstations evaluated at AMC, the computer key tray and monitor were both located on a fixed height worktable. The absence of a computer key tray, and the lack of adjustability of the computer table resulted in this worker abducting (raising) the shoulders and reaching forward to operate the keyboard and mouse.

CONCLUSIONS

Based on the PBZ air sample results and review of the workers' past and present BLLs, NIOSH investigators determined that a health hazard exists at AMC from exposure to various metals when workers are dismantling ships, torch cutting scrap metal in the process areas, and welding in the barge tanks. PBZ air sample results indicate that 8–hr TWA concentrations for lead, cadmium, nickel, copper, and manganese exceeded relevant exposure criteria. Although workers wore half–face air–purifying respirators equipped with HEPA filters, the most recent blood lead tests (collected May 1998) revealed that six of seven workers' BLLs increased 5 μg/dL to 36 μg/dL since the last blood lead tests collected in August 1997. These increases are likely due to the deficiencies in the respiratory protection and lead control programs. Also, the increases in BLLs may be because the half–face, air–purifying respirators equipped with HEPA filters are not protective enough. Two partial–shift PBZ air samples (one in the ship and one in the process area) collected for lead were above the MUC of 500 $\mu g/m^3$ for these respirators which indicates that there is potential for 8–hr TWA air concentrations for lead to exceed the MUC for these respirators. PBZ air sample concentrations for cadmium collected in the ship were above the MUC of 50 $\mu g/m^3$ for these respirators. Also, some safety and health hazards were identified during the NIOSH site visit, such as confined space entry, fall and trip hazards, sources of excessive noise, and lack of eye protection.

Based on the ergonomic evaluation of the shipbreaking and barge repair jobs, there were biomechanical risk factors that could precipitate or aggravate musculoskeletal disorders. Good work practices were observed among employees which can reduce their risk of developing musculoskeletal disorders, however additional engineering controls (e.g. portable lifting devices for heavy objects) would further reduce their risk. Evaluation of the office work environment revealed non–adjustable office furniture and employees reporting some musculoskeletal discomfort. However, simple ergonomic fixes, such as adjusting the height of the monitors and providing foot rests for a more comfortable posture in the seated workstations, seemed to reduce some of their reported musculoskeletal discomfort. Finally, a comprehensive ergonomics program encompassed within the shipyard safety program should be established. Specific recommendations to accomplish these goals are noted below.

RECOMMENDATIONS

The following recommendations are offered to help improve the lead control, respiratory protection, and ergonomics programs at AMC and to provide guidance in the development of a comprehensive confined space program.

• Workers' exposures to lead, cadmium, and other metals should be reduced through the use of engineering, administrative, and work practice controls. In the cases of lead and cadmium, the requirements outlined in the OSHA lead (29 CFR 1910.1025) and cadmium (29 CFR 1910.1027) standards must be followed.

Shipbreaking

• Consideration should be given to removing the deck of the ship before performing torch cutting activities inside the ship. This will provide more natural dilution ventilation.

• Local exhaust ventilation systems should be used in addition to the current dilution ventilation used to lower airborne metal concentrations. Supply air duct work should be positioned so that the local exhaust system is not affected. Because of the welding and cutting activities, all duct work should be fire retardant.

• Under the current conditions (i.e., workers wearing half–face respirators and only dilution ventilation supplied to work area), no more than one torch cutter should be working in one particular area, such as the engine room. As was seen during this survey, very high airborne concentrations of lead and cadmium were found during shipbreaking activities when one worker was performing torch cutting activities. If there were more workers torch cutting in the engine room, then the lead and cadmium concentrations may have been even higher.

Process Area

• Local exhaust ventilation systems should be used to lower airborne metal concentrations. Also, workers should stay upwind of smoke and fume generated during torch cutting activities whenever possible to further lower exposures.

• Respiratory protection used inside the ship (half–face air–purifying respirators) should be upgraded to at least a full facepiece air–purifying respirator equipped with HEPA filters, provided the above engineering and administrative controls do not lower the PBZ air sample below the MUC. As described in the results section, PBZ air sample concentrations for cadmium were greater than the MUC of 50 $\mu g/m^3$ for half–face, air–purifying respirators. Full facepiece air–purifying respirators have an APF of 50, whereas half–face respirators have an APF of 10. Because of the potential for workers to perform activities in hot temperatures, powered air–purifying respirators equipped with a tight–fitting facepiece and HEPA filters may be a better choice for respiratory protection because it will supply air to the worker's face at a constant flow rate which can help keep workers cool and comfortable. If AMC upgrades to full facepiece respirators, then quantitative fit–testing is required. The minimum fit–factor required is 500.[72]

Although the MUC of 500 $\mu g/m^3$ (8–hr TWA) for lead for half–face respirators was not exceeded, two partial–shift PBZ samples (one in the ship and one in the process area) were above 500 $\mu g/m^3$ which indicates that there is a potential for exceeding the MUC for lead for half–face respirators. Therefore, consideration should be given to upgrading respirators in the process area to full facepiece tight–fitting air–purifying respirators equipped with HEPA filters or powered air–purifying respirators equipped with a tight–fitting facepiece and HEPA filters.

• The respiratory protection program at AMC can be improved. Although a program was in place, certain elements were deficient (i.e., lack of a written program, improper respirator storage, and the lack of respirator cleaning and maintenance). The respiratory protection program must, at a minimum, comply with the requirements described in the OSHA respiratory protection standard (29 CFR 1910.134).[72] Publications developed by NIOSH can also be referenced when developing an effective respirator program, including the NIOSH Respirator Decision Logic and the NIOSH Guide to Industrial Respiratory Protection.[1,73] A comprehensive respiratory protection program should include the following elements:

- written operation procedures
- appropriate respirator selection
- employee training
- effective cleaning of respirators
- proper storage
- routine inspection and repair
- exposure surveillance
- program review
- medical approval
- use of approved respirators

The respiratory protection program should also include a provision that restricts workers from having any facial hair that comes between the sealing surface of the facepiece and the face. Respirators should be cleaned and inspected daily. Workers should be instructed to immediately report any problems with their respirators to the AMC representative in charge of health & safety issues.

Workers should not be permitted to make any modifications to the respirators, such as attaching rubber hoses to the facepiece (where the filters attach), running the hoses over the shoulders and attaching the filters to the end of the hoses located at the center of the back. Making such modifications will void their NIOSH–approved status. Using respiratory protection not approved by NIOSH does not satisfy the requirements of the OSHA respiratory protection standard (29CFR1910.134).

• Improvements to the lead control program should be made. The wash facilities should be modified to prevent contamination of the clean room, to increase the use of the showers, and to decrease the possibility of contaminating street clothes which are taken home.

Separate areas for workers' clean street clothing and dirty work clothing should be established. If possible, these areas should be in separate locker rooms which are separated by the shower room. This design will prevent recontamination of workers' skin and clothing by contaminated dust.

The clean room, shower, and lunch room should be cleaned on a daily basis and all soap and towel dispensers should be filled. Cleaning should be done with a special vacuum cleaner designed for cleaning toxic dusts and equipped with a HEPA filter. If use of a special vacuum is not possible, water washing or sweeping of dust after it has been wetted with water mist are acceptable.

To reduce the accidental ingestion of metals, AMC should stress the importance of not eating, drinking, or handling tobacco products in contaminated areas. As a general rule, workers should not be allowed to wear work coveralls and other outer clothing into the lunch areas, unless the dust has been removed from the clothing by vacuuming with a HEPA vacuum. Respirators should be worn during the vacuuming of contaminated clothing for protection from airborne dust.

Warning signs should be posted in the process and dry dock areas indicating lead work areas. Signage should also indicate that smoking, eating, and drinking are not permitted.

A medical removal plan should be added to the lead control program. The plan should describe the BLLs at which a worker will be removed from all lead exposures and at what BLLs that worker will be able to return to normal work activities. According to the OSHA lead standard, workers must be removed from all lead exposures when BLLs are equal to or greater than 60 µg/dL (or an average BLL of 50 µg/dL based on the three previous blood tests). The worker cannot return to normal work activities until two consecutive BLL tests indicate that the worker's BLL is at or below 40 µg/dL.[18]

An air monitoring program should be implemented to assess workers' exposures to lead, cadmium, and other metals. Because PBZ air samples were above the OSHA PELs for lead, cadmium, and copper, PBZ air monitoring should be conducted every three months as described in the OSHA standards. This monitoring may be discontinued when two consecutive measurements, taken at least two weeks apart, are below the action limit for these compounds. Additional air monitoring should be conducted if there has been a production, process, control, or personnel change or any other reason to suspect a change which may result in new or additional exposures.

Medical monitoring (i.e., blood lead levels) should be continued. However, AMC should also test workers' blood for zinc protoporphyrin (ZPP) at least every six months as described in the OSHA lead standard.

Significant decreases or increases in BLLs, such as the one described in the results section where one worker's BLL decreased from 25 to 2 µg/dL (92% decrease in 42 days), should be considered questionable and the worker should be retested as soon as possible.

- AMC should develop a comprehensive confined space program to protect workers who must enter confined spaces such as the barge tanks. The confined space program should be established consistent with the guidelines contained in the NIOSH criteria for a recommended standard, "Working in Confined Spaces," and at a minimum, comply with the requirements in the OSHA Permit–required confined space standard (CFR 1910.146).[74,75] Please refer to Appendix B for a description of the elements of a comprehensive confined space program.

AMC should provide additional lighting in the barge tanks so workers can see and move about the tank easier and safer. The lighting should be explosion proof.

All oxygen, propane, and other compressed gas hoses should be inspected for leaks (and repaired) prior to entering the barge tanks.

- AMC should enforce the use of approved safety glasses throughout the facility which will likely decrease the number of eye injuries recorded in the OSHA 200 logs. If workers are wearing safety glasses while torch cutting, then the glasses must provide the appropriate radiation protection.

- Because AMC distributes hearing protection to workers and the results of the noise measurements indicate potential for over exposures, AMC should develop a hearing conservation program. As a guide in the development of a hearing loss prevention program, AMC should refer to the NIOSH document, "Preventing Occupational Hearing Loss: A Practical Guide."[76] To prevent unnecessary exposures to noise as was observed under the barge, all compressed air hoses should be fixed.

Ergonomics

Office Ergonomics

- Consider purchasing office chairs that can be easily adjusted by the workers to optimize their fit and function for computer tasks. The back, height, and arm support features of the chairs should be easy to adjust. There are several vendors that supply good office chairs with ergonomic features. It is recommended that the office workers try several models to find out which ones work best for them before buying a permanent chair.

- Make foot rests available for all workstations, particularly if adjustable height platform computer workstations are not immediately purchased.

• Orient all computer screens at right angles (90 degrees) from windows to minimize outside light causing glare from the computer screens.

• Place foam or rubber padding along the edges of computer tables to reduce contact stress of the forearms and elbows.

• Remove all boxes and other obstacles [excluding footrests] under computer tables to provide leg room (at least 24") while working on the computer.

Welding

• Train workers to recognize that prolonged static and awkward postures while welding increase fatigue and reduce endurance, and therefore should be avoided. Tool modification and work practices that can minimize the effects of these risk factors are:

• Select light–weight welding tools that have angled tips so that workers can perform the tasks with minimal awkward postures. Workers should hold the tools with both hands whenever possible and practical.

• For existing tools, reduce the weight of the welding tool/lead combination by hanging the lead close to the welding tool on a hook. The hook can be fixed to a magnet to make the hook portable.

• Redesign the welder handle for neutral positioning of the arms and wrist.

• Lengthen the welder arm or make it expandable to reduce the need for bending and stooping.

• Lengthen the welder handle for better leverage and to keep the hose away from the body.

• Train workers in safe dismantling techniques (top down, etc.).

• Take more mini–breaks (approximately 30 seconds) for welding tasks that are on horizontal or overhead surfaces. A rule of thumb is to reduce welding time by 30 percent if the welding task is on a horizontal versus a vertical surface below the elbows, and reduce the welding time by 50 percent if the welding task is over head.

• Keep the horizontal distance between the hands and body to a minimum, especially during overhead work. This will minimize fatigue to the upper body and reduce biomechanical loading on the back.

Grinding

• Train workers to use a neutral and relaxed posture when performing grinding operations by keeping the horizontal distance between the tool and the body to a minimum. This can be done by removing all obstacles between the worker and tool.

• Replace grinding pads when needed to reduce the amount of effort required by the worker to perform the task, i.e., allow the tool to do the work. Workers should be trained to recognize when grinding pads need to be replaced.

• Use upright sander whenever possible.

• Provide knee pads that can be fitted to the individual worker and are comfortable (rubber straps) for use when grinding in the kneeling position.

• Use effectively–damped sanders to reduce exposure to segmental vibration. Workers should also wear insulated gloves to further reduce vibration exposure during grinding operations.

Asphalt Removal

• Train workers to reduce the potential for back injuries by using proper body mechanics when performing manual material handling tasks. Avoid lifting materials over 50 lbs by breaking asphalt into small pieces, and keep the load close to the body when lifting objects, such as asphalt pieces. Also, avoid twisting the body when lifting materials, and use two hands while lifting.

• Use powered tools such as jack hammers rather than "spud" bars when breaking up asphalt. This is more time efficient and will reduce impact shock and possible musculoskeletal disorders from the spud bar impacting the asphalt.

• Locate waste bins, wheel barrows, and other waste receptacles close to the work areas to minimize manual transport and inefficient production practices.

Torch Cutting

• Position and secure the piece being cut to prevent movement of the piece while cutting and falling of debris on the worker or other workers during and after a cut. Large metal pieces that are cut and fall to the ground can hit and flip smaller metal pieces through the air which can cause injury.

• Take occasional breaks from cutting during a work task to eliminate muscle fatigue accumulation.

Finally, it is recommended that an ergonomics program that is similar to the "Seven Step" program suggested by NIOSH[77] be incorporated into the shipyard safety program. The basic elements of this program are:

- Looking for Signs of Work–Related Musculoskeletal Disorders (WMSDs).
- Setting the Stage for Action.
- Training – Building In–House Expertise.
- Data Gathering–Medical and Health Indicators.
- Data Gathering–Job Risk Factors.
- Evaluating Job Risk Factors.
- Evaluating Control effectiveness.

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Table 1
Personal Breathing Zone Air Samples for Metals Collected from Workers on U.S.S. Ashtabula
HETA 97–0196–2755

Location/Job Task	Sample time	Sample volume (liters)	Lead		Cadmium		Nickel		Copper	
			TWA	**8–hour TWA**	**TWA**	**8–hour TWA**	**TWA**	**8–hour TWA**	**TWA**	**8–hour TWA**
April 2, 1998										
* Torch cutting & removing non–ferrous materials	0825 – 1545	804	—	**435**	—	**21**	—	**14**	—	**224**
* Fire watch & help move materials	0834 – 1130	350	571	**405**	7	**10**	109	**55**	229	**168**
	1206 – 1546	440	273		12		12		120	
April 3, 1998										
Torch cutting & removing non–ferrous materials	0739 – 1126	454	330	**253**	101	**61**	44	**23**	330	**228**
	1208 – 1549	442	174		19		7		124	
Fire watch & help move materials	0741 – 1126	461	325	**329**	87	**58**	35	**29**	347	**362**
	1210 – 1549	449	334		29		22		378	
Evaluation Criteria	**NIOSH REL**		**50**		**NA, CA**		**15, CA**		**100**	
	OSHA PEL		**50**		**5**		**1000**		**100**	
	ACGIH TLV		**50, A3**		**10, A2**		**100, A1**		**200**	
Minimum Detectable Concentrations			**0.6**		**0.1**		**0.6**		**0.1**	
Minimum Quantifiable Concentrations			**2.5**		**0.4**		**1.3**		**0.4**	

All sample concentrations are presented in micrograms per cubic meter (µg/m³)

* Because activities were the same during unsampled periods, the calculated TWAs are assumed to be representative of an 8–hour exposure.

TWA = time–weighted average NA = not available CA = carcinogen

A1 = confirmed human carcinogen A2 = suspected human carcinogen A3 = confirmed animal carcinogen

Table 2
Personal Breathing Zone Air Samples for Metals Collected from Workers in Process Area
HETA 97–0196–2755

Location/Job Task	Sample time	Sample volume (liters)	Lead		Cadmium		Nickel		Copper	
			TWA	8–hour TWA	TWA	8–hour TWA	TWA	8–hour TWA	TWA	8–hour TWA
April 2, 1998										
Torch cutting material removed from Glomar Explorer	0750 – 1114	398	43	**317**	ND	**Trace**	32	**30**	33	**19**
	1114 – 1410	343	612		Trace		32		4	
	1410 – 1530	154	370		ND		21		19	
Torch cutting material removed from Glomar Explorer	0750 – 1113	406	394	**399**	ND	**Trace**	44	**43**	39	**63**
	1220 – 1410	220	359		Trace		59		173	
	1410 – 1531	162	432		ND		30		38	
April 3, 1998										
Torch cutting material removed from Glomar Explorer	0740 – 1122	433	62	**41**	ND	**ND**	9	**16**	9	**9**
	1208 – 1527	388	18		ND		24		12	
Torch cutting material removed from Glomar Explorer	0730 – 1126	460	107	**67**	Trace	**Trace**	8	**8**	33	**32**
	1205 – 1519	388	19		ND		7		31	
Torch cutting material removed from Glomar Explorer	0738 – 1122	448	223	**122**	Trace	**Trace**	1	**1**	6	**6**
	1210 – 1521	382	3		ND		1		5	
Evaluation Criteria	**NIOSH REL**		**50**		**NA, CA**		**15, CA**		**100**	
	OSHA PEL		**50**		**5**		**1000**		**100**	
	ACGIH TLV		**50, A3**		**10, A2**		**100, A1**		**200**	
Minimum Detectable Concentrations (MDC)			**0.6**		**0.1**		**0.6**		**0.1**	
Minimum Quantifiable Concentrations (MQC)			**2.5**		**0.4**		**1.3**		**0.4**	

All sample concentrations are presented in micrograms per cubic meter (μg/m^3)
Trace = concentration between MDC and MQC TWA = time–weighted average ND = not detected NA = not available
CA = carcinogen A1 = confirmed human carcinogen A2 = suspected human carcinogen A3 = confirmed animal carcinogen

Table 3
Personal Breathing Zone Air Samples for Metals
Collected from Workers Inside Barge Tank in Dry Dock
HETA 97–0196–2755

Location/Job Task	Sample time	Sample volume (liters)	Lead TWA	Lead 8–hour TWA	Manganese TWA	Manganese 8–hour TWA	Nickel TWA	Nickel 8–hour TWA	Copper TWA	Copper 8–hour TWA
April 2, 1998										
* Stick welding inside barge tank	0757 – 1026	291	72	**102**	481	**873**	ND	**ND**	12	**18**
	1026 – 1127	119	26		185		ND		5	
	1210 – 1358	211	185		1801		ND		34	
† Stick welding inside barge tank	0741 – 1128	465	114	**126**	135	**286**	ND	**Trace**	8	**10**
	1206 – 1548	455	139		440		Trace		13	
* Stick welding inside barge tank	lost sample	—	—	**79**	—	**579**	—	**Trace**	—	**11**
	1036 – 1203	174	22		184		ND		5	
	1203 – 1422	278	115		827		Trace		15	
April 3, 1998										
Stick welding inside barge tank	0745 – 1130	450	467	**325**	80	**393**	2	**3**	17	**19**
	1211 – 1600	458	186		699		3		21	
* Stick welding inside barge tank	0744 – 1129	450	356	**356**	82	**82**	2	**2**	13	**13**
	lost sample		—		—		—		—	
Evaluation Criteria	**NIOSH REL**		**50**		**1000**		**15, CA**		**100**	
	OSHA PEL		**50**		**5000, C**		**1000**		**100**	
	ACGIH TLV		**50, A3**		**200**		**100, A1**		**200**	
Minimum Detectable Concentrations (MDC)			**0.6**				**0.6**		**0.1**	
Minimum Quantifiable Concentrations (MQC)			**2.5**				**1.3**		**0.4**	

All sample concentrations are presented in micrograms per cubic meter (µg/m^3)
* Because activities were similar during unsampled periods (or sample lost), the calculated TWAs are assumed to be representative of an 8–hour exposure.
† During morning sampling period, worker stick welded under barge. During afternoon sampling period, worker stick welded inside barge.
Trace = concentration between MDC and MQC   TWA = time–weighted average   ND = not detected   C = ceiling limit
CA = carcinogen   A1 = confirmed human carcinogen   A2 = suspected human carcinogen   A3 = confirmed animal carcinogen

Table 4
Personal Breathing Zone Air Samples for Metals Collected from Workers Under Barge in Dry Dock
HETA 97–0196–2755

Location/Job Task	Sample time	Sample volume (liters)	Lead		Manganese		Nickel		Copper	
			TWA	8–hour TWA	TWA	8–hour TWA	TWA	8–hour TWA	TWA	8–hour TWA
April 2, 1998										
Stick welding under barge	0802 – 1148	463	Trace	**Trace**	71	**46**	ND	**ND**	4	**3**
	1148 – 1710	660	ND		29		ND		3	
MIG and stick welding under barge	0756 – 1150	480	ND	**ND**	96	**54**	ND	**ND**	3	**2**
	1150 – 1710	656	ND		23		ND		1	
April 3, 1998										
Stick welding under barge	0755 – 1124	418	ND	**ND**	60	**75**	ND	**ND**	3	**4**
	1218 – 1617	478	ND		88		ND		5	
MIG welding under barge	0743 – 1125	444	Trace	**Trace**	54	**47**	ND	**ND**	8	**5**
	1207 – 1617	500	ND		40		ND		2	
Evaluation Criteria	**NIOSH REL**		**50**		**1000**		**15, CA**		**100**	
	OSHA PEL		**50**		**5000, C**		**1000**		**100**	
	ACGIH TLV		**50, A3**		**200**		**100, A1**		**200**	
Minimum Detectable Concentrations (MDC)			**0.6**				**0.6**		**0.1**	
Minimum Quantifiable Concentrations (MQC)			**2.5**				**1.3**		**0.4**	

All sample concentrations are presented in micrograms per cubic meter ($\mu g/m^3$)
Trace = concentration between MDC and MQC TWA = time–weighted average ND = not detected C = ceiling limit
CA = carcinogen A1 = confirmed human carcinogen A2 = suspected human carcinogen A3 = confirmed animal carcinogen
MIG = metal inert gas

Table 5
Bulk Paint Chip Sample Analysis
Collected from Metal Structures Removed from Glomar Explorer
Process Area
HETA 97–0196–2755

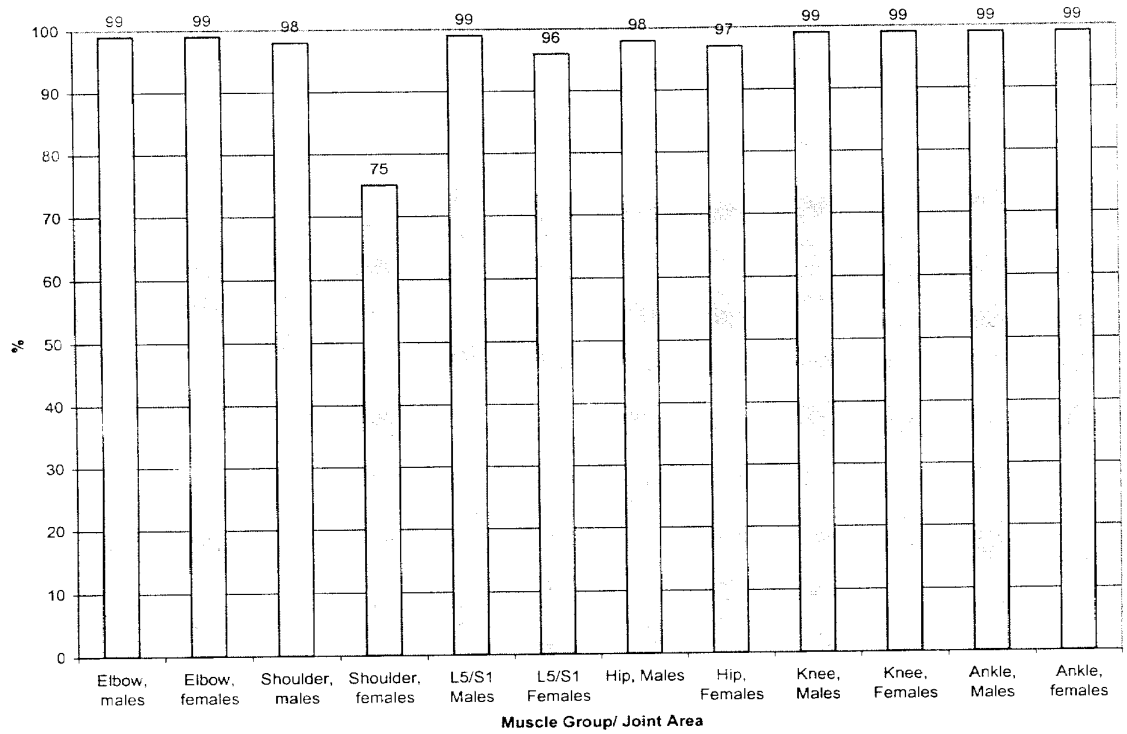
Sample Description	Grey paint collected from ladder cage on gimbal assembly	Grey paint with orange primer collected from gimbal assembly	Grey paint with orange and red primers collected from material around winch
Lead	95000	52000	790
Cadmium	not detected	not detected	7
Nickel	470	73	24
Manganese	580	200	230
Copper	670	110	220
Aluminum	5800	3600	6000
Barium	60000	84000	320
Cobalt	200	430	470
Chromium	8500	4100	97
Iron	150000	19000	32000
Magnesium	3900	3500	5000
Titanium	430	820	1600
Zinc	11000	7300	22000

All sample concentrations are presented in micrograms per gram of sample (µg/g)

Table 6
Astoria Ship–Breaking Task Analyses Using MVTA System
HETA 97–0196–2755

Task	*Element*	*Total Element Duration (sec)*	*Maximum Element Duration (sec)*	*Minimum Element Duration (sec)*	*SD*	*N*	*Mean Element Duration (sec)*	*% of Task Duration*
Welding	Welding	211.8	81.7	12.4	29.38	6	35.30	62.89
	Examine	7.6	7.6	7.6	0	1	7.6	2.26
	Re–position	42.21	22.17	5.57	8.3	3	14.07	12.53
	Rest	23.82	8.27	7.7	0.29	3	7.94	7.07
	Other	51.36	26.2	0.4	9.83	6	8.56	15.24
Cutting	Cutting	586.74	61.87	3.6	17.64	22	26.67	68.18
	Examine	64.74	17.77	0.67	5.28	13	4.98	7.52
	Re–position	136.29	19.83	1	5.35	21	6.49	15.84
	Rest	43.56	23.77	1.37	7.95	6	7.26	5.06
	Other	29.28	23.47	2.83	10.85	4	7.32	3.40
Asphalt Removal	Pounding	136.71	50.87	3.9	19.37	7	19.53	46.14
	Scraping	52.43	19.67	0.93	6.34	7	7.49	17.70
	Lifting	6.39	2.93	1.03	0.99	3	2.13	2.16
	Re–position	39.9	12.3	0.9	4.49	7	5.7	13.47
	Rest	15.12	9.17	1.47	3.88	3	5.04	5.10
	Other	45.71	12.1	1.5	3.81	7	6.53	15.42
Grinding	Grinding	46.6	35.7	10.8	17.58	2	23.3	39.27
	Examine	17.14	15.53	1.60	9.85	2	8.57	14.42
	Re–position	47.44	18.57	5.4	9.31	2	23.72	39.97
	Rest	7.5	7.5	7.5	0	1	7.5	6.32

Table 7: Percentage Capable of Performing Two-Handed Welding Task*



- Based on Michigan 2D Static Biomechanical Model, using the following variables:

<u>Force Parameters:</u>

Magnitude: 25 lbs
Direction: -90 degrees
Number of Hands: **2**

<u>Anthropometry Data:</u>

Percentile: 50% males; 50% females
Height: 70 in males; 64 in females
Weight: 166 lbs males; 137 lbs females

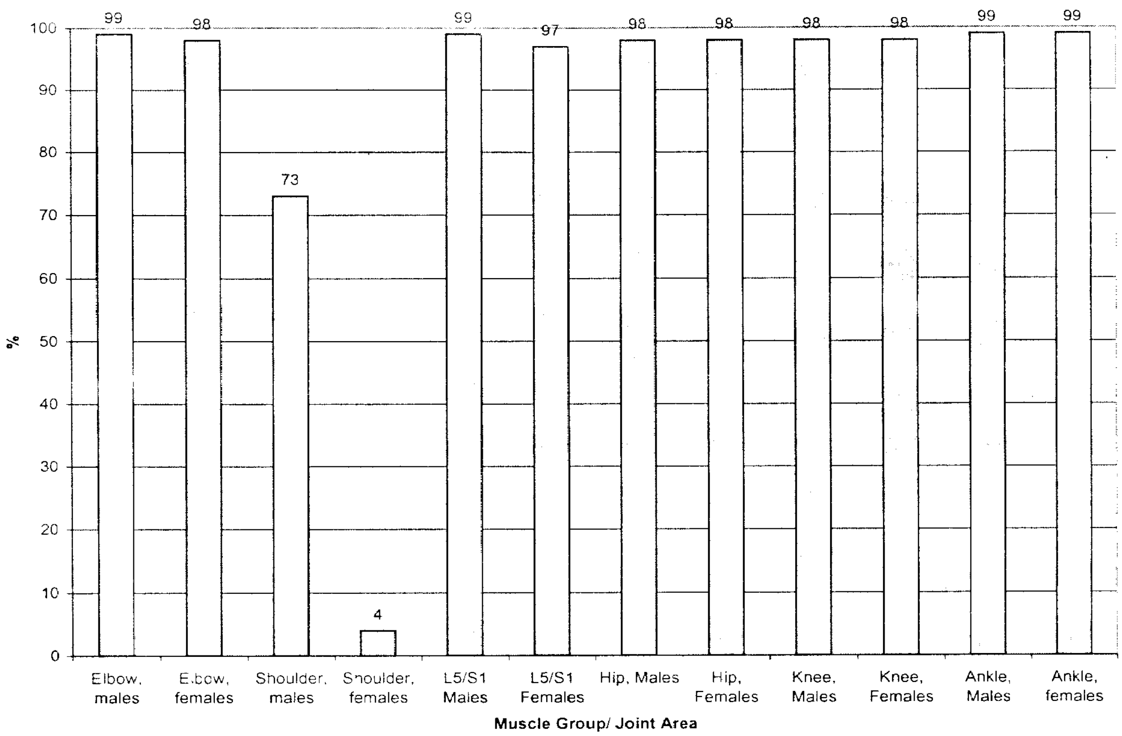
<u>Posture Data: Link Angles form Horizontal</u>

Lower Arm: 65 degrees
Upper Arm: -10 degrees
Torso: 95 degrees
Upper Leg: 110 degrees
Lower Leg: 80 degrees

<u>Load Variables:</u>

Horizontal distance of load = 14 in
Vertical distance of load = 62 in
L5/S1 to hand distance = 18 in

Table 8: Percentage Capable of Performing a One-Handed Welding Task*



- Based on Michigan 2D Static Biomechanical Model, using the following variables:

Force Parameters:

Magnitude: 25 lbs
Direction: -90 degrees
Number of Hands: 1

Anthropometry Data:

Percentile: 50% males; 50% females
Height: 70 in males; 64 in females
Weight: 166 lbs males; 137 lbs females

Posture Data: Link Angles form Horizontal

Lower Arm: 65 degrees
Upper Arm: -10 degrees
Torso: 95 degrees
Upper Leg: 110 degrees
Lower Leg: 80 degrees

Load Variables:

Horizontal distance of load = 14 in
Vertical distance of load = 62 in
L5/S1 to hand distance = 18 in

Figure 1: Symptoms Survey form NIOSH publication Elements of Ergonomics Programs: A primer based on workplace evaluations of musculoskeletal disorders (publications #97–117) pg. 87.

Tray 4–A. Symptoms Survey Form

Symptoms Survey: Ergonomics Program

Date _____/ _____/ _____

_____ _____ Job Name ___________________________
Plant Dept#

_____ _________________ _____years _____months
Shift Hours worked/week Time on this Job

Other jobs you have done in the last year (for more than 2 weeks)

_____ _____ ______________ _____months _____weeks
Plant Dept# Job Name Time on this Job

_____ _____ ______________ _____months _____weeks
Plant Dept# Job Name Time on this Job

(If more than 2 jobs, include those you worked on the most)

Have you had any pain or discomfort during the last year?

- ❑ Yes
- ❑ No (If NO, stop here)

If YES, carefully shade in area of the drawing which bothers you the MOST.

Figure 2: Symptoms Survey (continued) from NIOSH publication Elements of Ergonomics Programs: A primer based on workplace evaluations of musculoskeletal disorders (publications #97–117) pg. 88.

(Complete a separate page for each area that bothers you)
Check Area:

❑ Neck ❑ Shoulder ❑ Elbow/Forearm ❑ Hand/Wrist ❑ Fingers

❑ Upper Back ❑ Low Back ❑ Thigh/Knee ❑ Low Leg ❑ Ankle/Foot

1. Please put a check by the word (s) that best describe your problem

❑ Aching ❑ Numbness (asleep) ❑ Tingling

❑ Burning ❑ Pain ❑ Weakness

❑ Cramping ❑ Swelling ❑ Other

❑ Loss of Color ❑ Stiffness

2. When did you first notice the problem? ___________(month) __________ (year)
3. How long does each episode last? (Mark an X along the line)

_______/ _______/ _______/ _______/ _______/
1 hour 1 day 1 week 1 month 6 months

4. How many separate episodes have you had in the last year?______________________
5. What do you think caused the problem?____________________________________

____

6. Have you had this problem in the last 7 days?

❑ Yes ❑ No

7. How would you rate this problem? (mark an X on the line)
NOW

____
None Unbearable
When it is the WORST

____
None Unbearable

8. Have you had medical treatment for this problem?

❑ Yes ❑ No

8a. If NO, why not? ________________________________
8a. If YES, where did you receive treatment?
❑ 1. Company Medical Times in past year ______________________
❑ 2. Personal doctor Times in past year ______________________
❑ 3. Other Times in past year ______________________
Did treatment help?

❑ Yes ❑ No

9. How much time have you lost in the last year because of this problem?_______days
10.How many days in the last year were you on restricted or light duty because of this problem? ________days
11. Please comment on what you think would improve your symptoms ____________________________________

____

____

Figure 3: Computer Checklist from NIOSH publication: Elements of Ergonomics Programs: A primer based on workplace evaluations of musculoskeletal disorders (publications #97–117) pg. 99

Tray 5–G. Computer Workstation Checklist

"No" responses indicate potential problem areas which should receive further investigation.

1. Does the workstation ensure proper worker posture, such as		
horizontal thighs?	❑ yes	❑ no
vertical lower legs?	❑ yes	❑ no
feet flat on floor or footrest?	❑ yes	❑ no
neutral wrists?	❑ yes	❑ no
2. Does the chair		
adjust easily?	❑ yes	❑ no
have a padded seat with a rounded front?	❑ yes	❑ no
have an adjustable backrest?	❑ yes	❑ no
provide lumbar support?	❑ yes	❑ no
have casters?	❑ yes	❑ no
3. Are the height and tilt of the work surface on which the keyboard is located adjustable?	❑ yes	❑ no
4. Is the keyboard detachable?	❑ yes	❑ no
5. Do keying actions require minimal force?	❑ yes	❑ no
6. Is there an adjustable document holder?	❑ yes	❑ no
7. Are arm rests provided where needed?	❑ yes	❑ no
8. Are glare and reflections avoided?	❑ yes	❑ no
9. Does the monitor have brightness and contrast controls?	❑ yes	❑ no
10. Do the operators judge the distance between eyes and work to be satisfactory for their viewing needs?	❑ yes	❑ no
11. Is there sufficient space for knees and feet?	❑ yes	❑ no
12. Can the workstation be used for either right- or left-handed activity?	❑ yes	❑ no
13. Are adequate rest breaks provided for task demands?	❑ yes	❑ no
14. Are high stroke rates avoided by		
job rotation?	❑ yes	❑ no
self-pacing?	❑ yes	❑ no
adjusting the job to the skill of the worker?	❑ yes	❑ no
15. Are employees trained in		
proper postures?	❑ yes	❑ no
proper work methods?	❑ yes	❑ no
when and how to adjust their workstations?	❑ yes	❑ no
how to seek assistance for their concerns?	❑ yes	❑ no

Figure 4. Typical welding position for welding plate on hull of barge. Static loading from holding welding stick with one hand and welding leads with the other hand can lead to shoulder muscle fatigue and discomfort.

Figure 5. Employee using "spud" bar to scrape asphalt from the deck of the barge. Extended reaches, awkward postures, and high forces used to dislodge asphalt may cause musculoskeletal overexertion injuries to the back and upper limbs.

Figure 6. Employee using "spud" bar to break up asphalt on barge. Manual application and reaction forces to and from the spud bar may cause musculoskeletal disorders, especially when combined with high repetition and force.

Figure 7. Torch cutter moving sharp metal pieces away before the final cut of a large metal piece located above shoulder level. Large metal pieces that are cut and fall to the ground can hit and flip smaller metal pieces through the air which can cause injury.

Figure 8. Torch cutter moves out of the way before large metal piece falls to the ground. Constant safety awareness is needed to avoid direct injury, or in the case above, indirect by moving smaller metal pieces away from the "fall" zone of the larger metal pieces.

APPENDIX A

The Occupational Safety and Health Administration (OSHA) regulation 29 CFR 1910.146 defines a confined space as a space that meets these three criteria:

1) is large enough and configured so that a worker can bodily enter and perform any assigned work;

2) is a space that has limited or restricted means for entry or exit (for example, tanks, vessels, storage bins, vaults, and pits that have limited means of entry); and

3) space that is not designed for continuous worker occupancy.

OSHA further distinguishes confined spaces based on the potential of the space to pose hazardous exposure conditions and classifies these spaces as non–permit verses permit–required confined spaces. A space is a permit–required confined space if it meets the OSHA definition as listed above and it meets one or more of the following criteria:

1) a space that contains or has a potential to contain a hazardous atmosphere;

2) a space that contains a material that has the potential for engulfing (surrounding and capturing of a person by a liquid or finely divided solid substance that can be aspirated and cause death or that can exert enough pressure to cause death by strangulation, constriction, or crushing) the person entering the space. [One good example of a space that may have the potential of engulfment would be a grain bin or silo]; and

3) the internal configuration of the space is designed in a way that the person entering the space could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross section; or 4) a space that contains any other recognized serious safety or health hazard.[1]

NIOSH defines a confined space as "an area which by design has limited openings for entry and exit, unfavorable natural ventilation which could contain (or produce) dangerous air contaminates, and which is not intended for continuous employee occupancy.[2] The NIOSH criteria for working in confined spaces further classifies confined spaces based upon the atmospheric characteristics such as oxygen level, flammability, and toxicity. As shown in Table 1, if any of the hazards present a situation which is immediately dangerous to life or health (IDLH), the confined space is designated Class A. A Class B confined space has the potential for causing injury and/or illness but is not an IDLH atmosphere. A Class C Confined space would be one in which the hazard potential would not require any special modification of the work procedure. Table 2 lists the confined space program elements which are recommended (or must be considered by a qualified person, as defined by the criteria) before entering and during work within confined spaces based on the established hazard classification.

Table 1 – A
CONFINED SPACE CLASSIFICATION TABLE
HETA 97–0196–2755

Parameters	Class A	Class B	Class C
Characteristics	Immediately dangerous to life – rescue procedures require the entry of more than one individual fully equipped with life support equipment – maintenance of communication requires an additional standby person stationed within the confined space	Dangerous, but not immediately life threatening – rescue procedures require the entry of no more than one individual fully equipped with life support equipment – indirect visual or auditory communication with workers	Potential hazard – requires no modification of work procedures – standard rescue procedures – direct communication with workers, from outside the confined space
Oxygen	16% or less *(122 mm Hg) or greater than 25% *(190 mm HG)	16.1% to 19.4% *(122 – 147 mm Hg) or 21.5% to 25% (163 – 190 mm Hg)	19.5 % – 21.4% *(148 – 163 mm Hg)
Flammability Characteristics	20% or greater of LFL	10% – 19% LFL	10% LFL or less
Toxicity	**IDLH	greater than contamination level, referenced in 29 CFR Part 1910 Sub Part Z – less than **IDLH	less than contamination level referenced in 29 CFR Part 1910 Sub Part Z

* Based upon a total atmospheric pressure of 760 mm Hg (sea level)

** Immediately Dangerous to Life or Health – as referenced in NIOSH Registry of Toxic and Chemical Substances, Manufacturing Chemists data sheets, industrial hygiene guides or other recognized authorities.

NIOSH [1979]. Criteria for a recommended standard: working in confined spaces. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 80–106.

Table 2 –A
Check List of Considerations for Entry, Working in and Exiting Confined Spaces
HETA 97–0196–2755

	ITEM	CLASS A	CLASS B	CLASS C
1.	Permit	X	X	X
2.	Atmospheric Testing	X	X	X
3.	Monitoring	X	0	0
4.	Medical Surveillance	X	X	0
5.	Training of Personnel	X	X	X
6.	Labeling and Posting	X	X	X
7.	Preparation			
	Isolate/lockout/tag	X	X	0
	Purge and ventilate	X	X	0
	Cleaning Processes	0	0	0
	Requirements for special Equipment/tools	X	X	0
8.	Procedures			
	Initial plan	X	X	X
	Standby	X	X	0
	Communications/observation	X	X	X
	Rescue	X	X	X
	Work	X	X	X
9.	Safety Equipment and Clothing			
	Head protection	0	0	0
	Hearing protection	0	0	0
	Hand protection	0	0	0
	Foot protection	0	0	0
	Body protection	0	0	0
	Respiratory protection	0	0	
	Safety belts	X	X	X
	Life lines, harness	X	0	
10.	Rescue Equipment	X	X	X
11.	Recordkeeping/Exposure	X	X	

X = indicates requirement
0 = indicates determination by the qualified person

NIOSH [1979]. Criteria for a recommended standard: working in confined spaces. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 80–106.

REFERENCES – APPENDIX A

1. Code of Federal Regulations [1998]. 29 CFR 1910.146. Permit–required confined spaces. Washington, DC: U.S. Government Printing Office, Federal Register.

2. NIOSH [1979]. Criteria for a recommended standard: working in confined spaces. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 80–106.

APPENDIX B

Elements of a Comprehensive Confined Space Program
Astoria Metal Corporation
97–0196–2755

1. Written Program – A detailed written document is necessary to specifically describe the company procedures and policies in regards to confined space entry. The input from management, technical experts, physician(s), labor union (if applicable), and the affected employees should be considered when developing the confined space program. This program can only be effective with the full support of plant management and the strict adherence to the established procedures by employees.

2. Medical Examinations and Policies – Preplacement and periodic medical examinations should be provided to all employees included in the confined space management program. Periodic exams should be conducted at least annually, and should include a comprehensive work and medical history with special emphasis on sensory attributes and cardio–pulmonary systems (if respiratory protection is required). Written medical policies should be established which clearly describe specific predisposing conditions that cause the employee to be at higher risk of injury due to confined space entry (or rescue), and the limitations and/or protective measures implemented in such cases.

3. Employee Education and Training – All employees included in the confined space management program or emergency contingency procedures should receive periodic training regarding the hazards of confined spaces, entry and exit procedures, lock–out and other energy isolation methods, use of safety equipment including respiratory protection and communication systems, emergency rescue exercises, CPR and first aid procedures, and other precautionary measures of the site specific confined space management program. For training programs to be effective, classroom lectures should be supplemented with "hands–on" exercises, measures to evaluate competency, and "on the job" training of journey level workers under the field supervision of experienced workers. The content of the training program(s) should be tailored to the individual needs of workers who function in different capacities (i.e., confined space entrant, stand–by attendant, rescue personnel, site coordinator or program administrator).

4. Inventory and Posting – All equipment which contain hazardous confined spaces and may require work necessitating entry should be identified and a comprehensive inventory should be established which records the equipment identifier, location, function, and preventive maintenance schedule. These confined spaces should be posted in readily visible locations along all of the perimeter entrances. The information on the warning sign should include the potential hazards of the confined space, the required protective gear (and permit procedures) for entry, and the emergency contacts.

5. Permit Application and Review – In an effort to prevent unauthorized and improperly protected entry into (or work affecting) confined spaces a written application and permit approval system should be implemented. The application should describe the confined space, location, work tasks to be accomplished including the procedures, and time schedule. The application must be reviewed by a qualified person who can anticipate potential hazards, select the required precautionary measures (and equipment) necessary for entry, and grant approval via a written permit which contains all of this information. Naturally, strict adherence to the conditions described in the permit is essential for effective control of the potential hazards using a permit system.

6. Isolation of Energy – It is critical for all forms of potential energy to be isolated ("de–energized") prior to and for the duration of worker entry in confined spaces. This includes electrical circuits, mechanical components, flow of materials, and may entail lock–out/tag–out procedures of electrical boxes, blanking of pipelines and valves, and disconnecting mechanical drive trains or linkages. The minimum requirements to comply with the General Industry standard for lock–out procedures enforced by OSHA is described in 29 CFR 1910. 147. The underlying premise of an effective lock–out safety program is that for each worker a separate lock is used to isolate the source of energy, with only one key in possession of that worker while present within the confined space (or otherwise exposed to machinery hazards requiring lock–out).

7. Atmosphere Testing and Monitoring – In order to determine hazard potential of the atmosphere within a confined space initial testing the environmental conditions is essential prior to entry. Initial atmospheric tests must include evaluations of oxygen level, flammables/explosives, toxin concentrations, and possibly evaluations of physical agents or explosivity potential of airborne dust. Because of the potential for the atmosphere within a confined space to rapidly change (from the impact the work process or adjacent air spaces may have by generating air contaminants or reducing the oxygen partial pressure) continuous or frequent monitoring is advisable. Acceptable levels of oxygen range from 19.5 to 23.5% oxygen; levels below 19.5% warrant the use of supplied air respiratory protection to protect against the oxygen deficiency and levels above 23.5% expand the flammable limits of combustible and explosive materials requiring special attention to the fire potential. Satisfactory level of flammables is generally regarded as 10% of the lower flammable limit (LFL), however, the oxygen level must determined prior to monitoring the LFL due to the error (lower LFL determinations) possible with many instrument when used in an oxygen deficient atmosphere. The relevant occupational exposure criteria (NIOSH REL, OSHA PEL, or ACGIH TLV) should be applied to evaluate worker exposure to toxic air concentrations. Unknown atmospheres must be treated as containing the most hazardous level since the consequences could be catastrophic, requiring the application of the most protective measures (i.e., use of air supplied respiratory protection with escape provisions if the oxygen level was not determined).

8. Purge and Ventilate – In order to reduce air contaminants or increase the oxygen level to acceptable levels, it is often necessary to purge the air space by displacement with liquid or vapor (inert gas, water, steam, or cleaning solution) or by forced air ventilation. [If the vessel was displaced with liquid or vapor, it is essential to use forced air following the displacement and ensure adequate oxygen level by atmospheric monitoring.] After the space has been purged (or otherwise determined to contain a safe atmosphere) continuous ventilation is required to maintain the safe atmosphere for the duration of the work process requiring occupancy. Before forced air ventilation is utilized, one must consider the nature of the air contaminants, the size and orientation of the confined space, the work to be performed, as well as the number and location of workers present within the space. Oxygen must never be used in lieu of normal air (which only contains 20.9% oxygen); the use of oxygen can expand the limits of flammability and increase the possibility of fire or explosion and enhance the severity should one occur.

9. Respiratory Protection – Respiratory protection may be required to enter confined spaces depending on the hazard potential of the atmosphere. If respiratory protection is used for normal work procedures or rescue operations, a program must be developed in accordance with the OSHA standards as referenced in 29 CFR 1910.134. Appropriate respiratory protection must be selected on the basis of the air contaminants and exposure concentrations to ensure that the workers exposure does not exceed the protection factor of the respiratory. Air purifying respirators do not supply oxygen other than that present from the contaminated air, hence air purifying respirators must not be used in oxygen deficient atmospheres. Self contained breathing apparatus (SCBA) or an air supplied respirator with an escape air bottle are the only types of respiratory protection approved for confined space entry in an oxygen deficient atmosphere. The minimum service time for SCBAs should be calculated based on the entry time, plus the maximum work period, and

twice the estimated escape time to provide an adequate margin of safety. Accessibility through narrow openings present with many types of confined spaces is an important consideration which may preempt the use of this equipment.

10. Personal Protective Equipment and Safety Equipment – Additional safety and personal protective equipment besides respiratory protection may be necessary to adequately protect workers during confined space operations. All of the potential hazardous conditions and respective injury from unprotected exposure must be considered when selecting the appropriate safety equipment which may include hard hats, hearing protection, work gloves, cover–alls, (or chemical impermeable gloves and clothing), eye protection, fall protection, etc. Work being performed in classified flammable atmospheres warrants the use of explosion proof lighting, power tools and any other electrical equipment. Full chest harness fall restraints and retrieval equipment is advised over "safety" belts, but the effectiveness of this equipment for vertical retrieval is questionable without the associated mechanical lifting devices.

11. Cleaning and Decontamination – Decontamination of surfaces within confined spaces provides additional worker protection by reducing the inhalation potential (if the contaminated surface contains volatile components) and by eliminating a dermal contact hazard of toxic materials which could be absorbed or otherwise produce irritation/inflammation by direct contact. Obviously, it may be a preventive maintenance task such as cleaning that requires entry into the confined space in the first place; the cleaning procedures by itself can generate hazardous conditions especially if flammable materials are employed which warrants continuous (or frequent) monitoring of the atmosphere.

12. Stand–by Attendant and Communication System – No worker should be allowed to work in confined space areas without another person present directly outside the space. A buddy system allows workers to observe fellow workers during their duties for evaluation of confined space procedures, allows early detection and correction of problems, provides surveillance of work progress, and would also provide a quicker response to a confined space incident. The stand–by attendant cannot function as desired without effective communication with the confined space occupant(s); often visual observation of the confined space occupant by the attendant is obstructed necessitating radio contact or another means of effective audible communication.

13. Contractor Coordination Procedures and Policies – When work within a confined space is conducted by a hired contractor, the employer who owns and operates the confined space has a responsibility to ensure that appropriate confined space entry precautions are in fact utilized by the contractor. The contractor must be informed that the proposed work is within a confined space, and the potential hazards must be identified along with the minimum precautionary measures and procedures required for acceptable entry. The controlling employer should also coordinate and enforce adherence to the confined space entry procedures, especially when both contractor and host company employees must enter the space concurrently or when multiple contractors are present. The contractors have a legal responsibility to protect the safety of their own employees; as a check method, the contractor must obtain all of the necessary background information from the host company and insist on effective confined space entry procedure even if not required to do so by the host company. The contractor should also inform the host employer of the specific details of the confined space program and work procedures that will be employed including any additional hazards that the contracted work will generate.

14. Emergency Contingency Procedures – Well planned contingency procedures should be established in writing and followed during times of a confined space emergency. These procedures should address initial rescue efforts, CPR/first aid procedures, victim transport, medical facility/service arrangements, and emergency contacts. Specific individuals (and alternatives) should be assigned a function within the scope

of the contingency plan and periodic practice exercises should be conducted to enhance familiarity with the plan and identify any deficiencies. Everyone involved must memorize their role and responsibilities since response time is critical during a confined space emergency. Multiple fatalities due to confined space accidents are often due to a spontaneous reaction instead of a well planned and executed rescue operation. The importance of properly trained and equipped stand–by and rescue personnel with quick accessibility to the confined space location cannot be overstated. Special consideration must be given to specific design and orientation of each confined space when developing contingency procedures as well as the methods required to withdraw an unconscious or injured worker without producing additional injuries.

15. Assessment of Program Performance and Surveillance of Confined Space Related Incidents – In order to identify deficiencies with the confined space management program a periodic review is warranted. Input from the workers affected by the program is necessary for the evaluation of the program to be effective. Identification and analysis of the circumstances pertinent to any confined space accident is also crucial for correcting program deficiencies. Generating and maintaining records pertaining to each confined space operation, the protective measures employed, calibration of equipment, as well as information relative to confined space incidents or near misses are necessary to adequately evaluate the program.

For Information on Other
Occupational Safety and Health Concerns

Call NIOSH at:
1–800–35–NIOSH (356–4674)
or visit the NIOSH Web site at:
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