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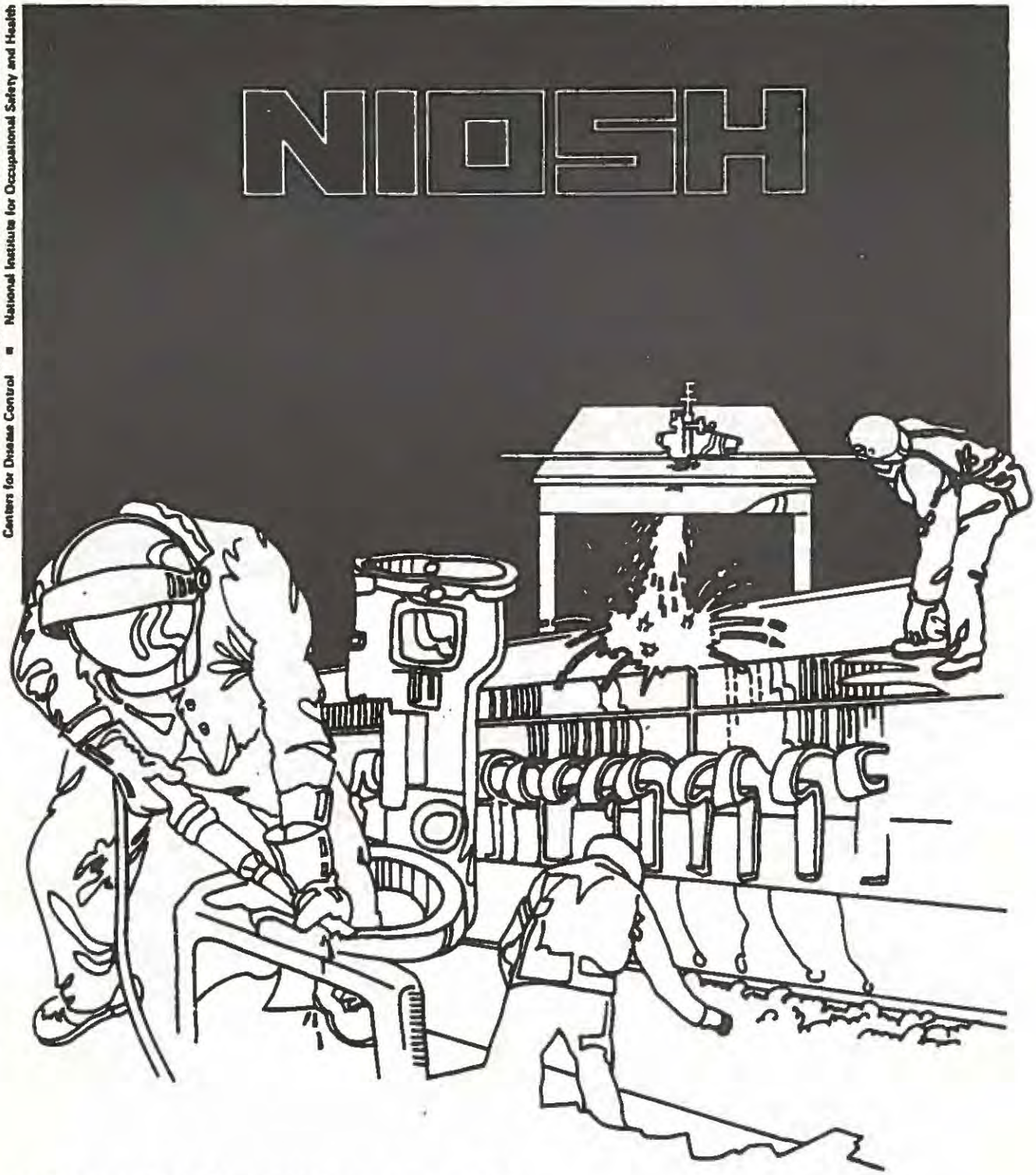

Health Hazard Evaluation Report

HETA 85-132-1598
MYSTIC SEAPORT
MYSTIC, CONNECTICUT

PREFACE

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

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

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May 1985
MYSTIC SEAPORT
MYSTIC, CONNECTICUT

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I. SUMMARY

On January 15, 1985, The National Institute for Occupational Safety and Health (NIOSH) was requested to evaluate occupational exposures to lead in shipfitters cutting and rivetting lead-painted iron plates aboard the Joseph Conrad, an iron-hulled sailing vessel at the Mystic Seaport, Mystic, Connecticut.

On January 31 and February 1, 1985, NIOSH investigators conducted an environmental and medical investigation. Personal (breathing zone) and area air samples were collected. Ventilation was assessed. Medical and occupational histories were taken. Venous blood samples were obtained for determination of blood lead, erythrocyte protoporporphyrin (EP) and hemoglobin levels. Measurements were made of exposure to noise.

Lead exposures in 7 personal air samples on shipfitters ranged from 108 to 500 ug/m^3 (mean, 257 ug/m^3). All were above the Occupational Safety and Health Administration (OSHA) exposure standard of 50 ug/m^3. In two short-term air samples, taken while the exhaust ventilation was temporarily disconnected, lead concentrations rose to 375 and 718 ug/m^3 (mean, 547 ug/m^3).

Noise level readings immediately adjacent to the riveting ranged from 120 to 123 dBA (mean 121 dBA). Readings obtained 10 to 15 meters from the rivetting averaged 114 dBA. These readings are substantially in excess of the noise exposure standard recommended by NIOSH.

Blood lead levels in ten shipfitters ranged from 25 to 53 ug/dl (mean, 37.8 ug/dl). Levels in three of these workers exceeded the upper normal limit of 40 ug/dl. Lead levels in shipfitters were significantly higher ($p \leq 0.001$) than in other shipyard workers (mean, 10.0 ug/dl). Smoking shipfitters (mean 47 ug/dl) had higher blood lead levels than non-smokers (mean 32 ug/dl; $p = 0.03$). Lead levels in shipfitters who regularly wore respirators were not lower than in those who wore no respirators ($p = 0.68$). Four shipfitters, but no other workers, had EP levels above the adult upper normal limit of 50 ug/dl. A close correlation was observed between blood lead and EP levels ($r = 0.70$). Prevalence of lead-related symptoms was not higher in shipfitters than in other workers. No cases of symptomatic lead poisoning were noted.

We conclude that shipfitters aboard the Joseph Conrad experienced excessive exposures to lead and to noise. The severity of the lead hazard was increased by (1) the high temperatures of the cutting and rivetting, which caused evolution of a lead fume, and (2) the need to work in a confined space. Although these hazards have now been abated by the completion of iron work aboard the Conrad, recommendations to prevent their recurrence are offered in Section VIII of this report.

KEYWORDS: SIC 3731 (Ship Building and Repairing);Lead; Noise

II. INTRODUCTION

On January 15, 1985, the National Institute for Occupational Safety and Health (NIOSH) received a joint request from workers and management at the Mystic Seaport, Mystic, Connecticut to evaluate occupational exposure to lead in workers cutting and rivetting lead-painted iron plates on the Joseph Conrad, a 103-year-old iron-hulled sailing vessel.

On January 31 and February 1, 1985, NIOSH investigators travelled to the Mystic Seaport to conduct an environmental and medical evaluation. Work practices and ventilation systems aboard the Conrad were assessed. Air and blood samples were obtained to evaluate exposures to lead. Measurements were made of exposure to noise.

Preliminary recommendations for the abatement of lead and noise exposures were made to shipyard officials on February 1, at the conclusion of the field investigation. Additional, more detailed recommendations were made in followup telephone conversations with Seaport staff on March 26, 1985. Letters summarizing individual results were sent to survey participants on April 4, 1985.

III. BACKGROUND

The Mystic Seaport is an outdoor maritime museum which includes historic ships, boats, buildings and exhibits relating to American maritime history. The museum was founded in 1929. Three major vessels, the Charles W. Morgan, America's last surviving wooden whaleship; the L.A. Dunton, a fishing schooner; and the full-rigged, iron-hulled training ship Joseph Conrad lie at the seaport's wharfs and docks. A major component of the museum is a preservation shipyard, in which skilled craftspersons employ traditional techniques in the preservation and restoration of historic vessels.

The Joseph Conrad, the subject of the present investigation, was launched at Copenhagen, Denmark on March 11, 1882. Originally named the Georg Stage, she saw service initially as a training vessel for Danish naval cadets. On June 26, 1905, near Copenhagen, the Georg Stage was rammed and sunk by the British steamer Ancona. Six weeks later, however, she was salvaged and continued service in Denmark for approximately another 30 years.

In 1934, the Georg Stage was purchased by an Australian yachtsman, Alan Viliers. Viliers changed the name to Joseph Conrad. Over the next two years, with Viliers as captain, she circumnavigated the globe by way of Cape Horn and the Cape of Good Hope.

In 1939, the Conrad was sold to an American, G. Huntington Hartford. Hartford used her as a private yacht and had her fitted with a diesel engine and other amenities.

In 1939, at the start of World War II, the Conrad was turned over to the U.S. Maritime Commission for use as a merchant marine training ship. Berthed at St. Petersburg, Florida, she served in that capacity throughout the war years.

In 1947, ownership of the Conrad was transferred by Act of Congress to the Mystic Seaport. Since that time she has been permanently berthed at Mystic, where she serves as a floating hostel for young people who come to the Seaport to learn the basics of small boat sailing, navigation, seamanship and maritime history.

The current refitting of the Conrad began in September 1984. She was down rigged, and the worn teak deck was removed to be replaced with new decking. Extensive iron work was undertaken belowdecks. The wiring and sprinklers are to be replaced. The structure of the galley house and of several companionways is being altered so as to conform more closely to the original design of the ship. To enable this work to continue throughout the winter months, the undecked hull was covered with protective plastic sheeting.

In keeping with the Shipyard's use of traditional restoration techniques, wrought iron plates were joined together with hot rivets, rather than by welding. In this technique, old rivets are removed with a pneumatic rivet-buster, and old lead-painted plates are cut out with oxyacetylene torches. New plates are then fastened with rivets which are heated in a forge, put into place with tongs and secured with pneumatic rivet guns. In the early stages of this work, a putty, which consisted of 15 per cent lead tetraoxide, was applied at the point of insertion of each rivet. That practice was, however, discontinued because the heated putty emitted a dense, acrid smoke, and also because of concern about exposure to lead.

Ventilation during the refitting of the Conrad consisted initially only of a fan which was situated at the top of the covered hull. Subsequently, as concern arose about possible exposure to lead, a local exhaust ventilation system employing a flexible duct was installed; this system allowed an exhaust duct to be placed adjacent to the point of rivetting to provide extraction ventilation.

Respirators, approved for protection against dust and organic vapors (activated carbon cartridge with prefilter) were available to workers for use during rivetting. A comprehensive system for respirator maintenance was, however, not in place, and workers were permitted to wear respirators over beards. Hearing protection (both ear-muffs and ear-plugs) was available.

IV. EVALUATION DESIGN AND METHODS

Industrial Hygiene

To evaluate workers' exposures to airborne lead, personal (breathing zone) and area air sampling was undertaken. Breathing zone air samples were collected on seven workers, all of whom were engaged in repair work aboard the Conrad. Area air samples were collected at two stationary locations while rivetting was underway.

Additionally, to recreate the more adverse exposure conditions which were reported to have existed during the initial phases of the refitting, we collected two short-term air samples with the local exhaust ventilation temporarily disconnected and with temporary reintroduction to the process of the lead-based putty.

Air samples were collected on cellulose ester filters with an 0.8 um pore size. Samples were analyzed for lead content by atomic absorption spectroscopy. Samples were ashed with nitric and perchloric acids according to NIOSH Method P&CAM 7300[1] and diluted to 25 ml. Analyses were then completed according to NIOSH Method P&CAM 7082[2].

Noise level readings were made using a General Radio Model 1565-B on an A-Weighting Network Setting.

Medical

All fifteen workers involved in the refurbishing of the Conrad were invited to participate in the medical evaluation. Also, workers from other areas of the shipyard were invited to participate for purposes of comparison. The evaluation consisted of a brief occupational history, which sought information on exposures to lead both at the shipyard as well as in other employment and in hobbies. Also information was obtained on the occurrence, in the month preceding evaluation, of the following possibly lead-related symptoms: headache, loss of appetite, abdominal pain, muscle weakness, insomnia, joint pains and irritability.

To evaluate lead exposure and toxicity, a venous blood sample was obtained from each worker. These samples were analyzed for blood lead concentration, erythrocyte protoporphyrin (EP) level, and hemoglobin content. Analyses were performed by Environmental Sciences Associates (ESA) Inc, Bedford, Massachusetts. Blood lead analysis was performed by anodic stripping voltammetry,[3] and EP was determined by an acid extraction technique.[4]

V. EVALUATION CRITERIA

Environmental Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for 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 if 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 evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLV's), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended standards, by contrast, are based primarily on concerns relating to the prevention of occupational disease.

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 or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

Lead

Inhalation of lead dust and fume is the major route of lead exposure in industry.[5] A secondary source of exposure may be from ingestion (swallowing) of lead dust deposited on food, cigarettes, or other objects. Once absorbed, lead is excreted from the body very slowly. Absorbed lead can damage the blood-forming organs, the peripheral and central nervous systems, and the kidneys.[6] Chronic lead exposure is associated with infertility, and lead exposure can cause fetal damage in pregnant women.

Blood lead levels below 40 ug/deciliter whole blood are considered to be normal levels in adults which may result from daily environmental exposure. The new Occupational Safety and Health Administration (OSHA) standard for lead in air is 50 ug/m^3, calculated as an 8-hour time-weighted average.[7] This standard also dictates that workers with blood lead levels greater than 50 ug/deciliter must be removed immediately from further exposure to lead.[7]

Erythrocyte protoporphyrin (EP) is a chemical compound normally found in small amounts in the red blood cells. In persons with increased lead absorption, lead interferes with the activity of enzymes within the red blood cells, and thus results in an abnormal increase in EP levels. In adult male workers, the upper limit of normal for the EP concentration is 50 ug/dl. EP levels begin to rise above that level in adult males, when blood lead levels exceed 25 ug/dl.[8]

NOISE

Exposure to high levels of noise may cause temporary or permanent hearing loss. The extent of damage depends primarily upon the intensity of the noise and the duration of the exposure. There is abundant epidemiological and laboratory evidence that protracted exposure to noise above 85 decibels (dBA) causes hearing loss in a portion of an exposed population.

OSHA's standard for occupational exposure to noise (29 CFR 1910.95)[9] specifies a maximum permissible noise exposure level of 90 dBA for a duration of 8 hours, with higher levels allowed for shorter durations. NIOSH, in its Criteria for a Recommended Standard,[10] proposed a limit of 85 dBA, 5 dB less than the OSHA standard.

Permissible noise exposure limits vary according to the duration of exposure. Time-weighted average noise limits for various durations of exposure are shown below:

Duration of Exposure (hrs/day)	Permissible Sound Level, dBA NIOSH[10]	OSHA[9]
16	80	-
8	85	90
4	90	95
2	95	100
1	100	105
1/2	105	110
1/4	110	115*
1/8	115*	-
	-	140 dB**

* No exposure is permitted to continuous noise above 115 dBA.
** No exposure is permitted to impact or impulse noise above a peak sound pressure level (SPL) of 140 dB.

When workers are exposed to sound levels exceeding the OSHA standard, engineering or administrative controls must be implemented to reduce exposures to permissible limits. The OSHA noise standard has recently been expanded to include a hearing conservation amendment[11]. For workers exposed to noise at levels above a TWA of 85 dB, this amendment will require noise exposure monitoring, audiometric testing, the use of hearing protective devices, where necessary, and employee education.

VI. RESULTS

Industrial Hygiene

Airborne concentrations of lead in seven personal (breathing zone) samples obtained on shipfitters aboard the Conrad ranged from 108 to 500 ug/m^3 (mean, 257 ug/m^3) (Table 1). All were above the standard of the Occupational Safety and Health Administration (OSHA) for occupational exposure to lead of 50 ug/m^3,[7].

Airborne lead concentrations in two general area air samples obtained at the rivetting operation while the local exhaust ventilation was in place were 73 and 108 ug/m^3 (mean, 90.5 ug/m^3). However, when the local exhaust ventilation was temporarily disconnected and lead-based putty temporarily put back into use, airborne lead concentrations in two samples were found to be 375 and 718 ug/m^3 (mean 547 ug/m^3). (Figure 1.) These latter findings represent worst case exposures.

No direct evaluation of the local exhaust ventilation system was undertaken. Visual assessment indicated, however, that it was effective in capturing the smoke and particulates generated during rivetting.

Short-term noise level exposures for rivetters ranged from 120 to 123 dBA (mean, 121 dBA). Each rivet required approximately 5 seconds for its installation, and approximately 120 rivets were set on each working day. Total noise exposure time per day was therefore 10 to 15 minutes. For that period of exposure, the measured noise levels exceeded the exposure limits recommended by NIOSH[10] and those set by OSHA[9] (see section V - Evaluation Criteria).

Medical

Occupational and medical histories were obtained on fourteen shipyard workers. A venous blood sample was obtained on thirteen of these workers; for the fourteenth, results were available of recent blood lead and EP determinations performed at the laboratory of the Connecticut Department of Health Services.

Ten of these workers were actively engaged in refitting the Conrad (including one supervisor); the participation rate among this group was 67 per cent (10 of 15). The remaining four workers were employed in other areas of the shipyard, where they had occasional contact with lead-based paint and with other lead products, but no reported exposure to heated lead or to lead fume.

Blood lead levels in the ten workers from the Conrad ranged from 25 to 53 ug/dl (mean, 37.8 ug/dl; standard deviation, 9.3 ug/dl). (Figure 2.) Levels in three of these workers (45, 52, and 53 ug/dl) exceeded 40 ug/dl, the level considered to represent the upper limit of normal for blood lead concentration in adult workers.[7]

Blood lead levels in the four workers in the comparison group ranged from 7 to 12 ug/dl (mean, 10.0 ug/dl; S.D. 2.1 ug/dl). This mean level was significantly lower than that of the workers on the Conrad ($p < 0.001$).

EP levels ranged from 27 to 132 ug/dl in the Conrad workers (mean, 53.9 ug/dl; S.D. 33.1 ug/dl). (Figure 2.) EP levels in four Conrad workers were above the upper normal limit of 50 ug/dl.[8] EP levels in the four workers in the comparison group ranged from 25 to 40 ug/dl (mean, 33.5 ug/dl; S.D. 6.9 ug/dl). The difference in EP levels between the two groups of workers was of marginal statistical significance ($p = 0.09$). A close correlation was found between blood lead and EP levels in the fourteen workers examined (correlation coefficient, $r = 0.70$).

Blood lead levels were found to be significantly higher in smoking shipfitters than in non-smokers (46.8 v. 31.8 ug/dl; $p = 0.03$). Neither use of a respirator ($p = 0.68$) nor regular hand-washing ($p = 0.36$) had any significant association with blood lead level. No association was found between blood lead level and either the number of hours worked with lead per week ($p = 0.54$) or the duration of exposure to lead at the shipyard ($p = 0.44$).

No cases of anemia were observed; all hemoglobin values were above 13.0 g/dl.

Symptoms of headache, decreased appetite, abdominal pain, muscle weakness, insomnia, joint pain and irritability were all equally common in Conrad workers and the comparison group; no statistically significant differences were seen in symptom frequency. (Table 2.)

VII. DISCUSSION

The environmental and medical data from this evaluation indicate that a serious hazard of occupational exposure to lead existed for workers refitting lead-painted wrought iron on the iron-hulled sailing vessel, Joseph Conrad.

Three factors appear to have augmented the severity of this lead exposure hazard. Most important was the fact that the critical operations -- rivetting and plate cutting -- are high-temperature procedures. Such operations when carried out on lead-painted plates, have the capacity to generate a very fine, highly respirable and consequently extremely toxic form of lead aerosol, termed a lead fume.[12] Lead fumes, because of their small particle size, are inherently more dangerous than the coarser dusts produced by such low-temperature operations as sanding, grinding or drilling.

The second factor which contributed to the hazard of the exposures aboard the Conrad was that the work had to be undertaken in a confined space. Ventilation in confined areas is inherently difficult and requires constant attention to details of ventilation and work practice.[13]

A third aggravating factor was the absence of any restrictions on smoking or eating in contaminated work areas. Significant quantities of lead may be absorbed from a contaminated sandwich or cigarette. To prevent such exposures, workers must be provided adequate education on the hazards and routes of lead exposure.[7]

Respirators were found in this evaluation to provide little protection against increased lead absorption. This finding reflects the inherent inefficiency of respirators as a form of protective equipment; it underscores the need for efficient extraction ventilation as a first line of defense against airborne toxins.[14] Also, however, the observed inefficiency of the respirators reflects the fact that no systematic program for respirator use had been established at the shipyard; thus no fit testing or respirator maintenance programs had been developed, and workers were allowed to wear respirators over beards.[15]

Fortunately, no cases of clinically evident lead poisoning occurred among workers on the Conrad, and there was no anemia. The two factors which appear to have prevented development of more severe toxicity were (1) the use of the local exhaust ventilation system and (2) the relatively brief duration of the refitting operation. The demonstration of a six-fold increase in mean air lead concentration (from 90 to 547 ug/m^3) during temporary disconnection of the local exhaust ventilation attests to the value of that ventilation system.

The noise exposures of workers aboard the Conrad were extremely serious. Such exposures, can, if continued, lead to irreversible hearing loss.[10]

The hazards observed in this investigation are now abated, since the refitting of the Conrad has largely been completed. These problems will, however, recur if additional refitting is done in the future. The recommendations offered in the next section of this report are intended therefore to prevent future recurrence of these hazards.

VIII. RECOMMENDATIONS

1. Materials Substitution: The best long-term solution to the problem of occupational lead exposure at the Seaport will be, whenever possible, to replace lead-based materials with materials which are formulated of less toxic substances[14]. We recommend therefore that a long-term plan for materials substitution be developed by the Seaport. Such substitution must, however, be approached cautiously. It is important to ascertain in advance that a substitute material is indeed less hazardous than the substance which it is intended to replace.

2. Ventilation: We recommend that the use of local exhaust ventilation during rivetting and welding be continued.[14] The use of local exhaust ventilation during welding and burning operations is especially important where the surface has previously been painted with a lead-based paint.

3. Surface Preparation: We recommend that when possible, paint and other lead-containing coatings be removed as part of surface preparation before cutting or welding is performed.

4. Lead-Based Putty: We recommend that the use of lead-based putty be avoided.

5. Personal Protection: We recommend that a program for the selection and use of personal protective equipment be implemented. This program should take into consideration protection of the head, the eyes, and the respiratory tract of workers. Special attention should be paid to establishing a written policy for personal respiratory protection. Information on the elements of such a policy may be obtained from the NIOSH Publication, "A Guide to Industrial Respiratory Protection."[15]

6. Hearing Conservation: Exposure to high levels of noise may cause temporary or permanent hearing loss. The extent of damage depends primarily upon the intensity of the noise and the duration of the exposure.

When workers at the shipyard are exposed to sound levels exceeding the OSHA standard, engineering or administrative controls must be implemented to reduce levels to permissible limits.[9] The OSHA noise standard has recently been expanded with a hearing conservation amendment.[11] For workers exposed at or above a TWA of 85 dB, the amendment will require noise exposure monitoring, audiometric testing, the use of hearing protective devices where necessary, and employee education.

7. Medical Monitoring: We recommend that a program of medical monitoring be established for workers at the shipyard and that a consultant physician be retained to oversee operation of this program. The program should take cognizance of the fact that workers at the shipyard are potentially exposed to a wide variety of hazardous chemical and physical agents, including lead, noise, silica, chromates, solvents and allergenic dusts.

IX. AUTHORSHIP AND ACKNOWLEDGEMENTS

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8. NIOSH, Region I

9. OSHA, Region I

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

XI. REFERENCES

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Table 1.

Personal (breathing zone) exposures to airborne lead of shipfitters - Mystic Seaport, Mystic, CT - 1985

HETA 85-132

Worker No.	Air Lead Exposure (ug/m^3)
1	328
2	114
3	500
4	115
5	186
9	108
10	448
mean =	257.0 ug/m^3

Legal standard for occupational exposure to lead = 50 ug/m^3.

Table 2.

Prevalence of reported symptoms in shipfitters and other workers - Mystic Seaport, Mystic, CT - 1985

HETA 85-132

Symptom	Symptom Prevalence (%)		Significance of Difference (p-value)
	Shipfitters (N=10)	Other Workers (N=4)	
Headache	40	25	0.58
Abdominal Pain	20	25	1.00
Decreased Appetite	0	25	0.29
Muscle Weakness	10	25	0.51
Insomnia	40	25	1.00
Joint Pain	10	25	0.29
Irritability	30	50	0.58

Figure 1.

Belowdecks area air lead concentrations with and without high-efficiency ventilation - Mystic Seaport, Mystic, CT - 1985

HETA 85-132

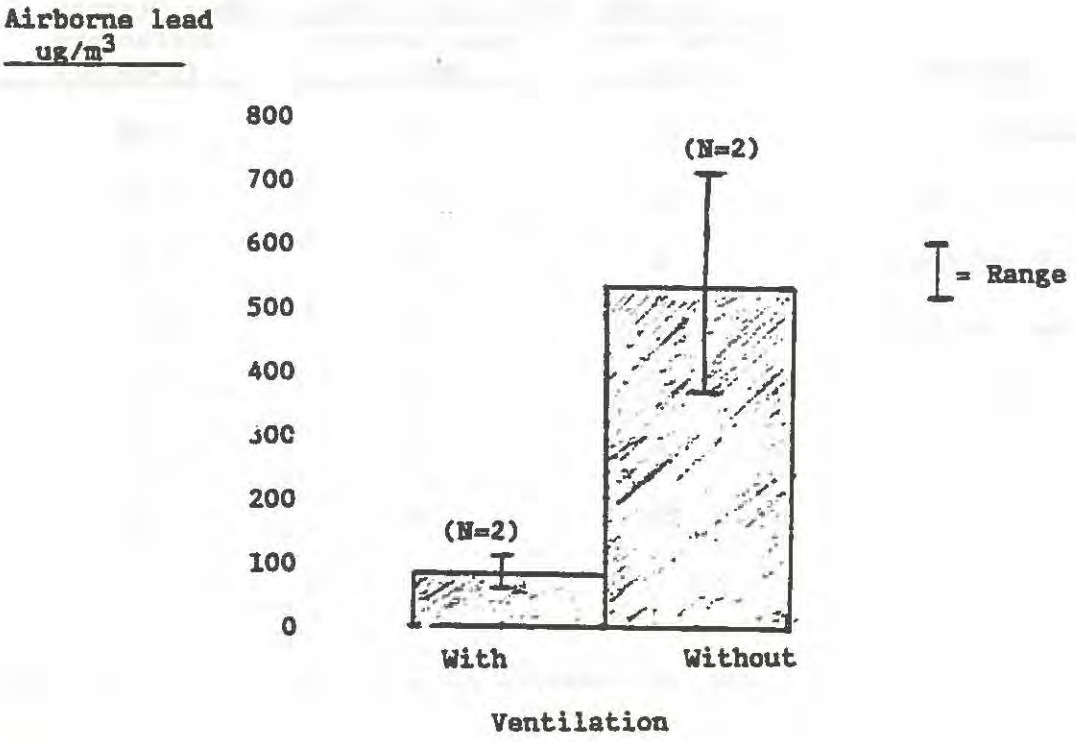
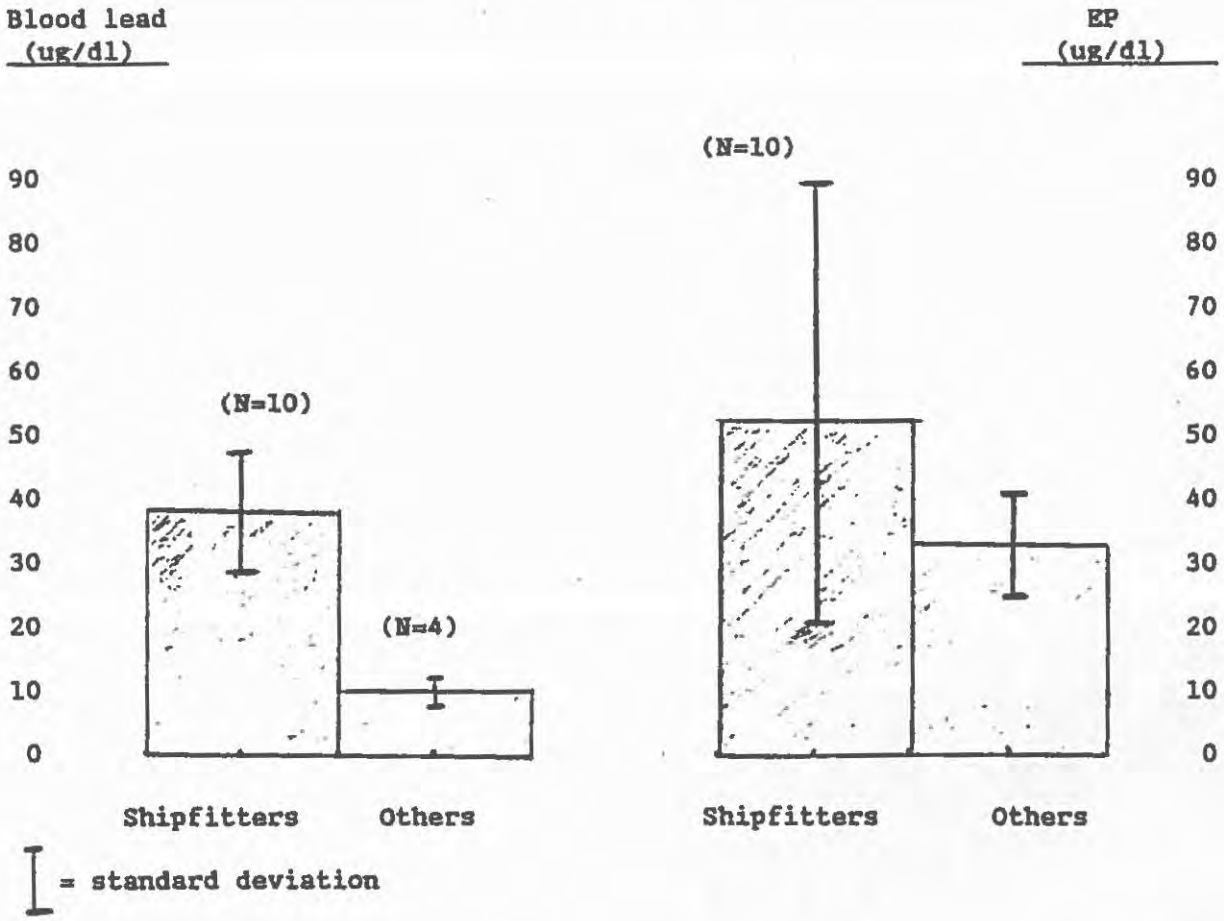


Figure 2.

Blood lead and erythrocyte protoporphyrin (EP) levels in shipfitters and other workers - Mystic Seaport, Mystic, CT - 1985

HETA 85-132



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