HEALTH HAZARD EVALUATION REPORT

HETA 92-0102-2537
SACRAMENTO ARMY DEPOT
SACRAMENTO, CALIFORNIA

PREFACE

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

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

HETA 92-0102-2537
OCTOBER 1995
SACRAMENTO ARMY DEPOT
SACRAMENTO, CALIFORNIA

NIOSH INVESTIGATORS:
Kenneth F. Martinez, M.S.E.E
Robert Malkin, Ph.D.

SUMMARY

A health hazard evaluation (HHE) was conducted by the National Institute for Occupational Safety and Health (NIOSH) at the Sacramento Army Depot in Sacramento, California. This investigation was performed in response to a request from the American Federation of Governmental Employees (AFGE), Local 1681. The areas of concern included the electrooptics work room of Building 555, and a small computer module located in Warehouse 3 (Bay 6). In Building 555, "possible" chemical agents cited in the request included the Chemical Agent Resistant Coating (CARC) paint, solder rosins and fluxes, and various solvents. Reported health problems included light-headedness, drowsiness, headaches, upset stomach, skin rashes, upper respiratory illness, sinus infections, and pneumonia. In the small computer module (Warehouse 3 [Bay 6]), the request cited air quality concerns.

On June 22-25, 1992, an initial site visit was conducted at the Sacramento Army Depot which included Building 555, Warehouse 3 (Bay 6), Building 320 (mezzanine office module), and Warehouse 7 (Bays 2 through 5). The areas in Building 320 and Warehouse 7 (Bays 2 through 5) were added during the initial site visit at the request of the union because of concerns of the indoor environmental quality. The site visit consisted of walk-through surveys of specified problem areas, physical inspection of heating, ventilating, and air-conditioning (HVAC) systems, and private interviews with employees. A symptom questionnaire was distributed to employees in Buildings 320 and 555.

A follow-up survey was conducted from March 29 through April 1, 1993. Environmental and medical investigations focused on Building 320 (mezzanine office module) and Building 555 (electro-optics work room). The environmental evaluation consisted of: (1) a walk-through survey of both buildings including HVAC inspection; (2) the collection of air samples for volatile organic chemicals (VOCs); (3) real-time measurements of carbon dioxide (CO_2), temperature, and relative humidity; (4) measurement of volumetric air flow rates in the ventilation systems serving areas of concern in both buildings; and (5) the collection of air samples in Building 555 for lead content. The medical evaluation consisted of follow-up confidential medical interviews with occupants in Buildings 320 and 555. Environmental concerns in Warehouse 3 (Bay 6) and Warehouse 7 (Bays 2 through 5) were evaluated by observation of the problem areas.

In Building 555 (electro-optics repair), qualitative personal breathing zone (PBZ) samples for VOCs revealed primarily acetone, ethanol, and isopropyl alcohol. Area air samples for these three organic solvents revealed all concentrations below the NIOSH Recommended Exposure Limits (RELs), the American Conference of Governmental Industrial Hygienists Threshold Limit Values®, and the Occupational Safety and Health Administration Permissible Exposure Limits. None of the PBZ samples collected had detectable lead (minimum detectable concentration:
1 $\mu g/m^3$ for a 1000 liter sample). Physical inspections of the rooftop AHUs did not reveal any visible evidence that would indicate a microbiologic reservoir. Specifically, the filters appeared free of debris accumulation; the ventilation ducts were in good condition; and the coils and surrounding area were absent of standing water and/or "slime" accumulation. Carbon dioxide (CO_2), temperature, and relative humidity measurement values were within the limits recommended by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). The most prevalent symptoms that improved when the employee left work included tiredness/fatigue, nose or sinus problems, dry throat, strained eyes, dry, itching or irritated eyes, and headache. However, symptoms prevalence was not markedly different from a published study of non-problem office buildings.

In the Building 320 mezzanine office module, PBZ samples for VOCs revealed primarily acetone, ethanol, and isopropyl alcohol. However, by comparison, the chromatograms revealed lower concentrations than those in Building 555. Additionally, all of the simultaneous samples collected on charcoal tubes and analyzed for these three compounds revealed concentrations below the MDC of 0.2 mg/m^3 for a 50 liter sample. Physical inspection of the rooftop AHU did not reveal any visible evidence that would indicate a microbiologic reservoir. Carbon dioxide (CO_2), temperature, and relative humidity measurement values were within the limits recommended by ASHRAE.

Based on the data from this evaluation, the NIOSH investigators were unable to attribute the symptoms found among employees to a particular compound since all measured exposures were below the NIOSH RELs. All activities within the Sacramento Army Depot were terminated with official closure of the base in 1995. However, the anticipated routine use of various organic solvents and the application of CARC paint during "touch-up" activities that have been relocated to other Department of Defense facilities may require consideration of engineering controls and/or the appropriate use of personal protective equipment to reduce potential exposures.

KEYWORDS: SIC 7629 (electrical and electronic repair shops, not elsewhere classified), acetone, ethanol, isopropyl alcohol, lead, silica, diisocyanante, indoor environmental quality.

INTRODUCTION

On December 26, 1991, the National Institute for Occupational Safety and Health (NIOSH) received a request from the American Federation of Governmental Employees, Local 1681, to conduct a health hazard evaluation of the Sacramento Army Depot, Sacramento, California. Specific areas of concern in the initial request included the electro-optics work room of Building 555 and a small computer module located in Warehouse 3 (Bay 6). In Building 555, "possible" chemical agents cited in the request included the Chemical Agent Resistant Coating (CARC) paint, solder rosins and fluxes, and various solvents. Reported health problems included light-headedness, drowsiness, headaches, upset stomach, rashes, upper respiratory illness, sinus infections, and pneumonia. For workers in Warehouse 3 [Bay 6], the request cited indoor air quality concerns.

On June 22-25, 1992, an initial site visit was conducted at the Sacramento Army Depot in Building 555, Warehouse 3 (Bay 6), Building 320 (mezzanine office module), and Warehouse 7 (Bays 2 through 5). Building 320 (mezzanine office module) and Warehouse 7 (Bays 2 through 5) were added during the initial site visit at the request of the union regarding concerns of the indoor environmental quality. The intent of this site visit was to collect pertinent information regarding building conditions and potential chemical exposures. The site visit consisted of walk-through surveys of specified problem areas, physical inspection of heating, ventilating, and air-conditioning (HVAC) systems, and private interviews with employees wanting to speak with the NIOSH investigators. A symptom questionnaire was distributed to employees in Buildings 320 and 555.

Based on the findings from the initial site visit, a follow-up survey was conducted from March 29 through April 1, 1993. Environmental and medical investigations focused on Building 320 (mezzanine office module) and Building 555 (electro-optics work room). The environmental evaluation consisted of: (1) a walk-through survey of both buildings, including HVAC inspection; (2) the collection of air samples for volatile organic chemicals (VOCs); (3) real-time measurements of carbon dioxide (CO_2), temperature, and relative humidity; (4) measurement of volumetric air flow rates in the ventilation systems serving areas of concern in both buildings; and (5) in Building 555, the collection of air samples for lead content. The medical evaluation consisted of follow-up confidential medical interviews with occupants in Buildings 320 and 555. Environmental concerns in Warehouse 3 (Bay 6) and Warehouse 7 (Bays 2 through 5) were evaluated by observation of the problem areas.

BACKGROUND

The Sacramento Army Depot, established in 1942, occupies approximately 50 acres in Sacramento, California. The Depot was a primary facility for the repair, overhaul, and/or modification of equipment and devices used by the U.S. Military. Additionally, the Depot served as a central supply facility for components of the U.S. Armed Forces. At the time of the NIOSH investigation, the Depot employed approximately 3400 (mainly civilian) employees.

The Depot was officially closed in 1994 as part of the initiative to reduce the size of the U.S. military.

BUILDING 555

Building 555 was designed for the repair of military electro-optic devices (night vision systems such as thermal and image enhancers) and laser range finders. The building occupies approximately 80,000 square feet in the center of the complex with 75% useable space. Electro-optic repair was located on the ground floor in the largest room in Building 555. Repair activities included the use of various solvents (predominantly ethanol, acetone, and isopropanol) and the use of soldering devices (with lead solder). The air to this room was supplied by three roof-top package HVAC units which were designed to control the air temperature to 73±4°F and the relative humidity to approximately 30%. Total building occupancy was approximately 230 at the time of the first site visit and decreased to 150 employees by the second visit. Fifty percent of the employees worked in the electro-optic repair room. Limited access was instituted for all laser test areas in the building.

Workers in Building 555 were exposed to a variety of potentially hazardous substances, depending on specific job duties, including acetone (and other solvents), epoxy resins, and lead solder. In addition, employees in Building 555 applied CARC paint to military equipment. According to base officials, the agent composition of CARC can vary and formulation specific Material Safety Data Sheets (MSDS) were available at the site where it was used. This was the case at the Depot. A CARC formulation used at the Depot that was of particular concern is known as 686A tan zenthane (MIL-C- 53039A); it contains silica (20-30% by weight), a homopolymer of hexamethylene diisocyanate (20-30% by weight), methyl isoamyl ketone (20-30% by weight), and lesser amounts of titanium dioxide, trivalent chromium, ethyl acetate, hexamethylene diisocyanate monomer, and aromatic hydrocarbons.

For parts requiring complete coverage, CARC paint formulations were applied using a compressed spray gun inside of a paint spray booth located adjacent to the electro-optics repair work room. Air from the paint spray booth was exhausted outdoors. Workers in the paint spray booth were equipped with hooded airline respirators in addition to full body chemical protective clothing. Freshly painted parts were moved to an adjoining room where they were allowed to cure (the air from this room was also exhausted outdoors). Touch-up application of CARC paint was conducted on a small table located against the Curing Room wall adjacent to the electro-optic repair room. Half-face respirators with appropriate cartridges were made available to employees conducting touch-up work.

BUILDING 320 MEZZAINE OFFICE MODULE

The enclosed mezzanine office module was constructed in 1985 within the confines of Building 320 (the area around the module was occupied by various machining operations). The module was occupied by approximately 12 employees of the Maintenance Resource Planning and Analysis Office. Air is supplied to the module by a dedicated package HVAC system. In response to occupant complaints of poor indoor air quality, pass-through vents were added to exterior module walls (in the summer of 1987), and the ventilation cycle was extended from 5:00 a.m. to 4:00 p.m.

WAREHOUSE 3 (BAY 6) AND WAREHOUSE 7 (BAYS 2-5)

There were eight large warehouses located in the center of the Depot. Each warehouse occupies approximately 315,000 square feet. Outside air enters the warehouses (Warehouse 3 [Bay 6] and Warehouse 7 [Bays 2 through 5]) through bay doors as a result of negative pressure created by turbine vents installed in the roof. Warehouse 3 (Bay 6) served as a storage area for small boxed items. Employee monitoring of warehouse operations (i.e., storage/retrieval of boxed items) was conducted out of a small module (224 square feet) built off to the side of Bay 6. Air is supplied to the module by a small in-wall package air conditioning unit that can be set to provide complete recirculation of interior air or 100% exterior air (not necessarily outside air). Warehouse 7 (Bays 2 through 5) accommodated a number of activities including equipment repair (structural and electrical) and office work. No additional mechanical ventilation systems were present. Lighting was provided by high intensity halogen lamps suspended from the warehouse roof.

EVALUATION METHODS

ENVIRONMENTAL

Building 555

Thermal desorption tubes were used to collect four personal breathing zone (PBZ) air samples on employees conducting soldering operations in Building 555 (Electro-Optics) and four area air samples to qualitatively evaluate the presence of VOCs. Air was drawn through each thermal tube with Gilian® personal sampling pumps at a calibrated flow rate of 50 cubic centimeters per minute (cm^3/min). Each stainless steel tube (configured for use with the Perkin-Elmer ATD 400 thermal desorption system) was packed with three beds of sorbent materials; a front layer of Carbotrap C (~350 mg), and middle layer of Carbotrap (~175 mg), and a back layer of Carboxen 569 (~150 mg). All samples were analyzed qualitatively using the ATD 400 thermal desorption system containing an internal focusing trap packed with Carbopack B/Carboxen 1000 sorbents. The thermal unit was interfaced directly to a gas chromatograph and mass selective detector. The qualitative air sample results were used to direct the quantitative analysis of charcoal tube air samples.

For quantitative analysis of VOCs (i.e., acetone, ethanol, and isopropanol), air samples were collected on charcoal tubes at 15 area locations in Building 555. Air was drawn through the sampling media, via flexible tubing, with Gilian® GilAir personal air sampling pumps. All sampling pumps were operated at a calibrated flow rate of 0.2 liters per minute (lpm). Sorbent tube analysis was conducted according to NIOSH Methods 1300 and 1400.[1]

Full-shift PBZ air samples for lead content were also collected on eight employees conducting soldering on electro-optic devices. Air was drawn through the 37-millimeter mixed cellulose ester filters, via flexible tubing, with Gilian® Model HFS 513A, high flow personal sampling pumps. All sampling pumps were operated at a calibrated flow rate of 2 lpm. Filter analysis was conducted according to NIOSH Method 7082.[1]

Direct measurements for temperature, humidity, and carbon dioxide (CO_2) concentration were collected at 15 sample locations inside the building and 1 location outdoors. Sampling was conducted at approximately 10:00 a.m. and again at 2:00 p.m. Carbon dioxide was measured using a Gastech RI 411 CO_2 monitor (Gastech, Inc., Newark, California) that was calibrated before and after the samples were collected using 800 parts per million (ppm) CO_2 in nitrogen (Alphagaz, Division of Liquid Air Corporation, Cambridge, Maryland) as a calibrant. Temperature and relative humidity (RH) were measured using a Vaisala HM 34 temperature and humidity meter (Vaisala Oy, Helsinki, Finland). This meter is capable of providing direct readings for dry-bulb temperature and RH, ranging from -4 to 140°F and 0 to 100%, respectively. Instrument calibration is performed monthly using primary standards.

Chemical smoke was used to visualize air flow in the evaluated areas and to determine potential pollutant pathways in these areas. The volume rate of air flow in cubic feet per minute (cfm) was measured at the supply air diffusers and exhaust grilles using a Shortridge Airdata™ Multimeter/Flowhood ADM Model 860/8405 with an Electronic Micromanometer.

Building 320 Mezzanine Office Module

Thermal desorption tubes were used to collect six area air samples to qualitatively evaluate the presence of VOCs. Sample locations are shown in Figure 1 (sampling and analytical methods are described on page 6). The qualitative air sample results were then used to direct the quantitative analysis of the charcoal tube air samples (i.e., for acetone, ethanol, and isopropanol). Area charcoal tube samples were collected along side the thermal desorption tube. Sorbent tube analysis was conducted according to NIOSH Methods 1300 and 1400.[1]

Direct measurements (identical to those described for Building 555) for temperature, RH, and CO_2 concentration were collected at six locations inside the building and one location outdoors. Chemical smoke was used to visualize air flow in the evaluated areas and to determine potential pollutant pathways in these areas. The volume rate of air flow was measured at the supply air diffusers and exhaust grilles using a Shortridge Airdata™ Multimeter/Flowhood ADM Model 860/8405 with an Electronic Micromanometer.

MEDICAL

The medical evaluation consisted of a questionnaire administered on the visit of June 22-25, 1992, and medical interviews conducted on the visit of March 29-April 1, 1993.

Questionnaires

The questionnaire was administered to all occupants of the mezzanine office module in Building 320 and the electro-optics work room in Building 555 present during the site visit of June 22, 1992. The symptom questionnaire allowed NIOSH investigators to assess symptom prevalences for a variety of symptoms including irritation, nasal congestion, headache, tiredness, dizziness, concentration problems, dry throat, cough, irritated eyes, wheezing, and shortness of breath. The questionnaire asked if the employee had experienced any of the symptoms while at work on the day of the survey, and also asked about the frequency of occurrence of these symptoms while at work at the Depot during the four weeks preceding the survey, and whether these symptoms tended to get worse, stay the same, or get better when they were away from work. The final section of the questionnaire asked about environmental comfort (too hot, too cold, unusual odors, etc.) experienced while the employees were working in the building during the four weeks preceding the questionnaire administration. In determining the prevalence data for both environmental and medical survey, responses of "not in the last 4 weeks" and "1-3 days in the last 4 weeks" were considered negative responses and "1-3 days per week in the last 4 weeks" and "every or almost every workday" were considered positive. A missing response was treated as a negative response. Questionnaire data was analyzed using SAS 6.08.

Interviews

To further investigate possible causes of the health complaints and the severity of the symptoms reported in the questionnaire, 24 employees in Building 550 and 6 employees in Building 320 were interviewed during the site visit of March 29-April 1, 1993, concerning symptoms that they felt were related to working at the depot. The sample of workers was selected because they either worked in the area of concern, were observed using potentially hazardous chemicals, or were identified by their union as having potential exposures.

EVALUATION CRITERIA

The diversity of activities identified in Depot buildings complicates the ability to classify individual areas as uniquely industrial or office space, particularly in the warehouses. By example, in Warehouse 7 (Bays 2 to 5), partitioned office environments were observed adjacent to electronic repair stations. The proximity of these environments could result in office personnel being exposed to agents normally not encountered in “standard” office settings.
For the purposes of this investigation, the Building 555 electro-optics work room is considered industrial and the Building 320 mezzanine office module is considered as an office space. Evaluation criteria are appropriately presented below:

INDUSTRIAL EXPOSURES

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 hyper-sensitivity (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),[2] 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs),[3] and 3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[4] In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

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

Organic Solvents

Acetone, ethanol, and isopropanol are organic solvents.[5] Many organic solvents are irritants of the eyes, mucous membranes, and upper respiratory tract. In addition, organic solvents can cause acute and chronic neurotoxic health effects.[6] Acute neurotoxic effects include headache, light-headedness, dizziness, weakness, poor concentration, incoordination, impaired balance, confusion, drowsiness and loss of consciousness, and respiratory depression. Peripheral neuropathies and chronic central nervous system disorders (organic affective syndrome and mild chronic toxic encephalopathy) have been reported among solvent-exposed workers. Organic affective syndrome is characterized by fatigue, memory impairment, irritability, difficulty in concentrating, and mild mood disturbance. Mild chronic toxic encephalopathy is manifested by sustained personality or mood changes such as emotional instability, diminished impulse control and motivation, and impairment in intellectual function manifested by diminished concentration, memory, and learning capacity. The extent to which chronic neurotoxicity is reversible remains to be established.

The relevant evaluation criteria for acetone, ethanol, and isopropanol are listed below as TWAs in ppm:

Compound	NIOSH	OSHA	ACGIH
Acetone	250 ppm	1000 ppm	750 ppm
Ethanol	1000 ppm	1000 ppm	1000 ppm
Isopropanol	400 ppm	400 ppm	400 ppm

Lead

Lead is ubiquitous in U.S. urban environments due to the former widespread use of lead compounds in gasoline and paints. In industry, exposure to lead occurs via inhalation of dust and fume, and ingestion through contact with lead-contaminated hands, food, cigarettes, and clothing. Absorbed lead accumulates in the body in the soft tissues and bones. Lead is stored in bones for decades, and may cause health effects long after exposure as it is slowly released in the body. Symptoms of lead exposure include weakness, excessive tiredness, irritability, constipation, anorexia, abdominal discomfort (colic), fine tremors, and "wrist drop."[7,8,9] Overexposure to lead may also result in damage to the kidneys, anemia, high blood pressure, infertility and reduced sex drive in both sexes, and impotence.[10] An individual's blood lead level (BLL) is a good indication of recent exposure to, and current absorption of lead. The frequency and severity of symptoms associated with lead exposure generally increase with the BLL. Under the OSHA general industry lead standard (29 CFR 1910.1025), the PEL for airborne exposure to lead is 50 µg/m^3 (8-hour TWA).[11] The standard requires lowering the PEL for shifts exceeding 8 hours, medical monitoring for employees exposed to airborne lead at or above the action level of 30 µg/m^3
(8-hour TWA), medical removal of employees whose average BLL is 50 µg/dL or greater, and economic protection for medically removed workers. Medically removed workers cannot return to jobs involving lead exposure until their BLL is below 40 µg/dL. The OSHA interim final rule for lead in the construction industry (29 CFR 1926.62) provides an equivalent level of protection to construction workers. ACGIH has proposed lowering the TLV for lead from 150 to 50 µg/m^3 (8-hour TWA), with worker BLLs to be controlled to at or below 20 µg/dL, and designation of lead as an animal carcinogen.[4] The U.S. Public Health Service has establish a goal, by the year 2000, to eliminate all occupational exposures that result in BLLs greater than 25 µg/dL.[12]

The occupational exposure criteria (above) are not protective for all the known health effects of lead. For example, studies have found neurological symptoms in workers with BLLs of 40 to 60 µg/dL, and decreased fertility in men at BLLs as low as 40 µg/dL. BLLs are associated with increases in blood pressure, with no apparent threshold through less than 10 µg/dL. Fetal exposure to lead is associated with reduced gestational age, birth weight, and early mental development with maternal BLLs as low as 10 to 15 µg/dL.[13] Men and women who are planning on having children should limit their exposure to lead.

The relevant evaluation criteria for lead are listed below as TWAs in µg/m^3:

Compound	NIOSH	OSHA	ACGIH
Lead	100	50	150

INDOOR ENVIRONMENTAL EXPOSURES

NIOSH investigators have completed over 1,500 investigations of the occupational indoor environment in a wide variety of non-industrial settings. The majority of these investigations have been conducted since 1979.

The symptoms and health complaints reported to NIOSH by building occupants have been diverse and usually not suggestive of any particular medical diagnosis or readily associated with a causative agent. A typical spectrum of symptoms has included headaches, unusual fatigue, varying degrees of itching or burning eyes, irritations of the skin, nasal congestion, dry or irritated throats, and other respiratory irritations. Typically, the workplace environment has been implicated because workers report that their symptoms lessen or resolve when they leave the building.

A number of published studies have reported a high prevalence of symptoms among occupants of office buildings.[14,15,16,17,18] Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints.[19,20] Among these factors are imprecisely-defined characteristics of HVAC systems, cumulative effects of exposure to low concentrations of multiple chemical pollutants, odors, elevated concentrations of particulate matter, microbiological contamination, and physical factors such as thermal comfort, lighting, and noise.[21,22,23,24,25,26] Indoor environmental pollutants can arise from either outdoor sources or indoor sources.

There are also reports describing results which show that occupant perceptions of the indoor environment are more closely related to the occurrence of symptoms than any measured indoor contaminant or condition.[27,28,29] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[30,30,31,32]

Less often, an illness may be found to be specifically related to something in the building environment. Some examples of potentially building-related illnesses are allergic rhinitis, allergic asthma, hypersensitivity pneumonitis, Legionnaires' disease, Pontiac fever, carbon monoxide poisoning, and reaction to boiler corrosion inhibitors. The first three conditions can be caused by various microorganisms or other organic material. Legionnaires' disease and Pontiac fever are caused by *Legionella* bacteria. Sources of carbon monoxide include vehicle exhaust and inadequately-ventilated kerosene heaters or other fuel-burning appliances. Exposure to boiler additives can occur if boiler steam is used for humidification or is released by accident.

Problems that NIOSH investigators have found in the non-industrial indoor environment have included: poor air quality due to ventilation system deficiencies, overcrowding, volatile organic chemicals from furnishings, emissions from office machines, structural components of the building and contents, tobacco smoke, microbiological contamination, and outside air pollutants; comfort problems due to improper temperature and RH conditions, poor lighting, and unacceptable noise levels; adverse ergonomic conditions; and job-related psychosocial stressors. In most cases, however, these problems could not be directly linked to the reported health effects.

Standards specifically for the non-industrial indoor environment do not exist. NIOSH, the OSHA, and the ACGIH have published regulatory standards or recommended limits for occupational exposures.[33,34,4] With few exceptions, pollutant concentrations observed in non-industrial indoor environments fall well below these published occupational standards or recommended exposure limits. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published recommended building ventilation design criteria and thermal comfort guidelines.[35,36] The ACGIH has also developed a manual of guidelines for approaching investigations of building-related complaints that might be caused by airborne living organisms or their effluents.[37]

Measurement of indoor environmental contaminants has rarely proved to be helpful in determining the cause of symptoms and complaints except where there are strong or unusual sources, or a proven relationship between contaminants and specific building-related illnesses. The low-level concentrations of particles and variable mixtures of organic materials usually found are difficult to interpret and usually impossible to causally link to observed and reported health symptoms. However, measuring ventilation and comfort indicators such as CO_2, temperature and RH, has proven useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems. NIOSH and the Environmental Protection Agency (EPA) jointly published a manual on building air quality, written to help prevent environmental problems in buildings and solve problems when they occur.[38] This manual suggests that indoor environmental quality (IEQ) is a constantly changing interaction of a complex set of factors. Four of the most important elements involved in the development of IEQ problems are: (1) a source of odors or contaminants; (2) a problem with the design or operation of the HVAC system; (3) a pathway between the contaminant source and the location of the complaint; and (4) the building occupants. A basic understanding of these factors is critical to preventing, investigating, and resolving IEQ problems.

The basis for measurements made during this evaluation are listed below:

Carbon Dioxide

Carbon dioxide (CO_2) is a normal constituent of exhaled breath and, if monitored, may be useful as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. The ANSI/ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends outdoor air supply rates of 20 cubic feet per minute per person (cfm/person) for office spaces and conference rooms, 15 cfm/person for reception areas, and 60 cfm/person for smoking lounges, and provides estimated maximum occupancy figures for each area.[36]

Indoor CO_2 concentrations are normally higher than the generally-constant ambient CO_2 concen-tration (range 300 to 350 ppm). When indoor CO_2 concentrations exceed 800 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected. Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased.

Temperature and Relative Humidity

The perception of comfort is related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperatures. Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. ANSI/ASHRAE Standard 55-1992, specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally comfortable.[37]

RESULTS AND DISCUSSION

ENVIRONMENTAL

Building 555

In general, the electro-optics environment appeared in good condition; all areas were well lit and visible surfaces were clean. Physical inspections of the rooftop AHUs did not reveal any visible evidence that would indicate a microbiologic reservoir. Specifically, the filters appeared free of debris accumulation; the ventilation ducts were in good condition; and the coils and surrounding area were absent of standing water and/or "slime" accumulation. Individual workstations were observed to contain small quantities of various chemical agents and products used in repair operations including acetone, ethanol, isopropanol, CARC paint (in rare instances), cyanoacrylate (a component of super glue), synthetic rubber adhesives, paint thinner, and epoxy resins. Air flow patterns (determined by the observation of smoke generated by stannic chloride smoke tubes) in the large room of the electro-optics facility indicated a general movement of air out to other building areas. This outward flow of air indicates that this room was under positive pressure.

CO_2 measurements in Building 555 are presented in Figure 2. Measurements were made at 15 locations throughout the evaluated areas and one outdoor location. In the building, CO_2 concentrations ranged from 350 to 425 ppm during the first measurement period (~10:00 a.m.) and from 350 to 450 ppm during the second measurement period (~2:00 p.m.). The outdoor concentrations ranged from 300 to 375 ppm during the two measurement periods. Temperature and RH measurements are presented in Figure 3 as means of two measurements at each sampling location over the day. In the building, temperatures ranged from 71.8 to 74.5°F during the first measurement period (~10:00 a.m.) and from 73.9 to 75.8°F during the second measurement period (~2:00 p.m.). The outdoor temperatures ranged from 66.5 to 77.2°F over the two measurement periods. The RH levels for all measurement periods were fairly stable around 40%. The indoor temperatures and RHs were within the limits recommended in the ASHRAE thermal comfort chart (Figure 4). The ASHRAE thermal comfort chart specifies the acceptable (10% dissatisfaction criteria) ranges of operative temperature and humidity for persons clothed in typical summer and winter clothing, performing mainly sedentary activity.[40]

The thermal desorption tube samples collected in Building 555 revealed primarily acetone, ethanol, and isopropanol. This was expected based on the regular use of these organic solvents during electro-optic repair operations in Building 555. Additionally, smaller amounts of other identified chemical agents included methyl ethyl ketone, methylene chloride, trichlorotrifluoro-ethane (Freon 113), 1,1,1-trichloroethane, toluene, perchloroethylene, siloxanes, and xylenes. These minor compounds can be found in the material safety data sheets of other chemical agents used at electro-optic repair work stations.

Based on the results of the thermal desorption tubes, the charcoal tube samples collected from Building 555 were quantitatively analyzed for acetone, ethanol, and isopropanol. These results are presented in Table I as TWAs over the sampling period. Attempts were made to conduct air sampling over an 8-hour workshift, however, the sample times on 5 of 10 workers were only 4-hours due to limited worker availability. The concentrations were all very low, and none exceeded the NIOSH, OSHA, or ACGIH exposure criteria. Sample concentrations ranged from non-detectable to 35.3 ppm for acetone, 0.1 to 6.7 ppm for ethanol, and non-detectable to 0.3 ppm for isopropanol. Additionally, all eight PBZ samples collected for airborne lead (resulting from the soldering operation) in Building 555 were below the minimum detectable concentration (MDC) of 1 $\mu g/m^3$ for a 1000 liter sample.

The operator in the paint spray booth was observed wearing full body protective clothing and a hooded airline respirator. However, the worker conducting CARC touch-up work was not wearing respiratory protection (although available). Workers reported that they sanded CARC painted surfaces without respiratory protection which, according to the Depot safety officer, is required. CARC paint is approximately 30% silica; whether or not free respirable silica is released during sanding operations is not known from this evaluation. Air flow patterns between the CARC painting area and adjacent rooms indicated an inward flow of air (i.e., the room was under negative pressure with respect to the electro-optics work room). This inward air movement minimizes the escape of paint contaminants out of the painting area.

Building 320 Mezzanine Office Module

The environment in the mezzanine office module of Building 320 appeared in good condition. Physical inspection of the rooftop AHU did not reveal any visible evidence that would indicate a microbiologic reservoir (i.e., the filters appeared free of debris accumulation; the ventilation ducts were in good shape; and the coils, and area directly beneath, were absent of standing water and/or "slime" accumulation). Visualization of air flow using smoke tubes indicated that the module was under positive pressure relative to other areas of Building 320. Positive pressure was confirmed by air flow measurement at the supply and return air diffusers (i.e., a total combined supply flow rate of 3060 cfm and a total combined return flow rate of 1690 cfm). Measurement results are illustrated in Figure 1.

CO_2 measurements in the mezzanine office module of Building 320 are presented in Figure 5. Measurements were made at 6 locations throughout the evaluated areas and one outdoor location. CO_2 concentrations in the building ranged from 450 to 500 ppm during the first measurement period (~10:00 a.m.) and from 400 to 475 ppm during the second measurement period (~2:00 p.m.). The outdoor CO_2 concentrations ranged from 350 to 375 ppm during the two measurement periods. Temperature and RH measurements are presented in Figure 6 as means of two measurements at each sampling location over the day. In the building, temperatures ranged from 72.3 to 73.2°F during the first measurement period (~10:00 a.m.) and from 74 to 74.4°F during the second measurement period (~2:00 p.m.). The outdoor temperatures ranged from 61.5 to 66.2°F over the two measurement periods. The RH levels for all measurement periods were fairly stable, in the low 40s. The indoor temperatures and RHs were within the limits recommended in the ASHRAE thermal comfort chart .

Chromatograms from thermal desorption tube samples collected in the Building 320 mezzanine office module had major constituents of acetone, ethanol, and isopropanol. However, these chromatograms revealed lower concentrations than those in Building 555. Additionally, all of the simultaneous samples collected on charcoal tubes and analyzed for these three compounds revealed concentrations below the MDC of 0.2 mg/m^3 for a 50 liter sample. All other compounds identified in the Building 320 office module were at very low concentrations.

Warehouse 3 (Bay 6) and Warehouse 7 (Bays 2-5)

The environment within the small module in Warehouse 3 (Bay 6) appeared in good condition; areas were well lit and visible surfaces were clean. Physical inspection of the in-wall air-conditioning unit did not reveal any visible evidence that would indicate a microbial reservoir. Specifically, the filters appeared free of debris accumulation; the ventilation ducts were in good condition; and the coils and surrounding area were absent of standing water and/or "slime" accumulation. The introduction of air outside the module was only available when the air-conditioning unit damper was set to the "outdoor" position. In this "outdoor" position, the air being introduced into the module would be from the warehouse interior. When the warehouse bay door (within 20 feet of the module) was open, as it was during the survey, adequate amounts of outdoor air were likely to be supplied to the interior of the module. However, with the bay door closed, minimal quantities of outdoor air are likely to be supplied.

Like the module environment in Warehouse 3, the only significant introduction of outdoor air into Warehouse 7 (Bays 2 through 5) was through open bay warehouse doors (bay doors were open on the day of the survey). This arrangement is not conducive to a stable thermal comfort environment as recommended by ASHRAE.[39]

MEDICAL

Medical Questionnaire - Buildings 320 and 555

One hundred and thirty questionnaires were distributed to employees in Building 320 and 555 and 118 employees responded for a participation rate of 91%. Seventy one percent were male. Reported symptoms were diverse and affected different body systems. Results of the symptoms questionnaire are given in Table II-IV. The number of workers reporting the symptom once a week or more while at work during the four weeks preceding the questionnaire administration (June 22, 1992) is given in the first column of Table II and the percentage of employees who reported experiencing the respective symptom once a week or more while at work is given on the second column of the table. The third column shows the percentage of employees who reported experiencing the respective symptom once a week or more while at work during the four weeks preceding the survey and also reported that the symptom tended to get better when they were away from work. The six most prevalent symptoms at the Depot (all with a prevalence rate greater than 20%) were tiredness/fatigue, nose or sinus problems, dry throat, strained eyes, dry, itching or irritated eyes, and headache.

The questionnaire also included questions concerning perceived environmental conditions. Thermal discomfort was prevalent at the Depot and 19% felt it was too hot, 11% felt it was too cold, and 25% thought it was, at times, either too hot or too cold. The perception of too little air (stuffiness) was reported by 45% of the respondents and chemical odors were reported by 30% of the respondents. (Table III)

Detecting chemical odors in the work area was also related to increased symptoms reporting. There were statistically significant increases in reported dizziness, nose/sinus problems, dry throat, headache, tiredness/fatigue, irritated eyes, concentration problems and cough among those employees reporting that they frequently detect chemical odors at work (Table IV).

Interviews - Building 555

A total of 23 current employees and one retired employee from Building 555 were interviewed and asked questions concerning symptoms that they felt were related to working at the Depot. Symptoms included: sinus problems or infections (7 workers); respiratory symptoms (i.e., bronchitis, cough and pneumonia [5 workers]); unusual tiredness or fatigue (4 workers); skin irritation (5 workers); headache (5 workers); and dizziness (3 workers). Five employees reported irritative symptoms when they detected the odor of the CARC paint. One employee reported that she used CARC paint at her desk, without ventilation or respiratory protection.

Skin problems were reported by 5 employees. One employee reported a skin irritation that consisted of "redness, little blisters, itchy and painful." The employee attributed this to acetone exposure which penetrated the gloves distributed by the Depot for skin protection. This condition was present even though she has been retired for 2 years. A second employee reported "welts" which he described as raised and fluid filled marks on the skin. A third employee reported a red, bumpy skin lesion that would last one week and go away and would leave a red mark. Another employee reported itching and "bumps" on the skin that was associated with either painting or sanding units coated with CARC paint. The manufacturer's MSDS for this formulation of CARC paint discusses the possibility of skin lesions (related to the trivalent chromium) very similar to what was described by some employees at the Depot. Acetone exposure also can result in drying of the skin and irritation.

Interviews - Building 320 Mezzanine Office Module

Six employees were interviewed in the mezzanine office module, representing all employees present on the day of the survey. Two of the employees reported symptoms of pruritis without any marks on the skin indicative of an insect bite. The work area had been cleaned since the first Sacramento site visit and two employees in the area, who had previously had incidents of pruritis and headache, reported improvement since the cleaning. The other two interviewed employees did not report any symptoms that they felt were related to the building.

CONCLUSIONS / RECOMMENDATIONS

In Building 555, no over-exposures were identified for the sampled compounds, which included acetone, ethanol, isopropanol, and lead. Additionally, carbon dioxide (CO_2), temperature, and relative humidity measurement values were within the limits recommended by ASHRAE. Although an assessment of exposures to individual components in the CARC paints was not conducted (the predominant components of specific CARC paint formulations include diisocyanates, silica, and various organic solvents), careful attention to the use and the potential health effects of high-toxicity components is warranted. For example, exposure to the diisocyanates can produce irritation of the skin, mucous membranes, eyes, and respiratory tract; increased airway obstruction (asthma); and to a lesser extent dermal sensitization and hypersensitivity pneumonitis.[40,41,42,43] Appropriate controls (i.e., paint spray booth, chemical protective clothing, and hooded airline respirators) were observed during the spray application of CARC paint. However, we observed CARC touch-up activities being conducted without respiratory protection or protective gloves (respiratory protection and gloves were available). Some of the reported health problems were consistent with skin or respiratory exposure to constituents of the CARC paint particularly for workers doing touch-up work.

In the Building 320 mezzanine office module, PBZ samples for VOCs revealed primarily acetone, ethanol, and isopropyl alcohol. Simultaneous quantitative air samples for these three compounds revealed concentrations below the MDC of 0.2 mg/m^3 for a 50 liter sample. Physical inspection of the rooftop AHU did not reveal any visible evidence that would indicate a microbiologic reservoir. Carbon dioxide (CO_2), temperature, and relative humidity measurement values were within the limits recommended by ASHRAE.

Reports of health complaints in office settings (such as in Building 320) have become increasingly common in recent years; unfortunately, the causes of these symptoms have not been clearly identified. Many factors are suspected (e.g., volatile organic compounds, formaldehyde, microbial proliferation within buildings, inadequate amounts of outside air, etc.). While it has been difficult to identify concentrations of specific contaminants that are associated with the occurrence of symptoms, it is felt by many researchers in the field that the occurrence of symptoms among building occupants can be lessened by providing a properly maintained interior environment. Adequate control of the temperature is a particularly important aspect of employee comfort.

Overall, the symptoms prevalence was not markedly different from an Environmental Protection Agency (EPA) study of non-problem office buildings, despite the presence of industrial chemicals at the Depot. The EPA used a similar questionnaire to the one used in this study and calculated prevalence rates similarly by looking at symptoms that occurred once a week or more and improved when the employee left the workplace. The EPA study found prevalences of 21% for nose or sinus problems (22% in this study), 25% for tiredness and fatigue (32% in this study), 30% for dry, itching eyes (22% in this study), and 24% for headache (16% in this study).[44]

Based on the results and observations of this evaluation, the following recommendations are offered to correct deficiencies and optimize employee comfort:

- Employee exposures to potentially irritating agents from soldering work or chemicals used in electro-optic repair can be controlled with supplemental ventilation, i.e., local exhaust ventilation. Local exhaust ventilation is defined by the ability of a system to capture airborne contaminants at the source. The classification of hood designs are categorized by the hood location relative to the contaminant generation point or escape. A simple classification scheme defines three categories: enclosures, exterior hoods, and receiving hoods.[45] Enclosures are the most desirable form of local exhaust control because the contaminants are released inside the hood.

- Although no airborne lead was detected in Building 555, solder particulate was observed on workstation surfaces. This can represent a potential hazard from exposure to lead through ingestion. As a result, eating and drinking should not be allowed in workstation areas. Additionally, hand-washing by employees should be emphasized prior to eating or smoking. Lead-contaminated clothing and/or other objects that are brought into the home environment also represent a potential exposure hazard in the home, particularly to children. The possibility of bringing lead contaminated objects (i.e., clothing) into home should be stressed to employees.

- CARC paint should be use in accordance with manufacturers recommendations for personal protective equipment. The need for respiratory protection while sanding and finishing CARC painted surfaces containing silica and chromium should be evaluated by Army industrial hygienists.

- Any worker who has skin contact with solvents at his or her workstation (i.e., acetone and/or alcohols) or who is applying CARC paint should wear gloves that are impermeable to the substance (for example, butyl rubber or Teflon® gloves for acetone and alcohols and butyl rubber or nitrile for diisocynates). If a skin rash occurs after exposure to one or more of these compounds, the rash should be evaluated by a physician who is knowledgeable about occupational skin disorders.

REFERENCES

AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared By:	Kenneth F. Martinez, M.S.E.E. Industrial Hygiene Engineer Industrial Hygiene Section
	Robert Malkin, Ph.D. Medical Officer Medical Section
Field Assist:	Nancy C. Burton, C.I.H., M.S. Industrial Hygienist Industrial Hygiene Section
Analytical Support:	DataChem Laboratories Salt Lake City, Utah
Report Formatted By:	Caren B. Day Office Automation Assistant Industrial Hygiene Section
Originating Office:	Hazard Evaluations and Technical Assistance Branch Division of Surveillance, Hazard Evaluations and Field Studies

DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report may be freely reproduced and are not copyrighted. Single copies of this report will be available for a period of three years from the date of this report from the NIOSH Publications Office, 4676 Columbia Parkway, Cincinnati, Ohio 45226. To expedite your request, include a self-addressed mailing label along with your written request. After this time, copies may be purchased from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

Copies of this report have been sent to:

1. AFGE Local 1681 Representative
2. Management Representative
3. OSHA Region IX, San Francisco, California

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

LOCATION	SAMPLE TIME (min)	SAMPLE VOLUME (L)	CONCENTRATION (ppm)		
			Acetone	Ethanol	Isopropanol
Worker A	252	12.5	0.2	0.2	ND
Worker B	240	12	ND	1	ND
Central Distribution	228	11.4	ND	0.2	ND
Worker C	234	11.7	ND	0.5	ND
Worker D	252	12.6	35.3	4.7	ND
TAS 4A, 4B	216	10.8	ND	0.1	ND
Station 3 Bench	240	12	ND	5.2	ND
Worker E	474	23.7	ND	0.7	ND
Worker F	420	21	ND	6.7	ND
Worker G	366	18.3	1.3	0.2	ND
Worker H	258	12.9	ND	1.2	ND
Worker I	438	21.9	ND	3.8	0.3
TAS 4A, 4B	426	21.3	ND	0.1	ND
Worker K	426	21.3	ND	3.7	ND
Table Top	426	21.3	ND	0.2	ND
Evaluation Criteria					
		OSHA	1000	1000	400
		NIOSH	250	1000	400
		ACGIH	750	1000	400

NOTE: Similar job descriptions exist for all sampled employees.
ND = none detected

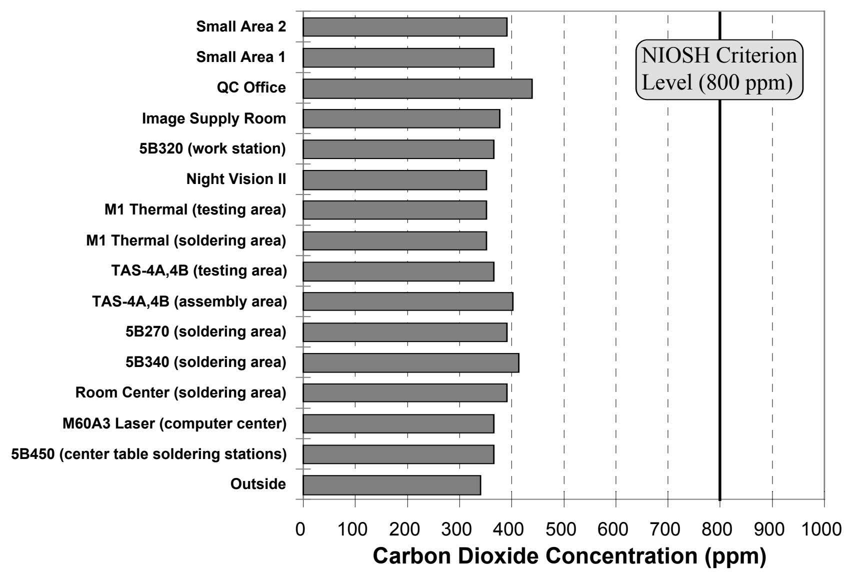
SYMPTOM	FREQUENCY	PERCENT	PERCENT THAT REPORTED SYMPTOM AND IMPROVED AWAY FROM WORK
Nose or sinus problems	52	44	22
Tiredness/fatigue	59	50	32
Dry throat	29	25	15
Strained eyes	47	40	26
Dry, itching or irritated eyes	44	37	22
Headache	28	24	16
Cough	20	17	5
Sore throat	16	14	6
Concentration problems	27	17	11
Dizziness	23	20	11
Shortness of breath	13	11	5
Chest tightness	14	12	6
Wheezing	14	12	4

ENVIRONMENTAL PARAMETER	NUMBER	PERCENT	ENVIRONMENTAL PARAMETER	NUMBER	PERCENT
Too much air	5	6	Too little air	53	45
Too hot	23	19	Too cold	13	11
Both too cold and too hot	30	25			
Too humid	12	10	Too dry	26	22
Tobacco odors in the workplace	9	7			
Chemical odors in the workplace	35	30			
Other odors in the workplace	21	18			

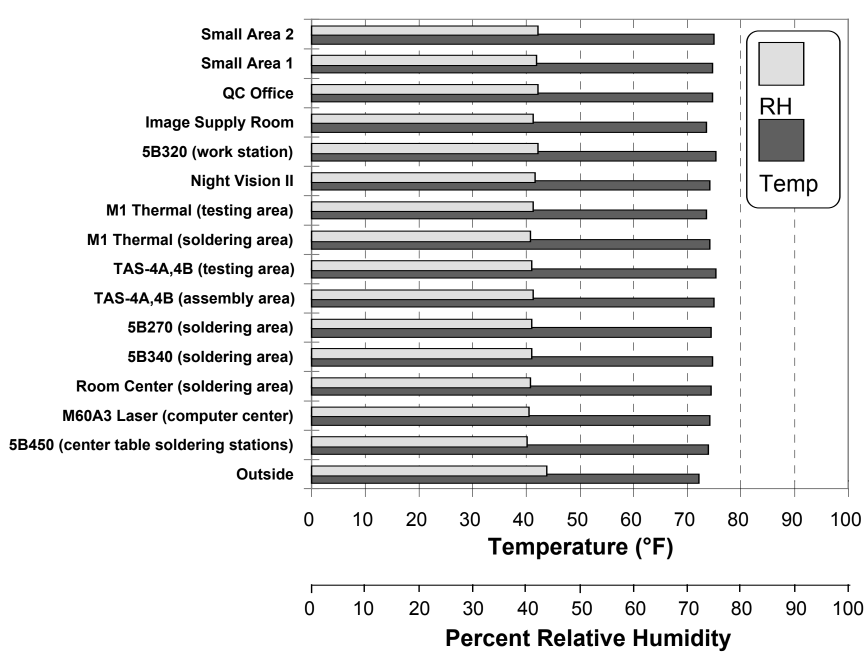
SYMPTOM	TOTAL NUMBER OF EMPLOYEES REPORTING SYMPTOMS	NUMBER AND PERCENT OF SYMPTOMATIC WORKERS DETECTING CHEMICAL ODORS	P-VALUE*
Dizziness	23	15(65%)	<0.001
Tiredness/fatigue	59	27(46%)	<0.001
Strained eyes	47	23(49%)	<0.001
Dry/irritated eyes	44	21(48%)	0.001
Dry throat	29	16(55%)	0.001
Headache	28	14(50%)	0.007
Nose/Sinus Problems	52	22(42%)	0.008
Concentration Problems	27	13(48%)	0.017
Sore throat	16	7(44%)	0.184
Cough	20	10(50%)	0.029
Chest tightness	14	6(43%)	0.250
Wheezing	14	6(43%)	0.250
Shortness of Breath	13	5(38%)	0.461

* p-value. The p-value is the probability of obtaining a chi-square statistic larger than the one actually calculated from the data

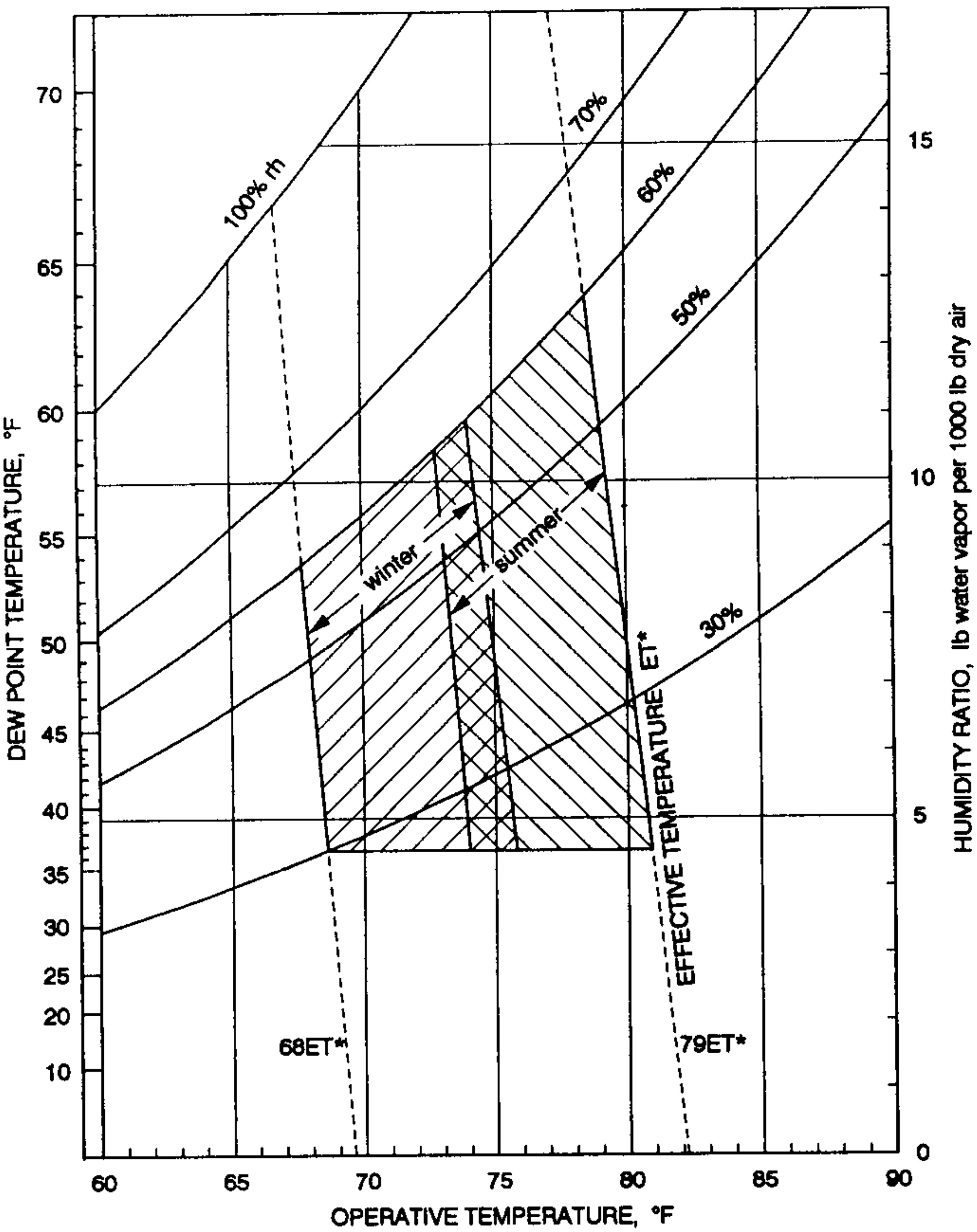

120
-380
230
F
E
280
250
-350
320
260
-380
C
D
280
150
-300
280
300
A
-280
B
300
290
Return air diffuser
Supply air diffuser



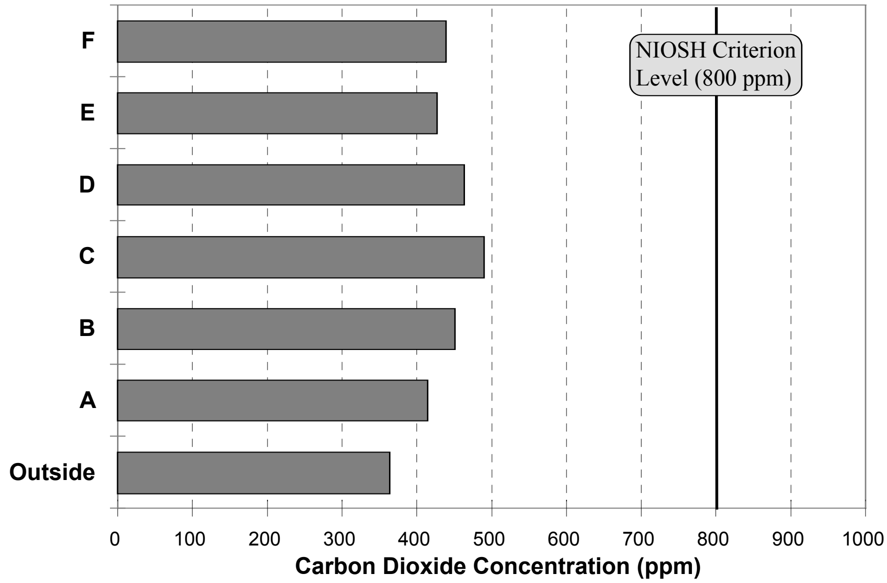
Small Area 2
Small Area 1
QC Office
Image Supply Room
5B320 (work station)
Night Vision II
M1 Thermal (testing area)
M1 Thermal (soldering area)
TAS-4A,4B (testing area)
TAS-4A,4B (assembly area)
5B270 (soldering area)
5B340 (soldering area)
Room Center (soldering area)
M60A3 Laser (computer center)
5B450 (center table soldering stations)
Outside
NIOSH Criterion Level (800 ppm)
0 100 200 300 400 500 600 700 800 900 1000
Carbon Dioxide Concentration (ppm)

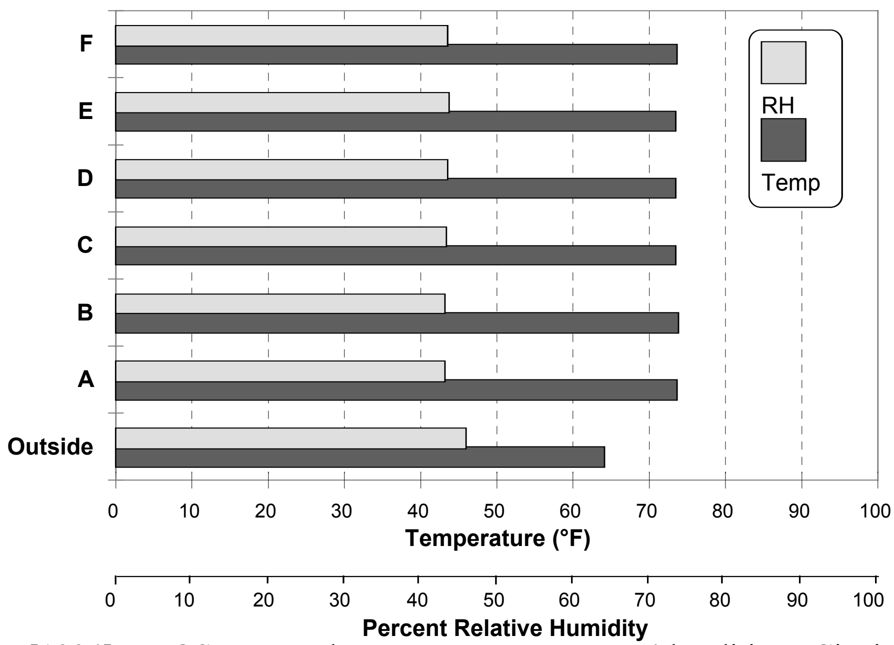


Small Area 2
Small Area 1
QC Office
Image Supply Room
5B320 (work station)
Night Vision II
M1 Thermal (testing area)
M1 Thermal (soldering area)
TAS-4A,4B (testing area)
TAS-4A,4B (assembly area)
5B270 (soldering area)
5B340 (soldering area)
Room Center (soldering area)
M60A3 Laser (computer center)
5B450 (center table soldering stations)
Outside
RH
Temp
0 10 20 30 40 50 60 70 80 90 100
Temperature (°F)
0 10 20 30 40 50 60 70 80 90 100
Percent Relative Humidity



70
65
60
55
50
45
40
35
30
25
20
10
DEW POINT TEMPERATURE, °F
15
10
5
0
HUMIDITY RATIO, lb water vapor per 1000 lb dry air
60
65
70
75
80
85
90
OPERATIVE TEMPERATURE, °F
100% rh
70%
60%
50%
30%
winter
summer
ET*
EFFECTIVE TEMPERATURE
68ET*
79ET*





1. NIOSH [1994]. NIOSH manual of analytical methods. 4th Edition. Cincinnati, OH: National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94-113.

2. CDC [1988]. NIOSH recommendations for occupational safety and health standards. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. MMWR *37*(suppl S-7).

3. ACGIH [1991]. Threshold limit values and biological exposure indices for 1994-1995. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

4. Code of Federal Regulations [1989]. OSHA Table Z-1. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

5. Hathaway GJ, Proctor NH, Hughes JP, Fischman ML [1991]. Chemical hazards of the workplace. 3rd ed. New York, NY: Van Nostrand Reinhold.

6. NIOSH [1987]. Current intelligence bulletin 48: organic solvent neurotoxicity. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87-104.

7. Hernberg S, et al. [1988]. Lead and its compounds. In: Occupational medicine. 2nd ed. Chicago, IL: Year Book Medical Publishers.

8. Landrigan PJ, et al. [1985]. Body lead burden: summary of epidemiological data on its relation to environmental sources and toxic effects. In: Dietary and environmental lead: human health effects. Amsterdam: Elsevier Science Publishers.

9. Proctor NH, Hughes JP, Fischman ML [1991]. Lead. In: Chemical hazards of the workplace. 3rd ed. Philadelphia, PA: J.B. Lippincott Company, Philadelphia, pp 353-357.

10. NIOSH [1978]. Occupational exposure to inorganic lead. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 78-158.

11. Code of Federal Regulations [1992]. OSHA lead standard. 29 CFR, Part 1910.1025. Washington, DC: U.S. Government Printing Office, Federal Register.

12. DHHS [1990]. Healthy people 2000: national health promotion and disease objectives. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, DHHS Publication No. (PHS) 91-50212.

13. ATSDR [1990]. Toxicological profile for lead. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry. DHHS (ATSDR) Publication No. TP-88/17.

14. Kreiss KK, Hodgson MJ [1984]. Building associated epidemics. In: Walsh PJ, Dudney CS, Copenhaver ED, eds. Indoor air quality. Boca Raton, FL: CRC Press, pp 87-108.

15. Gammage RR, Kaye SV, eds. [1985]. Indoor air and human health: Proceedings of the Seventh Life Sciences Symposium. Chelsea, MI: Lewis Publishers, Inc.

16. Woods JE, Drewry GM, Morey PR [1987]. Office worker perceptions of indoor air quality effects on discomfort and performance. In: Seifert B, Esdorn H, Fischer M, et al., eds. Indoor air '87, Proceedings of the 4th International Conference on Indoor Air Quality and Climate. Berlin Institute for Water, Soil and Air Hygiene.

17. Skov P, Valbjorn O [1987]. Danish indoor climate study group. The "sick" building syndrome in the office environment: The Danish town hall study. Environ Int. *13*:399-349.

18. Burge S, Hedge A, Wilson S, Bass JH, Robertson A [1987]. Sick building syndrome: a study of 4373 office workers. Ann Occup Hyg. *31*:493-504.

19. Kreiss K [1989]. The epidemiology of building-related complaints and illness. Occupational Medicine: State of the Art Reviews. *4*(4):575-592.

20. Norbäck D, Michel I, Widstrom J [1990]. Indoor air quality and personal factors related to the sick building syndrome. Scan J Work Environ Health. *16*:121-128.

21. Morey PR, Shattuck DE [1989]. Role of ventilation in the causation of building-associated illnesses. Occupational Medicine: State of the Art Reviews. *4*(4):625-642.

22. Mendell MJ, Smith AH [1990]. Consistent pattern of elevated symptoms in air-conditioned office buildings: A reanalysis of epidemiologic studies. Am J Public Health. *80*(10):1193-1199.

23. Molhave L, Bach B, Pedersen OF [1986]. Human reactions during controlled exposures to low concentrations of organic gases and vapors known as normal indoor air pollutants. Environ Int. *12*:167-175.

24. Fanger PO [1989]. The new comfort equation for indoor air quality. ASHRAE J. *31*(10):33-38.

25. Burge HA [1989]. Indoor air and infectious disease. Occupational Medicine: State of the Art Reviews. *4*(4):713-722.

26. Robertson AS, McInnes M, Glass D, Dalton G, Burge PS [1989]. Building sickness, are symptoms related to the office lighting? Ann Occup Hyg. *33*(1):47-59.

27. Wallace LA, Nelson CJ, Dunteman G [1991]. Work place characteristics associated with health and comfort concerns in three office buildings in Washington, D.C. In: Geshwiler M, Montgomery L, and Moran M, eds. Healthy buildings. Proceedings of the ASHRAE/ICBRSD conference IAQ'91. Atlanta, GA. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

28. Haghighat F, Donnini G, D'Addario R [1992]. Relationship between occupant discomfort as perceived and as measured objectively. Indoor Environ. *1*:112-118.

29. NIOSH [1991]. Hazard evaluation and technical assistance report: Library of Congress Madison Building, Washington, D.C. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HETA 88-364-2104 - Vol. III.

30. Skov P, Valbjørn O, Pedersen BV [1989]. Influence of personal characteristics, job related factors, and psychosocial factors on the sick building syndrome. Scand J Work Environ Health. *15*:286-295.

31. Boxer PA [1990]. Indoor air quality: A psychosocial perspective. J Occup Med. *32*(5):425-428.

32. Baker DB [1989]. Social and organizational factors in office building-associated illness. Occupational Medicine: State of the Art Reviews. *4*(4):607-624.

33. CDC [1992]. NIOSH recommendations for occupational safety and health: Compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 92-100.

34. Code of Federal Regulations [1989]. OSHA Table Z-1-A. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

35. ASHRAE [1990]. Ventilation for acceptable indoor air quality. Atlanta, GA: American Society of Heating, Refrigerating, and Air-conditioning Engineers. ANSI/ASHRAE Standard 62-1989.

36. ASHRAE [1992]. Thermal environmental conditions for human occupancy. Atlanta, GA: American Society for Heating, Refrigerating, and Air-conditioning Engineers. ANSI/ASHRAE Standard 55-1992.

37. ACGIH [1989]. Guidelines for the assessment of bioaerosols in the indoor environment. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

38. NIOSH [1991]. Building air quality: a guide for building owners and facility managers. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 91-114.

39. ASHRAE [1992]. Thermal environmental conditions for human occupancy. Atlanta, GA: American Society for Heating, Refrigerating, and Air-conditioning Engineers. ANSI/ASHRAE Standard 55-1992.

40. NIOSH [1978]: Criteria for a Recommended Standard...Occupational Exposure to Diisocyanates. DHEW (NIOSH) Publication No. 78-215. Cincinnati, Ohio: U.S. Dept. of Health, Education, and Welfare, Public Health Service, Centers for Disease Control, NIOSH.

41. NIOSH [1990]: Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 90-117. Cincinnati, Ohio: U.S. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control, NIOSH.

42. NIOSH [1986]: Occupational Respiratory Diseases. DHHS (NIOSH) Publication No. 86-102. Cincinnati, Ohio: U.S. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control, NIOSH.

43. Levy BS, Wegman DH (editors) [1988]: *Occupational Health: Recognizing and Preventing Work-Related Diseases*. Second Edition. Boston/Toronto: Little, Brown and Company.

44. Nelson NA, Kaufman JD, Burt J, Karr C. Health symptoms and the work environment in four nonproblem United States office buildings. Scand J Work Environ Health 21:51-59 (1995).

45. Burgess WA, Ellenbecker MJ, Treitman RD [1989]. Hood design. In: Ventilation for control of the work environment. New York, NY: John Wiley and Sons. pp:105-146.