HETA 96-0253-2682
General Dynamics, Electric Boat Division
Groton, Connecticut

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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by David Sylvain, M.S., CIH, and Robert Malkin, Dr. P.H., of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Gregory M. Kinnes, CIH, and Jonathan Rutchik, M.D. Analytical support was provided by Ardith A. Grote of the Measurements Development Section, Methods Research Support Branch, Division of Physical Sciences and Engineering (DPSE). Desktop publishing by Pat Lovell. Review and preparation for printing was performed by Penny Arthur.

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General Dynamics, Electric Boat Division
Groton, Connecticut
April 1998

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SUMMARY

On August 28, 1996, the National Institute for Occupational Safety and Health (NIOSH) received a Health Hazard Evaluation (HHE) request from the Metal Trades Council of New London County (MTC) on behalf of Electric Boat (EB) employees. The request, and accompanying documentation, indicated that workers were reporting health problems that they attributed to interior touch-up painting during construction of Seawolf submarines. Employees reported that brush and roller painting using Mare Island epoxy paint caused headaches, breathing difficulties, skin irritation, rashes, chest pain, shortness of breath, and asthma. Additional information was provided by the Connecticut State Division of Environmental Epidemiology and Occupational Health, which contacted NIOSH investigators concerning 13 employees whose physicians had notified the state surveillance system of a diagnosis of occupational asthma. Paint dust from grinding on painted surfaces, and paint decomposition products from welding on or near painted surfaces raised additional health concerns among workers.

On October 31 - November 1, 1996, NIOSH investigators conducted an initial site visit, which included an opening conference, employee interviews, medical records review, and a walk-through of nonclassified areas of the Seawolf class submarine that was under construction. On March 10-12, 1997, NIOSH investigators returned to EB to conduct environmental sampling; and to evaluate workers' peak expiratory flow rates (PEFRs).

Air and bulk samples were collected to characterize emissions from Mare Island epoxy paint and decomposition products generated by grinding and welding on previously painted surfaces. Air sampling for n-butyl alcohol (the principal solvent in Mare Island epoxy paint) was conducted during touch-up painting. A qualitative assessment of exposure to volatile organic compounds was performed using thermal desorption tubes. Air sampling was conducted during welding to assess exposure to bisphenol A, a major epoxy paint decomposition product. Bulk samples of Mare Island part A, part B, and cured paint dust were analyzed using solvent extraction and thermal methods. The percent composition of asthmagens in Mare Island part A, such as tetraethylenepentamine (TEPA) and triethylenetetramine (TETA)[1], was estimated using GC-MS.

The highest n-butyl alcohol concentrations were found in the three personal breathing zone samples (PBZ) collected on painters during touch-up painting in a tank (78 to 130 ppm). PBZ samples collected on painters in two other tanks indicated n-butyl alcohol concentrations of 2.4 - 25 ppm. Employees, stationed outside each of the tanks as "tank watch," were exposed to less than 1 ppm n-butyl alcohol. An area sample, collected in the immediate vicinity of a painter who brush-painted approximately 4 ft^2 of the overhead on the mess deck, revealed 1.5 ppm of n-butyl alcohol. The major VOCs, detected on most three-bed thermal desorption tube samples during painting,

were butanol, an aromatic naptha, toluene, xylene, benzaldehyde, and benzyl alcohol. Analysis for polyamines indicated that the part A bulk sample (mixed) contained 0.5% TETA and 0.2% TEPA. Phenol was the major compound generated when paint dust or dried paint was heated. Other compounds detected in the heated paint samples included acetaldehyde, acrolein, butanol, alkyl benzenes (aromatic naptha), benzyl alcohol, alkyl-substituted phenols, and traces of nitrogen compounds (pyridine, pyrazine, pyrole, and alkyl-substituted isomers of these). Air sampling during welding detected quantifiable concentrations of bisphenol A in two of the eight samples which were collected.

Respiratory status among workers on the submarine was determined by administering a symptoms questionnaire and performing serial PEFR measurements for a week. Measurements were recorded on a log sheet, as were employees' responses to questions each time the PEFR test was done. Questions on the log concerned: 1) the presence of markers of environmental exposure ("seeing" welding within 25 feet, or "smelling" paint) in the time period before the PEFR was performed, 2) the existence of symptoms (wheezing, chest tightness, cough, or a cold or flu), and 3) whether an inhaler was used. The hypothesis was that exposure to some chemical (used in the construction of the submarine), welding fume, or Mare Island paint resulted in a 20% decrease in peak flow among some workers, up to 3-4 hours after exposure.

Questionnaires were returned from 93 of approximately 400 employees working on the Seawolf submarine on a given day and involved all trades (painters, welders, pipe fitters, carpenters, and electricians); 81 returned peak flow data for the week-long period. Twenty-nine workers (31% of the 93) met the NIOSH investigators' definition of asthma (wheezing and either coughing, shortness of breath, or chest tightness) and 27 workers (29% of the 93) met the definition of occupational asthma (having the NOSH investigators' definition of asthma and also having wheezing either starting on the job or six hours after leaving the worksite). Of the 90 workers who answered a question concerning wheezing, 31 (34%) reported episodes of wheezing since starting work at EB. Having a change in peak flow >20% for any one day was related to"seeing" welding (odds ratio (OR) 2.1 95% confidence interval (CI) 1.3-3.4). "Smelling" paint was not related to having peak flow changes >20% for any one day.

Exposure to welding fume, and possibly to components of the epoxy resin paint (solvents, particularly n-butyl alcohol and pyrolysis products) may have contributed to bronchial hyper-responsiveness and occupational asthma. The statistically significant relationship that was found between "seeing" welding (as a marker for exposure), and different outcomes (wheezing, respiratory symptoms, and bronchial hyper-responsiveness) was consistent through almost all analyses. Recommendations include improving ventilation, greater attention to personal protective equipment, improved scheduling of job duties, and following existing safety and health guidelines.

Keywords: SIC 3731 (ship building and repairing), asthma, epoxy paint, n-butyl alcohol, pyrolysis products, respiratory irritants, welding.

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INTRODUCTION

On August 28, 1996, the National Institute for Occupational Safety and Health (NIOSH) received a Health Hazard Evaluation (HHE) request from the Metal Trades Council of New London County (MTC) on behalf of Electric Boat (EB) employees. The request, and accompanying documentation, indicated that workers had reported health problems they believed were due to the use of Mare Island epoxy paint on interior surfaces of submarines under construction at EB. In addition to the HHE request, the Connecticut State Division of Environmental Epidemiology and Occupational Health contacted NIOSH investigators and provided information concerning 13 employees whose physicians had notified the state surveillance system of a diagnosis of occupational asthma.

At the time of the request, painting was limited to touch-up using brushes and small rollers and was done in areas adjacent to other workers. No spray painting was being done at that time; when spray painting was necessary, it was conducted in areas where only painters were present and was reportedly performed on "off shifts" to minimize other workers' exposures. Paint dust from grinding on painted surfaces, and paint decomposition products due to welding on or near painted surfaces raised additional health concerns. Health problems noted in the request include headaches, breathing difficulties, skin irritation, rashes, chest pain, shortness of breath, and asthma.

On October 31 - November 1, 1996, an industrial hygienist and an epidemiologist conducted an initial site visit, which included an opening conference, employee interviews, medical records review, and a walk-through of nonclassified areas of the Seawolf class submarine that was under construction (SSN-22). On March 10-12, 1997, NIOSH investigators returned to EB to conduct air sampling during touch-up painting and to evaluate peak expiratory flow rates (PEFRs) of workers in SSN-22.

BACKGROUND

Submarine construction starts with the fabrication of hull cylinders (hull cross-sections) at an EB facility in Quonset Point, Rhode Island. Assembly and painting of decks and bulkheads are performed at Quonset Point, as is the installation of some internal components. The cylinders are transported to the EB Groton shipyard by barge, where they are welded together, and the various electronic and mechanical systems are installed. Assembly in this manner results in completion of major construction while the cylinders are open and ventilated; however, welding, touch-up painting, deck repainting, and other operations continue at Groton after the cylinders have been joined, and only a few openings are available for ventilation. During the walk-through, NIOSH investigators observed welding on the submarine. There was little or no shielding of visible welding arcs, and slag was observed falling from welding on an upper deck onto employees working below.

While a submarine is being fitted-out at Groton, all trades, e.g., carpenters, shipfitters, electricians, and painters, work throughout the vessel. Approximately 1500 workers were reported to have been assigned to the previous Seawolf-class submarine, SSN-21; 780 workers were assigned to SSN-22, which was under construction during this HHE, and according to a company official, approximately 450 workers were working *on* the boat at any one time. On SSN-22, approximately 60% of the workforce worked on the first shift, 25% on second shift, and 15% on third shift.

According to a MTC representative, the first complaints involving Mare Island paint arose in the late 1980s, when Mare Island was applied only in the tanks of earlier classes of submarines built at EB. At that time, painters were the only exposed workers, and only painters reported problems (e.g., headache, skin irritation). Painters' problems were addressed through use of personal protective equipment, including supplied-air respirators, and Saranax-coated Tyvek® suits. On Seawolf-class submarines, however, Mare Island paint is used not only in tanks but throughout all interior spaces, which exposes workers in all trades to paint and solvent vapors. Although spraying is limited to tanks, and is performed exclusively by painters, brush and roller touch-up painting is performed by all trades and occurs throughout the boat on all shifts. "Touch-up" is not well defined, and refers to sporadic, unpredictable, small painting jobs throughout the vessel that involve surface areas ranging from several square inches, to 40-50 square feet. Workers, other than the painter, are often in the vicinity of the painter during touch-up.

Mare Island, Formula 151 Type IV (MIL-P-2441/30(8H)), consists of: (1) Part A, which includes a polymeric fatty acid amide hardener (14.0%), magnesium silicate (16.7%), n-butyl alcohol (11.8%), and titanium dioxide (4.6%), and (2) Part B, which includes bisphenol A/epichlorohydrin-based epoxy resin (23.5%), naptha solvent containing xylene, cumene, and trimethylbenzenes (9.5%), and magnesium silicate (17.8%).[2] According to a representative of the Ciba Specialty Chemical Company, the manufacturer, the polymeric fatty acid is composed of approximately 30% benzyl alcohol, which would bring the total component of volatile solvent in the paint to approximately 26%. EB considers the paint to have toxic properties which may affect the skin, nervous and respiratory system.[3]

At the time of the first site visit in November 1996 approximately 60% of the employees worked on the day shift, 25% worked the second shift, and 15% worked the third shift. Fifteen employees were interviewed by NIOSH investigators. Employees were selected for an interview by representatives of the Metal Trades Council, based on their symptoms, availability, and desire to talk to NIOSH investigators. Two other employees were selected by NIOSH investigators during the walk-through tour and asked about the presence of any symptoms. Among interviewed employees, the most frequently occurring symptoms after exposure to Mare Island paint were rash (5), burning eyes (4), chest pain (4), and headache (4). Four workers reported asthma, either with a new onset after exposures at the boatyard, aggravation of existing asthma, or reactivation of childhood asthma that was felt by their physicians to be related to exposure to Mare Island Paint. Three workers reported a rash on the forearms and hands that they said was specific to working on the Seawolf submarine. These workers reported that all symptoms were worse on the Seawolf boat because of an increased use of Mare Island paint, and workers reported that their symptoms increased with increased exposure to the paint.

All interviewed employees reported that the smell of the paint was bothersome, and all reported deficiencies with the ventilation in the submarine. There are only two entrances into the submarine once the hull is complete, and finding enough room for sufficient fresh air and exhaust ductwork is difficult. EB is presently utilizing some of the submarine's ventilation duct work for increased air circulation. Because there are only a few openings on the boat, union officials expressed concern over emergency egress in case of fire during construction.

The company physician reported that she was unaware of serious health problems related to the use of Mare Island paint, and was not aware of skin irritations (called the Seawolf rash), mild cough, or nausea being attributed to the paint. Most of the reported problems from the paint were nonspecific irritant symptoms. According to the physician, the most commonly reported complaints from exposure to the paint were a paint smell in the urine, headache, and burning eyes. Soft tissue injuries or injury to the eyes were the most common reasons for employees' visits to the plant health facility and most disabilities were due to previous asbestos exposure or vibratory white finger disease.

All company medical records were reviewed regarding employee visits for injuries and symptoms that might be related to exposure to Mare Island paint for the period January 1990-October 1996. Review of medical records for that time period revealed approximately 55 workers who had reported to the shipyard medical facility with reports of symptoms that they felt were related to paint exposure. Although the number of workers had declined from approximately 11,000 to 4,000 during that time period, the number of visits related to paint increased. Approximately 25 visits regarding symptoms thought to be related to Mare Island paint were recorded in the four-year period, January 1990-December 1994, and approximately 30 visits were recorded in the time period in the two-year period 1995-1996, when the workforce was smaller. According to management, use of Mare Island paint in the Seawolf program increased during that time period, starting in 1995. The most commonly reported symptoms of workers in 1995-1996, which were possibly related to Mare Island paint use, were dizziness or lightheadedness, nausea, rash, headache, breathing problems (including chest tightness or shortness of breath) and eye irritation.

METHODS

Industrial Hygiene

On March 10-12, 1997, air and bulk samples were collected to characterize exposure to: (1) constituents of Mare Island epoxy paint during touch-up painting, and (2) decomposition products generated by grinding and welding on previously painted surfaces. Air samples were collected using calibrated, battery-operated sampling pumps with the appropriate sorbent tube or filter media connected by Tygon® tubing. Quantitative and semi-quantitative area and personal breathing zone (PBZ) sample concentrations were calculated based on the actual monitoring time (time-weighted average [TWA-actual] concentrations). Calibration of air sampling pumps with the appropriate sampling media was performed before and after the monitoring period. Field blanks were collected and submitted to the laboratory for each analytical method.

Air Sampling

Personal Breathing Zone

NIOSH investigators identified painters who would be performing touch-up painting throughout the shift, and welders who would be welding on or near previously painted surfaces, preferably in locations where paint could not be stripped prior to welding. Painters and welders, who met these criteria, were selected immediately prior to the start of the shift. During painting, PBZ sampling was conducted for n-butyl alcohol (the principal solvent in Mare Island epoxy paint), and volatile organic compounds. Exposure to volatile organic compounds was evaluated using thermal desorption tubes to collect air samples for qualitative analysis. Qualitative analysis was selected in order to identify volatile organic compounds, other than n-butyl alcohol, which are released during use of Mare Island epoxy paint.

PBZ sampling was conducted during welding to assess exposure to paint decomposition products. Since Bisphenol A was identified in the literature as a thermal decomposition product of epoxy paint[4] and a validated sampling method was available, bisphenol A was selected to assess the presence of thermal decomposition products. Air sampling for welding fume was not conducted during the industrial hygiene evaluation.

Area

Area air sampling was conducted to assess n-butyl alcohol (quantitative assessment) and volatile organic compounds (qualitative assessment) in areas where touch-up painting was being performed. Since the presence of workers (other than painters) in the vicinity of touch-up painting was unpredictable, area sampling was selected to evaluate exposures that could have occurred if other workers had been present. No area samples were collected for welding fume.

n-Butyl Alcohol

Eighteen PBZ samples were collected by drawing air through a solid sorbent tube (coconut shell charcoal, 100 mg/50 mg) at a nominal flow rate of 0.100 liters per minute (lpm). Samples were desorbed with carbon disulfide and 2% n-propanol. Analysis was performed using a Hewlett-Packard Model 5890A equipped with a flame ionization detector (GC-FID) according to NIOSH Manual of Analytical Methods (NMAL), Fourth Edition, Method 1401 (modified).[5]

Volatile Organic Compounds

PBZ and area samples were collected on 18 tubes containing three beds of sorbent materials, and 4 tubes containing only Tenax-GR. The Tenax-GR tubes were used to detect additional, high molecular weight compounds which might not be collected effectively using three-bed tubes. The three-bed tubes contained a front layer of Carbopack Y (≈90 mg), a middle layer of Carbopack B (≈115 mg), and a back section of Carboxen 1003 (≈150 mg). Prior to use, the tubes were cleaned by conditioning at 375°C for two hours. When not in use, tubes were capped and stored in metal tube containers to prevent contamination. Samples were collected at a nominal flow rate of 0.050 lpm.

Thermal desorption tube samples, and blanks, were analyzed using a Perkin-Elmer ATD 400 (ATD) automatic thermal desorption system, which was interfaced directly to a HP5980A gas chromatograph and a HP5970 mass selective detector (TD-GC-MSD). In addition, "spikes" were used to obtain estimates of VOC concentrations in thermal desorption tube samples. Spikes were prepared using stock solutions containing known amounts of several solvents: butanol, hexane, toluene, xylene, an aromatic naptha, benzaldehyde, and benzyl alcohol. To prepare the spikes, blank thermal desorption tubes were inserted into a GC injector; and aliquots of stock solutions (0.1-1.0 µl) were injected into the gas chromatograph, and onto the tubes, using helium at a flow rate of 40-50 cc/minute for ten minutes.

Bisphenol A

Eight PBZ samples were collected during welding by drawing air through a glass fiber filter at a nominal flow rate of 1.5 lpm. Analysis was performed using a high performance liquid chromatograph (HPLC) equipped with an ultraviolet detector according to NIOSH Manual of Analytical Methods (NMAL), Second Edition, Method P&CAM 333 (modified).

Bulk Sampling

Three bulk samples were collected and submitted for analysis: one sample each of Mare Island parts A and B (unmixed); and one sample of Mare Island paint dust generated by grinding on a previously painted surface. The bulks were analyzed by solvent extraction, and by heated analysis using the ATD. For solvent extraction, all three bulks were extracted with carbon disulfide, and analyzed by GC-MS using one 30-meter DB-1 capillary column (splitless mode). A portion of the paint dust was placed in a glass tube configured for the ATD, heated to 375°C; the headspace was then analyzed by GC-MS. Parts A and B of the paint were mixed, allowed to air dry overnight, then heated and analyzed in the same manner as the paint dust. In addition, a portion of the part A sample was heated and analyzed separately by GC-MS.

The percent composition of tetraethylenepentamine (TEPA) and triethylenetetramine (TETA) in Mare Island part A was estimated using GC-MS. An aliquot of the top layer of the part A sample was weighed, then the sample was mixed thoroughly by shaking; a portion of the mixed sample was weighed. Approximately equal portions (49-51 mg) of standards (TEPA and TETA), the top layer, and part A (mixed) were weighed into beakers. Each beaker was rinsed with methanol, added to 10 ml volumetric flasks, diluted to volume with methanol, and mixed. Aliquots (1 µl) of the four solutions were analyzed in duplicate by GC-MS.

Medical

The medical study, conducted on March 10-13, 1997, assessed whether exposures at EB, particularly to Mare Island paint or welding fume (since a large amount of welding was observed by NIOSH investigators), resulted in respiratory effects. Possible respiratory effects among workers on the submarine were determined by administering a symptoms questionnaire and performing serial peak expiratory flow rate (PEFR) measurements. The hypothesis was that exposure to some chemical used in the construction of the submarine, welding fume, or Mare Island paint resulted in a 20% decrease in peak flow among some workers, up to 3-4 hours after exposure, or the development of respiratory symptoms, as determined by the questionnaire responses.

The medical evaluation occurred while workers from all trades (painters, welders, electricians, carpenters, pipe fitters) were present on the boat. All workers on the submarine were eligible to participate in the study, and workers were originally informed about the study at a regular meeting conducted by their union. According to a union official, more than 80% of the electricians, machinists, and pipe fitters present at the meeting expressed interest in the study, but only about half of the carpenters said they would participate.

Union officials stated that they approached all workers in a given area of the boat, and selected those areas with the largest number of workers present during the days of the evaluation. Ninety-nine workers initially enrolled in the study, and 93 workers completed the questionnaire. These workers predominantly worked in the forward compartment of the submarine where there was a total of approximately 250 workers. Due to Navy security regulations, the NIOSH investigators were unable to enter certain areas of the boat where the workers were recruited and the number of workers in any specific area of the boat was not known by the NIOSH investigators.

All employees who agreed to participate in the study were given an informed consent form followed by a packet consisting of a peak flow meter, daily recording forms, instructions, a standard HETAB consent form, and an initial questionnaire (Appendix A). Initial instructions for using the peak flow meter were given at this time. The questionnaire asked about work history, medical history, whether the worker was taking medications, history of cigarette smoking, and whether the participant presently experienced wheezing, cough, chest tightness, or shortness of breath. Due to time constraints, employees were instructed to complete the questionnaire at home and return it either the next day to a NIOSH investigator or by mail to NIOSH with their peak flow meter.

For this study, we defined a case of asthma as: (1) reported wheezing lasting more than thirty minutes, along with either cough, chest tightness, or shortness of breath, or (2) use of an inhaler when wheezing, regardless of the duration of the wheezing. Asthma with wheezing, either starting on the job or starting up to six hours after leaving the worksite, was considered "occupational" asthma. The preponderance of questions on the questionnaire concerned factors that may make an employee wheeze, either at home or work.

Peak Flow Testing

NIOSH investigators used Wright's portable peak flow meters to obtain serial determinations of the PEFR of all employees who completed the questionnaire. These measurements were made for seven consecutive days, including non-work days, and enabled us to identify workers having bronchial hyper-responsiveness, a possible sign of asthma. PEFR is defined as the "maximum flow which can be sustained for a period of 10 milliseconds (ms) during a forced expiration starting from total lung capacity."[6]

PEFR testing was conducted at five different times during the day (when the participant awoke, after arriving at work, in the middle of the work day [lunchtime or mid-shift break for off shifts], the end of the work day, and once four hours after leaving work). Serial peak flow readings, including readings after exposure at work, were used to determine whether there was a delayed reaction to an exposure at work. Three exhalations were recorded each time, and the maximum of the three was used for PEFR determination. Along with the PEFR test, participants were asked to record: (1) the presence of any acute symptoms (i.e., wheezing, shortness of breath, chest tightness, or cough) experienced immediately preceding the PEFR test, (2) the presence of any relevant environmental exposures ("smelling" Mare Island paint, "seeing" welding), and (3) the use an inhaler during the preceding time period. This information, along with the results of the peak flow test, were to be recorded on an accompanying log sheet (Appendix B). "Smelling" paint or "seeing" welding within 25 feet were used as markers of exposure to those items. No attempt was made to verify either the presence or magnitude of the exposure to welding fume or paint for most employees. However, NIOSH investigators were informed by both union and management officials that Mare Island paint has a distinct odor that employees would recognize and associate with the paint. However, it was possible that one worker's exposure to either paint or welding fume may have been very different from another's.

Peak flow logs from each worker were considered interpretable if they met certain criteria. A worker's record was included in the analysis if valid records from a minimum of four of the seven survey days were present. Individual worker records from a 24-hour survey day were considered valid if they contained peak flow results from at least four recording times that spanned at least 10 hours that day. Logs which failed to meet these minimal criteria were excluded from statistical analysis.

As noted previously, at each peak flow recording time only the largest of the three recorded values was used for calculations and subsequent interpretation. For each worker, an <u>overall mean</u> peak flow was calculated using the largest value from all available recording times during the study period, and a <u>daily mean</u> was calculated from the largest values on that day. A diurnal rhythm exists in PEFR measurements, with minimum measurements usually occurring in the early morning and maximal measurements occurring approximately 8-12 hours later.[7] Diurnal variation in peak flow, called the daily amplitude mean, was calculated as the difference between the daily maximum and minimum best values for the survey day divided by the daily mean. Overall variation in peak flow was determined by calculating the amplitude mean for the study period, which is the difference between the maximum and minimum best values for the entire survey, divided by the overall mean for the study period. It was therefore possible to have a study period amplitude mean >20% without having any one day >20%, for example if the amplitude mean either gradually increased or decreased during the study period. Peak flow data were analyzed using "Peak Flow Processing Software Version 2.15" and a variation greater than (>) 20% for either analysis was an indicator of increased airway responsiveness.[8]

A relationship between airflow changes and workplace exposures is suggested if: (1) peak flow level is lower on work days compared to days away from work, (2) variation in daily amplitude mean >20% is seen on work days and is not seen on days off work, or (3) peak flow decreases are temporally associated with a discrete exposure.[9] Data were analyzed separately for those participants having a daily amplitude mean >20% and those with a study period amplitude mean >20%. Participants whose amplitude mean (either daily or for the entire survey) of >20% was due solely to an outlier high reading of the meter (one substantially higher than the other two readings at the same session), were excluded from further analysis.

Statistical Analysis

Analysis of the results utilized both the questionnaire and the peak flow meter results, including the accompanying log sheets. First, the questionnaire was analyzed to determine if the participant met the case definition of "asthma" or "occupational asthma." Environmental exposures were analyzed to determine if either "seeing," welding, or "smelling" paint was related to the case definition of "asthma" or "occupational asthma." Second, the PEFR test was used as an objective measure of airways hyper-responsiveness that might be related to exposures at a given time during the work day, and associations between PEFR changes and exposure variables were examined. For exposures that occurred only at work ("seeing welding" or "smelling paint"), analyses were done only for work days.

New variables were created: (1) to create new exposure variables of "smelling" paint "ever," and "seeing" welding within 25 feet (the approximate size of the largest compartment on the submarine) "ever," and (2) to combine the symptoms variables cough, chest tightness, and shortness of breath to form one variable, which we called respiratory symptoms. This symptom, as well as the symptom wheezing, was combined over the study period so that reporting either any wheezing or any respiratory symptoms at work or at home *after* work was considered either "ever" wheezing, or "ever" respiratory symptoms. These variables were used in all statistical analyses relating to the PEFR.

Logistic regression modeling was performed to simultaneously account for the effect of multiple exposures on wheezing, respiratory symptoms, and PEFR. Separate statistical models were examined: (1) having an amplitude mean >20% for either the study period or for any one day as a function of ever "smelling" Mare Island paint and ever "seeing" welding within 25 feet, and (2) wheezing or respiratory symptoms "ever" as a function of "seeing" welding within 25 feet or "smelling" paint during the work day. We used the odds ration to estimate the risk associated with each exposure. An odds ration above 1 means that there is an increased risk associated with that exposure. We also calculated the 95% confidence interval (CI) and a 95% CI that does not include one was used to determine statistical significance. Statistical analysis was performed with SAS version 6.11.[10]

Peak flow graphs with an amplitude mean >20% were individually reviewed by NIOSH investigators to determine if PEFR changes might possibly be due to a recorded exposure at that time ("smelling" paint or "seeing" welding), and therefore, be occupationally related. These aptitude means were verified by a board certified occupational medicine specialist.

EVALUATION CRITERIA

Industrial Hygiene

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

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs)[11], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs™)[12] and (3) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs)[13]. In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards that are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH reals, the ACGIH TLVs, or whichever is the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

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

n-Butyl Alcohol

N-butyl alcohol, also called butanol, is a colorless, flammable liquid used as a solvent in paints, lacquers, resins, and dyes. It is also used in the manufacture of detergents, rayon, and butyl compounds.[14,15] The odor of n-butyl alcohol has been variously described as pungent; rancid, sweet, and winelike; and similar to that of burnt fuel oil.[14,15,16] The odor threshold is reported to be in the range of 1 to 15 ppm; however, the threshold can increase to 10,000 ppm after an exposed person adapts to the odor.[14,15]

n-Butyl alcohol vapor is irritating to the eyes, nose, and throat, and can produce ocular symptoms such as blurred vision, lacrimation, photophobia, and a burning sensation.[14,16] Long-term systemic effects on the auditory nerve, including hearing loss (hypoacusia), have been reported among exposed workers.[15,17]

An acutely toxic dose of n-butyl alcohol can be absorbed through unbroken skin.[18] It has been suggested that direct contact of the hands with n-butyl alcohol for one hour may result in an absorbed dose that is four times greater than the dose that would result from inhalation of 50 ppm for one-hour.[14] Although many studies report skin absorption to be a significant route of entry, the ACGIH has proposed deletion of the TLV skin notation for n-butyl alcohol because of a study that concluded that the absorbed dose due to skin absorption is insignificant when compared with absorption by other routes.[12,19] NIOSH, however, continues to include a skin notation with its REL.

The NIOSH REL for n-butyl alcohol is a ceiling limit of 50 ppm, and includes a skin notation to prevent skin absorption. The current OSHA PEL is 100 ppm as an eight-hour TWA. (The 1989 ceiling limit of 50 ppm and skin notation were vacated in the 1992 court ruling.) The ACGIH TLV is a 50 ppm ceiling. ACGIH proposes to change this value to a 25 ppm ceiling limit.[12,19]

Volatile Organic Compounds

Volatile organic compounds (VOCs) comprise a large class of chemicals that are organic (i.e., containing carbon) and have a sufficiently high vapor pressure to allow part of the compound to exist in the gaseous state at room temperature. These compounds are emitted in varying concentrations from many sources including, adhesives, solvents, paints, cleaners, waxes, cigarettes, and combustion sources. The irritant potency of VOC mixtures produced by these sources is variable, depending on the nature of the source and the rate and concentration of VOCs released.

Paint Degradation Products

Welding and flame-cutting of painted metal generate a wide array of organic degradation products, in addition to welding fume from the electrode and/or base metal. However, the *major* degradation products from pyrolized paint depend upon the particular type of paint that has been heated to the point of degradation, e.g., epoxy paints (phenol and bisphenol A), polyvinylbutyral paints (butyraldehyde and butyric acid), and alkyd paints (aliphatic organic acids, aldehydes, and phthalic anhydride).[20]

Workers who weld or cut painted metal have reported upper respiratory tract and eye irritation, nausea, nasal and sinus congestion, wheezing, and chest tightness.[4,20,21] Worker concerns about the effects of paint fume were supported by an early study of rats exposed to pyrolysis products of epoxy resins, which led investigators to conclude that pyrolysis products presented a possible health hazard.[22] More recently, researchers have suggested that exposure to organic degradation products may contribute to long-term health effects, such as cancer, allergic skin reactions, and asthma.[20]

DGEBA Epoxy Resin Systems

Uncured epoxy resins are high-viscosity liquids, or solid resins, that can be reacted with a curing agent to produce a cross-linked polymer. Diglycidyl ether of bisphenol A (DGEBA) resin is a very common epoxy resin that is derived from a reaction between bisphenol A and epichlorohydrin. Polyamine, polyamide, or anhydride curing agents (hardeners) are commonly used with DGEBA resins. Cured resins find use as adhesives, protective coatings, molding compounds, laminates, and plastics.[23,24]

DGEBA, one of the glycidyl ethers that are common components of epoxy resin systems, is an active ingredient in epoxy resins. Other glycidyl ethers are frequently incorporated into epoxy resin systems as reactive diluents. During the curing process, the epoxy group of the glycidyl ethers react to form cross-linkages; thus, glycidyl ethers are generally not present in fully-cured products.[23] Similarly, little, if any, epichlorohydrin (a severe irritant, systemic toxin, and carcinogen[11,15,16,23]) should be present in DGEBA resins, as the epichlorohydrin epoxy groups are consumed during the reaction with bisphenol A.[23,24]

Lower-molecular-weight, lower-viscosity, liquid DGEBA resins are more acutely toxic than high molecular weight, very viscous or solid resins.[23,24] Prolonged or repeated contact with uncured, or incompletely cured DGEBA resin can cause dermatitis and skin sensitization; however, sensitization more commonly results from the glycidyl ether diluents and hardeners, than from contact with the resin.[23] Although uncommon, skin sensitization may result from exposure to vapor (uncured resin) or fine dust (cured resin) at concentrations below the level that would cause direct irritation.[23] It has been estimated that approximately two percent of workers exposed to epoxy systems may become sensitized despite good industrial hygiene practices.[23]

Due to low volatility, uncured DGEBA resins generally present little risk of exposure via inhalation; however, this is not the case if resin is sprayed, or if it is cured at high temperatures. Well-cured resins are essentially inert, containing few, if any, unreacted epoxide groups; however, cured epoxy dust, generated during grinding or other mechanical processes, may cause respiratory symptoms.[23,24] It has been suggested that these symptoms are due to residual hardener which is released from the cured resin during grinding.[24]

Aliphatic polyamine and anhydride hardeners can cause eye, skin, and respiratory tract irritation. Studies of ethylene amines, including DETA and TETA, have demonstrated that these compounds can produce primary irritation and skin sensitization.[25] Asthmatic symptoms among workers exposed to polyamines suggest that these compounds can cause respiratory tract sensitization.[24] DETA not only causes skin sensitization, but is also likely to cause pulmonary sensitization.[25] Various anhydride hardeners can induce asthma in exposed workers.[24] Polyamide hardeners have not been investigated as extensively as polyamine and anhydride hardeners; however, available information indicates that the polyamides are much less toxic than other types of hardeners.[24]

Medical

Occupational Asthma

Asthma, a lung disorder characterized by reversible obstruction of the lung airway system (called the bronchial tubes) causes episodic respiratory symptoms, including shortness of breath, wheezing, chest tightness, and cough. Asthma at the workplace may be true occupational asthma (due to conditions in the work environment), or work-aggravated asthma (where pre-existing asthma is made worse by an exposure at work, or acute episodes triggered).

Airway obstruction is caused, or made worse by workplace exposure to dusts, fumes, gases, or vapors.[26] In the U.S., asthma occurs in about 5-10% of the general population; 15% of these cases are thought to be occupational.[27]

Occupational asthma can be categorized according to whether or not latency (the period between first exposure and onset of symptoms) exists. Occupational asthma with latency includes immunologically mediated asthma, and the period of exposure preceding the first attack may range from a few weeks to several years. This is the most common type of occupational asthma and is similar to non-occupational allergic asthma. Susceptible workers develop an immunologic response (usually IgE antibodies) after being exposed to substances at work, and repeated exposure causes asthma to develop.

Occupational asthma without latency is usually due to a very high exposure to irritant gasses or fumes and may be known as reactive airways dysfunction syndrome (RADS),[28] or if the exposure is lower, low-dose RADS.[29] Neither RADS nor low dose RADS have an immunologic component and are more related to bronchial hyper-responsiveness due to exposure to an irritant. RADS is related to an acute, one-time high exposure to a respiratory irritant such as irritant gases, fumes, or chemicals whereas low dose RADS is related to repeated low-dose exposure to respiratory irritants.[30,31,32,33,34] Asthma that may be attributable to irritant exposures has received less study than allergy-induced asthma, and its prevalence is unknown.

Asthma with latency can be divided into diseases with different clinical patterns.[35] These patterns include:

1. Isolated Early. Occurs within a few minutes after an inhalation challenge, maximum intensity within 30 minutes, ends within 60-90 minutes. Allergic asthma (IgE dependent) falls into this category.

2. Isolated late. Occurs 4-6 hours after exposure, maximal intensity within 8-10 hours and ends in 24-48 hours. IgE independent asthma often falls into this category.

3. Biphasic. Early reaction with recovery followed by a late reaction. IgE independent agents may also be related to this type of reaction.

4. Continuous. No remission between the early and late phases.

RESULTS

Industrial Hygiene

The results of personal breathing zone (PBZ) air sampling for n-butyl alcohol are presented in Table1. These PBZ samples represent the exposure of painters who were brush-painting inside three tanks, identified as Aux-1, Aux-6, and San-3. Additional PBZ samples were collected on workers stationed outside of each of the tanks ("Tank Watch").

A single PBZ sample collected in San-3 measured 2.4 ppm n-butyl alcohol during painting; three samples collected in Aux-6 on two consecutive days revealed 16 to 25 ppm. Area sampling in Aux-6 during each of the two sampling periods showed 0.26 and 1.2 ppm (Table 1). The highest n-butyl alcohol concentrations were found in the three PBZ samples collected on painters in Aux-1: 78 to 130 ppm. Employees who were stationed outside each of the tanks as Tank Watch were exposed to less than 1 ppm n-butyl alcohol.

The area sample identified in Table 1 as "Area Sample/Mess Deck," was collected in the immediate vicinity of a painter who brush-painted approximately 4 ft^2 of the overhead on the mess deck. This sample revealed 1.5 ppm in the vicinity of a typical touch-up application.

Estimated VOC concentrations in thermal desorption tube samples are presented in Table 2. Sample A03534 was lost due to the high concentration of butanol in that sample, which overloaded the mass spectrometer. Of the remaining samples, sample number A03777 revealed the highest concentrations of VOCs. Since the sampling and analytical techniques used in these analyses have not been validated, all results should be considered as estimates.

The major VOCs which were detected on most three-bed thermal desorption tube samples were butanol, an aromatic naptha, toluene, xylene, benzaldehyde, and benzyl alcohol. Butanal was also detected, possibly as an impurity or thermal decomposition product resulting from the large amount of butanol on the samples. The aromatic naptha was similar to an Aromatic 100 solvent, and consisted primarily of C_9H_{12} alkyl benzenes (propyl-, trimethyl-, methylethyl- benzenes, etc.), and some $C_{10}H_{14}$ alkyl benzenes (dimethylethyl-, methylpropyl-, tetramethyl benzenes, etc.). Other compounds detected on these samples included acetone, isopropanol, butyl cellosolve, C_9-C_{12} aliphatics, siloxanes, hexane, limonene, dimethyl glutarate, and napthalene. No additional compounds were detected on the Tenax thermal desorption tubes.

The aromatic solvent detected on the thermal desorption tube samples was the same as the naptha detected in the part B paint bulk sample. Part B also contained some xylene and bisphenol A-epichlorohydrin resin product. The bulk sample of part A contained butanol, benzaldehyde, benzyl alcohol, and xylene. Analysis for polyamines indicated that the part A bulk sample (mixed) contained 0.5% TETA, and 0.2% TEPA. The paint dust sample contained butanol, xylene, aromatic naphtha, and benzyl alcohol.

Heating the bulk materials to 375°C generated many additional compounds which were not detected in the solvent extracted bulks. Phenol was the major compound generated when paint dust or dried paint was heated. Other compounds detected in the heated paint samples included acetaldehyde, acrolein, butanol, alkyl benzenes (aromatic naptha), benzyl alcohol, alkyl-substituted phenols, and traces of nitrogen compounds (pyridine, pyrazine, pyrole, and alkyl-substituted isomers of these).

Air sampling did not detect appreciable quantities of bisphenol A during welding. As shown in Table 3, quantifiable concentrations of bisphenol A were present in two of the eight samples. Of the remaining six samples, bisphenol A was detected (but not quantifiable) in two samples; and it was not detected in four samples (i.e., below the minimum detectable concentration).

Medical

Characteristics of the Study Population

Ninety-three persons completed the questionnaire, and 81 returned the peak flow measurement data for a week-long period in March 1997. Ninety-two participants answered the question concerning gender and 83 were males and 9 were females. All of the building trades working on the boat at that time were evaluated in the study (Table 4). The mean number of years a participant worked at EB was 17 (range 7-34). Of the 74 workers answering the question, 31 participants (42%) currently smoked an average of 19 cigarettes per day (range 2-35). Fifty-eight participants (64%) worked on the day shift, 31 (34%) worked on the evening shift, and 2 (2%) worked nights. Thirty workers (33% of the 90 workers answering the question) reported that they never wore a respirator while at work, 12 (13%) reported that they always wore a respirator, and 48 (53%) reported that they sometimes did. All 12 painters reported wearing a respirator, 6 sometimes and 6 always.

Asthmatic Symptoms

Data on the number of employees reporting wheezing, along with other possible signs of asthma (shortness of breath, chest tightness, or cough), are presented in Table 5. Of the 90 workers answering the question, 31 (34%) reported episodes of wheezing since starting work at EB. Table 6 provides further details of wheezing among EB employees. Twenty-two workers (24% of 90 workers) reported that their wheezing sometimes started while they were at work. Twenty workers (22%) reported that their wheezing followed certain job duties or after exposure to certain chemicals. Nine employees reported that their wheezing occurred after exposure to paint emissions, five felt that their wheezing was related to dust (including paint dust), and two each mentioned welding, fiberglass, or grinding metals. Wheezing was reported to start at various times after exposure at work, ranging from immediately to six hours (Table 7).

Sixteen workers (55% of the 31 workers with wheezing) reported that the wheezing that started at the job continued at home. Of those 16 workers, 10 reported that the wheezing continued at home for one hour, and 3 reported that the wheezing lasted two or more hours. On non-work days, 15 workers (52% of the 29 workers reporting wheezing who answered this question) reported that the wheezing did not occur at all, 11 (38%) said it occurred less frequently on non-work days than work days, and 3 (10%) reported that the wheezing remained the same on non-work days. No worker reported that the wheezing occurred more frequently on non-work days. Eighteen workers (20% of 90 workers answering the questions about wheezing) reported that their wheezing sometimes started at home. Twenty workers (22% of 90 workers) responded that they wheeze on both work and non-work days, four (4% of 90 workers) reported that they wheezed on work days only, and no participants reported that they only wheeze at home. Seven workers, whose wheezing started at home, felt that it was related to previous exposure to Mare Island paint at work, and five felt that the wheezing at home was related to welding fume at work. Twenty workers (22% of 90) reported that their wheezing occurred after specific job duties.

Twenty-nine workers (31% of 93 workers) met the epidemiologic definition of asthma, and 27 workers (29% of 93 workers) met the definition of occupational asthma. All workers who reported that they were presently taking medicine for asthma were already classified as meeting the epidemiologic classification of either asthma or occupational asthma. Using multiple logistic regression modeling, having the epidemiologic classification of asthma was related to both "seeing" welding and "smelling" paint, but the classification of *occupational* asthma was only related to "seeing" welding (Table 8).

Peak Flow Testing

Serial peak flow measurements for 81 workers were completed correctly and met the requirements for inclusion in the analysis. One worker returned his peak flow results but not his questionnaire; nevertheless, he was included in the peak flow analysis. Data from five workers with peak flows > 20% for the study period were excluded from this and further analyses of the peak flow data because the positive result was due to an outlier recording. This left 35 workers with an amplitude mean greater than 20% for the study period (46% of 76 workers). Data from two participants who had an amplitude mean result > 20% for any one day were also excluded from the one-day analyses because the positive result was due to an outlier reading, leaving 23 (29%) of 79 workers with an amplitude mean greater than 20% for any one day. Seven of 10 painters (5 expected) and 12 of 24 electricians (11 expected) had an amplitude mean > 20% for the study period. This was not statistically significant ($p=0.1$). As one might expect, painters were more likely to smell paint than electricians; paint was "smelled" by painters 16 times (10 expected) and not 53 times (59 expected) and paint was smelled by electricians 18 times (25 expected) and not 151 times (144 expected, $p=0.03$). Both painters and electricians were less likely to "see" welding than expected and painters reported "seeing" welding 8 times (18 expected) and electricians saw welding 33 times (47 expected, $p = 0.0001$). Participants in the study were more likely to report "seeing" welding than "smelling" paint. Paint was "smelled" by 34 different workers a total of 84 times and welding was "seen" by 48 workers a total of 157 times ($p=0.001$).

Thirteen workers (16% of the 79 workers) had an amplitude mean >20% for any one day and asthma (OR 4.3, 95% CI 1.5, 12.1) and 13 workers had occupational asthma (OR 5.3 95% CI 1.8, 15.3). Sixteen workers (21% of 76 workers) had an amplitude mean >20% for the study period and asthma (OR 3.0, 95% CI 1.1, 8.1) and the same number had occupational asthma (OR 4.1 95% CI 1.4, 11.7). A physician diagnosis of asthma was related to having an amplitude mean greater than 20% for the study period (OR 6.2, CI 3.4, 11.5) and for any one day (OR 6.5, CI 3.8, 11.1).

Twenty-three workers reported either "seeing" welding within 25 feet or "smelling" paint and had an amplitude mean > 20% for either the study period or any one day. Of those 23, 12 workers had a peak flow pattern that appeared to be work-related, and 4 of the 23 workers used an inhaler at work. Possible occupational causes for amplitude mean calculations >20%, as derived from the daily logs, are given in Table 9.

Cigarette smoking "now" was not related to having an amplitude mean >20% for any one day (OR 1.0, 95% CI 0.32, 3.0), or for the study period (1.4, 95% CI 0.48, 3.9). Similar results were found for having "ever" smoked: amplitude mean >20% for any one day OR 1.3, 95% CI 0.48, 3.6; or amplitude mean >20% for the study period OR 1.8, 95% CI 0.70, 4.7. Since cigarette smoking was not found to be related to having an amplitude mean in excess of 20% for either any day or the study period in a univariate analysis, it was not considered in the multiple regression analysis.

Peak Flow Testing and Exposures

An amplitude mean >20% for any one day was related to "seeing" welding "ever" (OR 2.1, 95% CI 1.3-3.4). "Smelling" paint "ever" was not related to having an amplitude mean >20% for any one day (OR 0.8, 95% CI 0.6-1.1). (Table 10) These effects of "seeing" welding are different when related to having an amplitude mean >20% for the study period, and the effects of welding were not as pronounced. Neither "seeing" welding (OR 1.4, 95% CI 0.95-2.3) nor "smelling" paint (OR 1.3, 95% CI 0.95-1.6) was related to having an amplitude mean >20% for the study period.

Peak Flow Testing and Self-Reported Wheezing and Respiratory Symptoms

Wheezing and respiratory symptoms were more related to "seeing" welding than "smelling" paint. Both "smelling" paint and "seeing" welding, however, were statistically related to reporting wheezing and respiratory symptoms. In a multiple logistic regression analysis, the odds ratio for employees experiencing respiratory symptoms were more than twice as great for "seeing" welding than for "smelling" paint and the odds ratio for wheezing and "seeing" welding was approximately twice as great as that for wheezing and "smelling" paint (Table 11). "Ever" wheezing or "ever" having respiratory symptoms were also related to having an amplitude mean >20% for the study period or for any one day of the study. Results were similar if we looked at work days only or all days of the study (Table 12).

DISCUSSION AND CONCLUSIONS

Bronchial hyper-responsiveness (a greater than 20% change in amplitude mean for the study period) was found in 46% of the workers who participated in the study. Based on available environmental and medical data we could not determine an exact cause for the bronchial hyper-responsiveness recorded at EB. However, in multiple regression analyses for all time periods, wheezing, respiratory symptoms (Table 12), and occupational asthma (Table 8) were more strongly associated with "seeing" welding within 25 feet than with "smelling" paint. PEFR changes >20% for any one day of the project were also more associated with "ever seeing" welding than with "ever smelling" paint (Table 10). Besides paint and welding fume, there were additional exposures to potential respiratory irritants, and possibly to chemical sensitizers such as isocyanate-containing materials that were applied to the exterior of the submarine (used in the mold in place [MIP] process) and epoxy resin components that might contribute to bronchial hyper-responsiveness and occupational asthma. Potential respiratory irritants include the welding fume, dust from grinding of painted metal surfaces, and solvents, particularly n-butyl alcohol.

Nine workers (45% of the workers answering the question) reported that their wheezing occurred within 1 hour after a particular job duty or using particular chemicals at work, suggesting an immediate bronchial response. However four workers reported that they started wheezing 4 to 6 hours after exposure, which would suggest a more delayed response and, possibly, a different etiology of the wheezing for these workers. In this case, it is possible that workers were responding to different agents in the work environment.

Selection of the participants in the study was a concern, in that NIOSH personnel could not enter all work areas of the submarine for the purpose of recruiting for the study. Information about the study was given to the employees by their unions at regularly scheduled union meetings. At the time of the study, the union representative went to areas of the boat where numerous workers were working and asked for volunteers from the group of workers who were previously informed of the study. It is possible that workers with respiratory problems were more likely to volunteer for the study; however, we have no information indicating if, or to what extent, this occurred. Workers were not restricted to one area of the boat and tended to move throughout the submarine during the course of a workday, so locating a specific worker at a specific time would have been difficult. However, the high prevalence of workers with possible work-associated PEFR changes, suggests an occupational respiratory problem despite possible flaws in the selection methodology.

Although the use of peak flow meters has been extensively studied, there are some concerns regarding reliability and reproducibility. These concerns are related to the improper recording of both the measurement and the time of measurement, particularly with the honesty and compliance of the participants. One study of 21 workers evaluated over 36 days found that the recorded PEFR value precisely corresponded with electronically stored values 52% of the time, and that recorded time was within one hour of the stored time 71% of the time.[36] Another study found similar results, with only 55.3% of the measured records being completely accurate as to PEF level and time.[37] In the present study, we eliminated workers whose peak flow readings were influenced by an outlier and workers who did not complete at least five days of the testing. Peak flow is effort-dependent, meaning that the harder the person blows into the meter, the greater his or her measured PEFR will be. This is one of the disadvantages of unsupervised use of the peak flow meter, in that it is not known if a person is using maximal effort or using the meter properly at any given time. However, each set of PEFR data suggesting work-related bronchial hyper-responsiveness was reviewed to verify that the recorded readings and resulting computer analysis made sense and were not fabricated and to determine if PEFR changes were temporally associated with recorded exposure events.

Another limitation of this study was that we were unable to measure individual exposures for all of the workers. We asked the workers if they either smelled paint or saw welding within 25 feet of their work area, and utilized the odor of the paint and the visualization of welding as markers for the exposure. The actual concentration would depend on ventilation at the job task site, the size of the area painted, or the extent and duration of the welding. Local exhaust ventilation (LEV) was not routinely used to capture welding fume or paint, thus most was released into the general work environment (interior compartments) where other workers were present.

Although it is company policy to remove paint from both sides of decks, bulkheads, and other surfaces prior to welding, employees reported that paint which could not be removed from inaccessible areas would be burnt (pyrolized) during welding. Employees and union officials commented that the pyrrolized paint emitted an objectionable odor. During the walk-through, NIOSH investigators observed burnt paint on an *accessible* overhead surface, caused by welding on the deck above: the paint on this surface could have been removed by grinding prior to welding. On March 10-12, 1997, PBZ air sampling for bisphenol A, a degradation product of epoxy paint, revealed only low concentrations of bisphenol A; however, these results reflect a number of variables (e.g., position of the welder relative to the plume, air movement, proximity to unremoved paint) which could not be assessed, as NIOSH investigators did not have access to high-security areas where most welding was performed. Some of the sampled welders reported that the welding plume did not pass through their breathing zone; even so, this could result in a small exposure for the welder while exposing other workers who might be in the plume rising above the welder. Analysis of cured Mare Island epoxy paint found phenol to be the major paint degradation product. Among other effects, phenol is a respiratory irritant.[38]

Brush application of Mare Island paint can result in exposures to n-butyl alcohol. Air monitoring in three tanks on March 10-11, 1997, revealed concentrations ranging between 2.4 and 130 ppm. The highest concentrations (78-130 ppm) were found in Aux-1(Auxiliary Machine Room-1, 4th level). Two samples, CT-3 and CT-12, (Aux-1 painters) include approximately one-hour of air sampling outside of the tank, as the painters reportedly sat and waited for welders to do some work in the tank that they had been painting a short while earlier. It is not known what, if any, respiratory protection was worn by the welders in that tank. Ventilation in the tanks was provided by fans that were mounted topside (on the exterior of the submarine). Supply air and exhaust ventilation were provided using flexible ducts that extended down to the tanks. On March 11, 1997, air was provided by a 4-inch diameter supply trunk and exhausted through a 6-inch (estimated diameter) trunk.

At the time of the NIOSH evaluation, five flexible eight-inch exhaust ducts entered the submarine, each splitting into three four-inch ducts. No ventilation measurements were made; however, a company representative reported a flow rate of approximately 150 cubic feet per minute (cfm) for each four-inch duct. The number of available ducts is limited by the number of available hull openings. Company representatives reported that flexible ducts pass through a topside opening that is also used to bring equipment and large items into the vessel and therefore must be disconnected when equipment is brought aboard. Although LEV and supply air would ideally be available at all operations where air contaminants are generated, the time and effort involved in dragging flexible ducts through a maze of ladders and passageways to a specific job site discourages its use during smaller, short-term operations. Although LEV appears to be a persistent problem throughout construction, the ship's ventilation system is used to provide additional supply air as soon as it becomes operational.

While samples collected during painting in tanks represent suspected "worst-case" conditions, the area sample collected on the mess deck, assessed exposure to n-butyl alcohol during a typical touch-up operation. During sampling on the mess deck, a slight, but noticeable movement of air away from the sampling pumps was noted. Thus, the direction of air movement on the mess deck may have resulted in somewhat lower n-butyl alcohol concentrations in these samples than would have been collected if the sampler had been "downwind" of the painting. However, it should be noted that LEV was available for this job, but was not used. The painter wore a full-face respirator, one of the three nearby workers wore a half-face respirator, and the others wore no respiratory protection. No respiratory discomfort or irritation was reported by any of the workers or observers in this area, including the NIOSH investigator.

According to a representative of Ciba Speciality Chemicals, the manufacturer of the polyamide hardener in Mare Island part A, the hardener contains less than 4% free TETA. Analysis of the part A bulk sample found 0.7% amine content: 0.5% TETA, and 0.2% TEPA. Thus, exposure to the amine component from this paint appears to be minimal. Nevertheless, some studies have linked epoxy paint and aliphatic polyamines in other formulations to development of respiratory symptoms and other respiratory problems, including asthma.[39,40] Solvents, similar to those found in the paint used at EB, have also been linked to either asthma or development of bronchial hyper reactivity. In a study of paired twins, exposure to organic solvents was found only in the twin who reported asthma, and exposure to irritants was more common in asthmatics than in nonasthmatics.[41] Increased bronchial hyperresponsiveness was found in a study of house painters that the authors suggest might be related to exposure to the volatile organic compounds found in water-based house paint.[42]

At EB, hand-held grinders are used by painters, shipfitters, sheet metal workers, electricians, and other tradespeople to remove paint from metal surfaces. Grinding generates paint and metal dust; although respiratory protection is supposed to be worn by workers while grinding, nearby workers in the grinding area may be exposed to grinding dust. Epoxy paint dust can be a respiratory irritant in some individuals and may, infrequently, result in sensitization.

Skin effects were reported by some interviewed employees. Three workers reported a red, raised, itchy rash, usually on the forearms, that they called the "Seawolf rash." Epoxies may be associated with contact dermatitis; both the hardener and the resin have been implicated, but the reports usually involve either the diglycidyl ether of bisphenol A or nonbisphenol A type resins, or hardeners other than the polyamide hardener used at EB.[43] One report focused on airborne exposure and resultant contact urticaria, but the compounds that were implicated (anhydrides) were different from those used at EB.[44]

This study did not address exposures associated with the application of isocyanate-containing compounds to the exterior of the submarine. This process was completed by the time we arrived and we were unable to measure exposure. According to the company, isocyanate levels were kept very low through the use of ventilation; nevertheless, the large quantity of isocyanate-containing materials used raises questions about the potential for exposure. Isocyanates can induce immediate, late, and dual (combined intermediate and late) asthmatic responses: the late asthmatic reaction predominates on inhalation challenge testing.[45] In a study of 29 workers referred for specific inhalation challenges with isocyanates, 7 had an immediate response, 15 had an early late or late response, and 7 had dual reactions.[46]

Exposures to welding fumes may result in a variety of health effects including metal fume fever, siderosis, chronic bronchitis, and asthma.[47] The most common abnormalities in large controlled studies of active welders are acute or chronic airway symptoms (bronchitis), and there are not many studies of either asthma or nonallergic airway hyperresponsiveness in welders.[48] Even so, welding is considered to be a leading cause of occupational asthma by some researchers.[49]

According to a union official in November 1997, working conditions at the yard had improved since the NIOSH survey, and symptoms reporting had declined, although painting and welding were still occurring. According to a union safety official, improvements in construction already enacted at EB include:

1. Scheduling large painting jobs for third shift

2. Placing signs in the area where painting will occur, and roping-off the area. In addition, workers are being informed by the painters where painting will occur.

3. Improved ventilation: the ship's ventilation system is operational, and there is improved airflow to most areas of the ship.

Some of the improvements that were made are discussed and recommended in the EB safety Manual (D-645. Rev June 1995). A section of the EB manual is devoted to the safe use of Mare Island paint, and recommends the use of a half-face, or Ultra Twin (full-face) respirator with a GMA filter and nitrile butyl (green) gloves while brush painting in enclosed spaces or outdoors. The same recommendation is given for use in confined spaces except an Ultra Twin respirator is mandated. The company also mandates that: (1) no hot work be done within 10 feet of painting, (2) warning signs be posted, and (3) management announce the location of the brush painting on Cascon or paging systems (if available).

RECOMMENDATIONS

1. To the extent possible, preconstruction planning should ensure that sufficient "cutouts" are present in the hull to allow access for sufficient exhaust and supply ventilation.

2. Paint emissions and welding fume should be exhausted outside of the boat, especially if welding occurs near painted surfaces.

3. Investigate using the torpedo tubes as a portal for exhaust and fresh air ventilation. Since the torpedo tubes contain sensitive equipment, this may involve a production change, delaying preparation of the tubes until auxiliary ventilation is no longer needed.

4. Utilize the ship's ventilation system as soon as possible. Priority should be given to completing the ship's duct work and starting the ship's fan for that duct.

5. The PPE program should be reviewed to ensure that an adequate level of protection is provided.

a. The respiratory protection program should require an adequate level of protection for *all* workers in areas where painting, welding, or other contaminant-producing work is performed. If one worker is required to wear respiratory protection while painting, welding, etc., adjacent workers should also wear similar respiratory protection, since the exposure may be similar.

b. Workers should wear eye protection at all times in construction areas (safety lenses and side shields). If workers are required to remain in an area where welding is occurring, welding screens or curtains should be used to minimize the hazard to nearby workers. If that is not possible, workers should either be removed from adjacent areas while welding is taking place or be required to wear eye protection of the correct shade, as recommended by the American Welding Society.

6. Paint should be removed from behind an area to be welded and within 6 inches of the weld. This may be accomplished by grinding the paint with proper exhaust ventilation. If the paint cannot be removed by welding because it is inaccessible, respiratory protection should be used by all workers in the vicinity, since the pyrolysis products of Mare Island paint include respiratory irritants, such as phenol.

7. Management, in cooperation with the union, should insure that relevant safety and health guidelines are being followed by the workers and that all safety concerns are addressed before work begins. Painting should be scheduled so that it is isolated from other tasks in the construction process. Management and union representatives should work to ensure that company guidelines for removing paint before welding are followed.

8. The existing EB safety manual should be followed particularly regarding the sections on notification and respiratory protection.

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Table 1
Air Sampling, n-Butyl Alcohol.†
Electric Boat Division of General Dynamics
Groton, Connecticut

Date	Activity/Location	Sample #	Time	Period (minutes)	Volume (liters)	n-Butyl Alcohol (ppm)	Comments
3/10/97							
	Tank Watch/Aux-6	CT-1	1733-1943	130	13.1	(0.081)	
	Brush Painting/Aux-6	CT-7	1720-1942	142	14.3	18.	
	Area Sample/Aux-6	CT-10	--	74	7.49	0.26	Pump was started when painter entered tank. Pump was in tank.
	Tank Watch/Sanitary-3	CT-8	1728-1914	106	10.6	0.19	
	Brush Painting/Sanitary-3	CT-2	1725-1928	123	12.5	2.4	
3/11/97							
	Brush Painting/Aux-6	CT-5	1602-1748 1823-1948	191	19.3	16.	
	Brush Painting/Aux-6	CT-6	1606-1748 1825-1947	184	18.6	25.	
	Area Sample/Aux-6	CT-15	1640-1748 1851-1948	125	12.7	1.2	
	Tank Watch/Aux-1	CT-16	1619-1806	107	10.7	0.43	
	Brush Painting/Aux-1	CT-12	1600-1754[1] 1843-1945	176	17.7	130.	Painters did not paint or enter tank after 1802 because welders had entered the tank. These exposure estimates includes this period when painters sat outside the tank wearing sampling pumps.
	Brush Painting/Aux-1	CT-3	1555-1802 1827-1946	206	20.7	94.	
	Brush Painting/Aux-1	CT-4	1600-1746[1]	106	10.6	78.	Pump was not running while painter sat outside tank for approximately 60 minutes, 1840-1940.
	Area Sample/Mess Deck	CT-9	1018-1057	39	3.94	1.5	Brush painting approximately 4 ft^2.

† Footnotes appear following Table 2.

Table 2
Air Sampling, Thermal Desorption Tubes
Electric Boat Division of General dynamics
Groton, Connecticut

Date	Location/Activity	Sample #	Time	Period (minutes)	Volume (liters)	Organic Compounds[2] Compound	Estimated ppm	Comments
3/11/97								
	Aux-1/Brush Painting (area sample)	A03777	1555-1805	130	6.56	n-butyl alcohol hexane toluene benzyl alcohol benzaldehyde xylene aromatic naptha	65. 0.004-0.6 0.004-0.6 0.003-0.5 0.004-0.5 3. 12.	Sample A03534 was lost due to a high concentration of butanol. Of the remaining samples, A03777 revealed the highest concentrations.
3/10/97 & 3/11/97								
	Aux-1, Aux-6, San-3, Brush Painting & Tank Watch (PBZ & area samples)	--	--	--	--	n-butyl alcohol hexane toluene benzyl alcohol benzaldehyde xylene aromatic naptha	0.07-20. <1.5 <1.4 <1.2 <1.2 <1.2 5.1	These are estimated concentrations from seventeen samples collected side-by-side with the charcoal tube samples reported in Table 1.

ppm = parts per million.
( ) = Value is between the minimum detectable concentration (MDC) and minimum quantifiable concentration (MQC). (The MDC and MQC are determined by the analytical limits of detection and quantitation, and the volume of the air sample.) For Table 1, the range of these values is 0.025 - 0.082 ppm, based on an average sample volume of 13.2 liters.
< = Less than.
1. Approximate time of sampling.
2. Qualitative analysis of organic compounds is best suited for organic compounds with molecular weights below 300, and boiling points at or below that of a C_{12} alkane ($\leq$ 200°C). Since the sampling and analytical techniques used in these analyses have not been validated, all results in Table 2 should be considered to be estimated concentrations. The estimates for samples other than A03777 are based on an average sample volume of 4.84 liters.

Table 3 Air Sampling, Bisphenol A Electric Boat Division of General Dynamics Groton, Connecticut							
Date	**Activity/Location**	**Sample #**	**Time**	**Period (minutes)**	**Volume (liters)**	**Bisphenol A (ppm)**	**Comments**
3/10/97							
	Stick welding/COC, 3rd level, frame 39	GFF-1	--	165	267.	<0.0002	High tensile steel.
3/11/97							
	Stick welding/Forward Compartment	GFF-2	0718-1105	227	361.	0.00098	Welder reported black, stringy paint was released from work surface during welding. High tensile steel.
	Stick welding/COC	GFF-3	0726-1134	248	394.	(0.00020)	High tensile steel.
	Stick welding/Engine room, upper level, fr 99	GFF-4	0808-1107	179	287.	<0.0001	Stainless steel.
	--	GFF-5	1200-1333	93	148.	<0.0003	No welding was performed during this period. Welder reported being near grinding. The sample filter was discolored.
3/12/97							
	Stick welding/Forward compartment, starboard	GFF-6	0722-1050	208	333.	0.0025	High tensile steel.
	Stick welding/COC, 2nd level	GFF-7	0727-1122	235	377.	<0.0001	High tensile steel.
	TIG welding/COC, 2nd level, forward	GFF-13	0748-1108	200	316.	(0.00018)	

ppm = parts per million.
( ) = Value is between the minimum detectable concentration (MDC) and minimum quantifiable concentration (MQC). (The MDC and MQC are determined by the analytical limits of detection and quantitation,
and the volume of the air sample.) For Table 3, the range of these values is 0.0001 - 0.00045 ppm, based on an average sample volume of 310 liters.
< = Less than.

Table 4 Job Duty of Study Participants Electric Boat Division of General Dynamics Groton, Connecticut HETA 96-0253 March 10, 1997 n=91		
Trade	Number of workers	Percent of participants
painters	12	13
carpenters	12	13
welders	5	6
electricians	28	31
pipe fitters	15	17
other	19	21

Table 5 Wheezing and Other Symptoms of Asthma from the Questionnaire Electric Boat Division of General Dynamics Groton, Connecticut HETA 96-0253 March 10, 1997 n=92		
Symptom	number	percent of respondents
Wheezing (ever) since working at EB	31	34
Wheezing (past 6 months)	26	28
Wheezing (before working at EB)	5	5
Wheezing and shortness of breath	22	24
Wheezing and chest tightness	12	13
Wheezing and cough	26	28

Table 6 Wheezing Electric Boat Division of General Dynamics Groton, Connecticut HETA 96-0253 March 10, 1997 n=90		
	yes	percent yes
Wheezing when employee has a cold or sinus infection	29	32%
wheezing ever starts while at work	22	24%
wheezing occurring after specific job duties or using specific materials	20	22%
wheezing ever starting at home	18	20%
saw a physician for wheezing	17	19%
wheezing once a week or more	11	12%
wheezing lasting 30 minutes or more	10	11%
wheezing at home for more than 1 hour following certain activities at work	10	11%
wheezing prior to starting at Electric Boat	5	6%

Table 7 Number of Hours After Exposure Before Wheezing Starts in Workers Attributing Their Wheezing to Exposure at Work Electric Boat Division of General Dynamics Groton, Connecticut HETA 96-0253 March 10, 1997 n=20		
time	frequency	percent
immediately	1	5
within one hour	8	40
1 to 3 hours	7	35
4 to 6 hours	4	20
more than 6 hours	0	0

Table 8
Classification of Asthma and Occupational Asthma and Exposure to Welding and Paint
Electric Boat Division of General Dynamics
Groton, Connecticut
HETA 96-0253
March 10, 1997
n=20

Asthma classification	Odds Ratio (95% Confidence Interval)
exposure	
"Seeing" welding	3.5 (2.2-5.7)
"Smelling" paint	1.4(1.1-2.0)
Occupational asthma classification	Odds Ratio (95% Confidence interval)
exposure	
"Seeing" welding	3.6 (2.2-5.8)
"Smelling" paint	1.0 (0.7-1.3)

Table 9
Peak Flow Patterns Consistent with an Occupational Exposure
Among Persons with Amplitude Mean >20%
Electric Boat Division of General Dynamics
Groton, Connecticut
HETA 96-0253
March 10, 1997
n=12

pattern	n	%
daily amplitude mean > on workdays than weekends	2	17
PEF recovery on 2nd day of weekend-decline with seeing WELDING at work when return	2	17
PEF declined every day at work	1	8
PEF recovery on weekend after seeing WELDING and smelling PAINT during workweek	2	17
large drop in PEF at work associated with both smelling PAINT and seeing WELDING during that day	1	8
drop in PEF at work associated with smelling paint that day and next morning	2	17
more than one reason	2	17

Table 10 Peak Flow Changes Related to "Seeing" Welding and "Smelling" Paint "Ever" Multiple Logistic Regression Electric Boat Division of General Dynamics Groton, Connecticut HETA 96-0253 March 10, 1997	
Amplitude Mean >20% for any one day	
exposure	Odds Ratio and 95% Confidence Interval
seeing welding "ever"	2.1 (1.3-3.4)
smelling painting "ever"	0.8 (0.6-1.1)
Amplitude Mean > 20% for the study period	
exposure	Odds Ratio and 95% Confidence Interval
seeing welding "ever"	1.5 (0.95-2.3)
smelling painting "ever"	1.3 (0.95-1.6)

Table 11 Relationship between Painting and Welding and Reported Wheezing and Respiratory Symptoms on PEFR logs Multiple Logistic Regression Electric Boat Division of General Dynamics Groton, Connecticut HETA 96-0253 March 10, 1997	
Wheezing	Odds Ratio and 95% Confidence Interval- wheezing on work days only
"Smelling" Paint	1.6 (1.1-2.3)
"Seeing" Welding Within 25'	2.6 (1.5-6.5)
Respiratory Symptoms	
"Smelling" Paint	1.7 (1.2-2.5)
"Seeing" Welding Within 25'	3.7 (1.8-7.6)

Table 12 Relationship between Peak Flow Readings and Reported Wheezing and Respiratory Symptoms Before PEFR Measurement Session Multiple Logistic Regression Electric Boat Division of General Dynamics Groton, Connecticut HETA 96-0253 March 10, 1997		
Wheezing	Odds Ratio and 95% Confidence Interval-on work days only	Odds ratio and 95% Confidence Interval-on all days
PEFR > 20% for one day	6.8 (3.5-13.2)	6.9(3.8-12.7)
PEFR >20% for the study period	8.6 (3.5-21.0)	11.1 (4.6-26.4)
Respiratory Symptoms		
PEFR >20%for one day	5.9 (3.6-9.6)	5.1 (3.4-7.8)
PEFR >20% for the study period	6.1 (3.8-9.8)	6.8 (4.4-10.4)

APPENDIX A

February 1997

Form Approved
OMB No. 0920–0260
Expires August 31, 1997

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
U.S. PUBLIC HEALTH SERVICE
CENTERS FOR DISEASE CONTROL AND PREVENTION
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

ELECTRIC BOAT DIVISION OF GENERAL DYNAMICS, GROTON, CONNECTICUT
JUNE 1997
HETA 96-0253

To help determine whether breathing problems occurring among some employees are related to working at Electric Boat, please complete the attached questionnaire. Your participation in this evaluation is voluntary, but very important. Your completed questionnaire will be collected and analyzed by NIOSH investigators and your responses WILL NOT BE SEEN BY MANAGEMENT OR UNION REPRESENTATIVES.

After completing the questionnaire, please return it to the NIOSH study investigator.
Pick up your peak flow meter, recording forms, and instructions before returning to work.

YOUR PARTICIPATION IN THIS SURVEY IS APPRECIATED.
THANK YOU FOR BEING AN IMPORTANT PART OF THIS EVALUATION

ID NUMBER ____ ____ ____ (1-3)
DATE __ __/__ __/97 (4-9)

LOCATION AREA ___ (10)

NOTE:
(The numbers alongside multiple-choice answers and on right margins are for coding purposes. *Please ignore*)
Answer ALL questions. If your answer is No, please check NO.

PERSONAL INFORMATION (PLEASE PRINT)

Last Name: ____

First Name: ____

Middle Initial:____

Mailing Address:

Street ______________________________________

City ____

State ______ (Zip Code) ____________________

Telephone: (_____) - __________-________________
area code number

How old were you on your LAST birthday?

________ #years (12-13)

WORK HISTORY

1. **How long** have you worked at **ELECTRIC BOAT**?

    ____ #years (14-15)

2. In what **COMPARTMENT** did you work today? Also, please **specify** the **exact location** - (Example: torpedo, galley, etc.)

    a.____ *Forward* compartment >Location:________ (16-17) ____ 1
    b.____ *Reactor* compartment > Location:________ (18-19) ____ 2
    c.____ *Engine* compartment > Location:________ (20-21) ____ 3

3. What is your *current* JOB TITLE?

    ____ painter 1
    ____ carpenter 2
    ____ welder 3 (22)
    ____ electrician 4
    ____ pipefitter 5
    ____ other (please specify) 6 ______________________

4. **How long** have you worked at your **CURRENT JOB**?

    ____ #years (23-24)

5. What is your *current* WORKSHIFT?

    ____days 1
    ____evenings 2 (25)
    ____nights 3

6. Do you wear a **RESPIRATOR** while you are at work?

    ____ no 0
    ____ yes, always 1 (26)
    ____ sometimes 2

SMOKING HISTORY

7. Have you **EVER** smoked **CIGARETTES**? (If you've smoked **fewer** than 100 cigarettes in your **entire life**, answer NO.)

____ no^0 (Skip to q.#11)
____ yes^1(continue) (27)

8. Do you **CURRENTLY** smoke **cigarettes**?

____ no^0 (Skip to q.#9)
____ yes^1(continue) (28)

(If yes, **how many** cigarettes do you currently smoke <u>per day</u>? 20 cigarettes=1 pack)

_____# cigarettes per day (Skip to q.#10)

(29-30)

9. When you **USED** to smoke, how many *cigarettes, on average,* **did** you smoke **per day**?

_____# cigarettes per day (31-32)

10. How **many years** *altogether* have you smoked cigarettes? ____#years (33-34)

MEDICAL HISTORY

11. Since you **began working** at **Electric Boat** have you had episodes of **WHEEZING**?

____ no^0 (Skip to q.#41, page 8)
____ yes^1(continue)

(35)

12. In what **YEAR** did you **first notice** your **wheezing**? 19 __ __

(36-37)

13. Were these episodes of **wheezing** usually **accompanied with**:

a. Shortness of breath?___no^0 ___yes^1 (38-39)
b. Chest tightness?___no^0 ___yes^1 (40-41)
c. Cough?__no^0 ___yes^1 (42-43)

14. Have you had episodes of **wheezing** within the **last 6 months**?

____ no^0
____ yes^1

(44)

15. Did you *wheeze* PRIOR to working for **Electric Boat**?

___ no^{0}
___ yes^{1} (45)

16. Do you usually *wheeze* when you have a **cold** or **sinus infection**?

___ no^{0}
___ yes^{1} (46)

17. Do you **presently** have a *cold* or a *sinus infection*?

___ no^{0}
___ yes^{1} (47)

18. When you have *wheezing*, **how long** does it **usually** last?

___ Less than 30 minutes^{1}
___ 30 minutes or more^{2} (48)

19. Have you ever seen a **Medical Doctor** about your *wheezing*?

___ no^{0} ___ yes^{1} (49)

20. Do you take **any Medication** when you **begin wheezing**?

___ never^{0} (Skip to q.#21)
___ sometimes^{1}
___ always^{2} (50)

List **Medications** you take when you *begin* wheezing:

____

____

21. Do you take **any Medication** to *PREVENT* wheezing?

___ never^{0} (Skip to q.#22)
___ sometimes^{1} (51)
___ always^{2}

List **Medications** you take to *prevent* wheezing:

____

____

THE FOLLOWING QUESTIONS ASK ABOUT YOUR WHEEZING *WHILE AT WORK*:
****

22. Does your *wheezing* ever start while you are at **work**?

___ no[0] (Skip to q.#32 page 6)
___ yes[1] (continue)

(52)

23. How **frequently** do you have *wheezing* that **begins at work**?

___ *every* work day[1]
___ *more* than *once a week* but *less* than *every day*[2]
___ *more* than *once a month* but *less* than *once a week*[3]
___ *less* than *once a month*[4] (53)

24. Does the *wheezing* that **begins at work** usually occur following certain **job duties** or after **exposure** to **specific materials**?

___ no,never[0] (Skip to q.#27)
___ yes[1](continue) (54)

25. Please describe the **job duties** you are doing or **materials** you are using **at work** that you think are related to your *wheezing*.

JOB DUTY	MATERIAL(S)
____________________________	____________________________
____________________________	____________________________
____________________________	____________________________

26. **How SOON** after **beginning** the above **job duties** or **using materials** at **work** does your *wheezing* occur?

___ *Immediately*[1]
___ within one hour[2]
___ 1 to 3 hours[3] (55)
___ 4 to 6 hours[4]
___ more than 6 hours[5]

27. Do you ever take **any Medication** for *wheezing* when you **wheeze at work**?

___ no[0] (continue) (56)
___ yes[1]

28. If you **do NOT take medication** for *wheezing at work,* **how long does the** *wheezing* last?

___ *less* than *30 minutes* without taking medication[1]
___ *more* than *30 minutes* without taking medication[2]
___ I *always take medication* when I wheeze[3] (57)

THE FOLLOWING QUESTIONS ASK ABOUT YOUR WHEEZING *WHILE AWAY FROM WORK*:

****

29. Does the wheezing *that begins at work* **CONTINUE** after **COMING HOME FROM WORK?**

___ no[0] (Skip to q.#31)
___ yes[1] (continue) (58)

30. How **many hours** does the *wheezing* **continue** after you leave work **before it stops?**

__ __ # hours (59-60)

31. On **DAYS** you **DO NOT WORK** (including weekends/vacation) does the *wheezing* occur:

___ Not at all[1]
___ Less frequently than on workdays[2]
___ Same as workdays[3]
___ More frequently than on workdays[4] (61)

****

32. Does your *wheezing* ever **BEGIN AT HOME?**

___ no[0] (Skip to q.# 41)
___ Yes[1] (continue) (62)

33. **If yes,** does it start **within 6 hours** after you **return home from work**?

___ never[0]
___ sometimes[1]

34. Do you think that your always[2] *wheezing* that **starts at home** is a **result** from your (63)
doing certain **job duties** or from exposure to **specific materials** while you were at work?

___ no,never[0] (Skip to q.#35)
___ yes[1] (continue)
___ Don't know [2] (64)

If yes, please list the **Job Duty(s)** you were doing or **Materials** you were exposed to at work that are **related to your** *wheezing* **at home**:

JOB DUTY	MATERIAL(S)
____________________	____________________
____________________	____________________
____________________	____________________

35. Does your *wheezing* **at home** occur **only on days** that you have **worked**?

___ I wheeze on *non-work* days *only*[1]
___ I wheeze on *work days only*[2] (65)
___ I wheeze on *both work and non-work* days[3]

****

36. Do you ever **begin** *wheezing* **at home** - not work related - following **certain activities** or **exposure to specific materials**?(**Example**: gardening, housework, exercise, remodeling, hobbies, etc.)

___ no[0] (Skip to q.#39)
___ yes[1] (continue) (66)

37. What **activities** or **materials** you use ***at home*** cause you to *wheeze*?

ACTIVITY	MATERIAL(S)
____________________	____________________
____________________	____________________
____________________	____________________

38. **How SOON** after **beginning** the above **activities** or **use of materials** ***at home*** does your *wheezing* occur?

___ *Immediately*[1]
___ within 1 hour[2]
___ 1 to 3 hours[3] (67)
___ more than 6 hours[5]
___ 4 to 6 hours[4]

39. Do you take **any Medication** when you *wheeze* **at home**?

___ no[0] (continue)
___ yes[1] (Skip to q.#41) (68)

40. If you **do NOT take medication**, how long does the *wheezing* last **at home**?
___ *less* than *30 minutes* <u>without taking medication</u>[1]
___ *more* than *30 minutes* <u>without taking medication</u>[2]
___ I *always take medication* when I wheeze[3] (69)

****

MEDICAL INFORMATION: ASTHMA

41. Have you *ever* been told by a **Medical Doctor** that you have **Asthma**?
___ no[0] (Skip to q.#51)
___ yes[1] (continue) (70)

42. Did you have *asthma* as a **child** (18 years or younger)?
___ no[0] (Skip to q.#44) ___ yes[1] (continue)
___ don't know[2] (71)

43. **If Yes**, do you **still have it** as an **adult**?

___ no[0] (Skip to q.#51)
___ yes[1] (Skip to q.#47) (72)

44. Were you first diagnosed as having asthma when you were an **adult** (over age 18)

___ no[0]
___ yes[1] (73)

45. In what **year** did your *asthma* as an *adult* **first begin**? 19 ___ (74-75)

46. Where you working at **Electric Boat** when your *asthma* **first began**?
___ no[0]
___ yes[1] (please go to Question 48) (76)

47. If you had *asthma* before you began working at Electric Boat, has it **gotten worse**
(more severe or more frequent) **since working** at Electric Boat?

___ no^0
___ yes^1 (77)

48. Has a *Medical Doctor* ever **prescribed** specific **medication**(s) for your **ASTHMA**?

___ no^0 (Skip to q.#51)
___ yes^1(continue) (78)

49. Are you **presently** taking **any medication**(s) for your *ASTHMA* ?

___ no^0
___ yes^1 (79)

50. Please list what **medication**(s) you **presently** take for **ASTHMA** and **how often**:

MEDICATION(S)
HOW OFTEN

a. ____________________________

______ REGULARLY - ONCE A DAY^1

______ REGULARLY - MORE THAN ONCE A DAY^2

______ AS NEEDED^3 (80-81)

b. ____________________________

______ REGULARLY - ONCE A DAY^1

______ REGULARLY - MORE THAN ONCE A DAY^2

______ AS NEEDED^3 (82-83)

c. ____________________________

______ REGULARLY - ONCE A DAY^1

______ REGULARLY - MORE THAN ONCE A DAY^2

______ AS NEEDED^3 (84-85)

d. ____________________________

______ REGULARLY - ONCE A DAY^1

______ REGULARLY - MORE THAN ONCE A DAY^2

______ AS NEEDED^3 (86-87)

51. Are you **presently** taking any OTHER *prescribed* *medications*?

____ no^0 (Go to **COMMENTS**)
____ yes^1 (continue) (88)

52. List what *OTHER prescribed medications* you are **presently** taking and the **reason**:

MEDICATION(S)	REASON FOR TAKING
________________	________________
________________	________________
________________	________________
________________	________________

COMMENTS:

(Please use the space below for any comments you have about the questionnaire, your work, etc.)

____

____

____

____

END OF QUESTIONNAIRE

THANK YOU FOR YOUR PARTICIPATION!

PLEASE TURN IN YOUR QUESTIONNAIRE TO A NIOSH REPRESENTATIVE

APPENDIX B

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
ELECTRIC BOAT, GROTON, CONNECTICUT
HETA 96-0253--**PEAK FLOW METER TEST RECORDING**

Name____ **ID#** ____ ____ ____ ____

Date _______/_______/97 WORKSHIFT: **Begin** ______ am/ pm **End** _____ am/pm

DAY: Sun - Mon - Tues - Weds - Thurs - Fri - Sat (circle one) DID **NOT** WORK TODAY _____

Time of day	***Actual* time**	**Peak Flow Meter Reading**	**Since your last test, did you? (check all that apply)**	**Since your last test did you use an Asthma inhaler?**
1) Awakening	____ : ____ a.m. __ p.m.__	**1st** attempt _________ **2nd** attempt _________ **3rd** attempt _________	___ did you **wheeze**? ___ have **shortness of breath** ? ___ did you **cough** or have **chest tightness**?	_____ YES _____ NO
2) Arrival at work	___ : ____ a.m. __ p.m.__	**1st** attempt _________ **2nd** attempt _________ **3rd** attempt _________	___ did you **wheeze**? ___ have **shortness of breath**? ___ did you **cough** or have **chest tightness**?	_____ YES _____ NO
3) Lunchtime or mid-shift break	___ : ____ a.m. __ p.m.__	**1st** attempt _________ **2nd** attempt _________ **3rd** attempt _________	___ did you **wheeze**? ___ have **shortness of breath**? ___ did you **cough** or have **chest tightness**? ___ *smell* **Mare Island paint**? ___ **weld** or have *another worker* **welding within 25' of you?** ___ did you wear a respirator?	_____ YES _____ NO
4) Before leaving work	___ : ____ a.m. __ p.m.__	**1st** attempt _________ **2nd** attempt _________ **3rd** attempt _________	___ did you **wheeze**? ___ have **shortness of breath**? ___ did you **cough** or have **chest tightness**? ___ *smell* **Mare Island paint**? ___ **weld** or have *another worker* **welding within 25' of you?** ___ did you wear a respirator?	_____ YES _____ NO
5) 4 hours after leaving work	___ : ____ a.m. __ p.m.__	**1st** attempt _________ **2nd** attempt _________ **3rd** attempt _________	___ did you **wheeze**? ___ have **shortness of breath**? ___ did you **cough** or have **chest tightness**?	_____ YES _____ NO