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SUMMARY

In September 1994, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a health hazard evaluation (HHE) at the Golden Valley facility of the Tennant Company in Minneapolis, Minnesota. The request concerned various symptoms among employees in two administrative offices and concerns about welding fumes in the production area. On November 18, 1994, NIOSH investigators collected air samples for welding fume (analyzed for total fume or metals), evaluated the ventilation systems serving the two office areas, measured temperature and relative humidity in the offices, and collected air samples for volatile organic compounds in the office areas. The NIOSH medical officer conducted confidential interviews with all seven frame welders and two spot welders, reviewed the Log and Summary of Occupational Injuries and Illnesses (OSHA 200 logs) for the period January 1993 through October 1994 (focusing on reports for welders and office workers) and distributed questionnaires to employees working in the Marketing, Plant Management, Shop Floor Control, and Legal Departments who were present on the day of the NIOSH evaluation.

Exposures to welding fume and most metals were below the applicable evaluation criteria. Eight-hour time weighted average welding fume concentrations ranged from 0.33 to 1.6 mg/m^3. Of 26 metals measured, only eight - aluminum, chromium, copper, iron, manganese, nickel, titanium, and zinc - were present in greater than trace amounts. Titanium dioxide was present in greater than trace amounts in two of five samples. These two results, 0.0007 and 0.0009 mg/m^3, 8-hour TWA, were less than the OSHA PEL of 15 mg/m^3 and the ACGIH TLV of 10 mg/m^3. NIOSH recommends that titanium dioxide exposures be reduced to the lowest feasible concentration. Exposures to total chromium, which ranged from 0.003 to 0.01 mg/m^3, 8-hour TWA, indicate that potential exposures to hexavalent chromium among frame welders should be evaluated. Manganese results ranged from 0.083 to 0.27 mg/m^3, and, while these results are below current evaluation criteria for manganese (the NIOSH REL of 1 mg/m^3 TWA, 3 mg/m^3 STEL; OSHA PEL of 5 mg/m^3 as a ceiling; and ACGIH TLV of 1 mg/m^3, TWA), the ACGIH has announced that the TLV for 1995-1996 will be reduced to 0.2 mg/m^3, TWA.

Questionnaires were completed by all seven workers in Marketing, all five workers in Plant Management, three of four workers in the Legal Department, and all four workers in Shop Floor Control. Dry/itching/irritated eyes (53%), headache (42%), stuffy nose (37%), and dry/itching skin (37%) were the most commonly reported symptoms. The most frequent "building related" symptoms were headache (42%), pain or stiffness in back/shoulder/neck (37%), dry/itching/irritated eyes (32%), and tired/strained eyes (32%). Overall, 58% of the respondents reported having one or more symptoms that had occurred at work one or more days a week during the preceding 4 weeks and tended to get better when away from work.

The relative humidity in the plant managers offices and marketing offices was outside of the thermal comfort criteria recommended by ASHRAE, and some deficiencies were noted in the ventilation systems. These included roofing supplies stored near the outdoor air intake for the marketing offices, and supply fans which do not run constantly in the air handlers serving the plant manager's offices. Thus these air handling units do not supply the ASHRAE-recommended 20 cubic feet per minute of outdoor air per occupant for office spaces.

Results of the analysis of welding fume samples for titanium dioxide were less than the OSHA PEL and ACGIH TLV. NIOSH recommends that titanium dioxide exposures be reduced to the lowest feasible level. While exposures were below current evaluation criteria, the results of welding fume analysis for chromium and manganese are a cause for concern. No apparent environmental cause was found for the office workers' symptoms. However, some deficiencies were noted in the ventilation systems. Recommendations to address these deficiencies and reduce or further characterize exposures of welders to chromium and manganese are provided in the Recommendations section of this report.

KEYWORDS: SIC 3589 (Service Industry Machinery, Not Elsewhere Classified), Floor Sweepers, Welding, Indoor Environmental Quality, Welding Fume, Chromium, Manganese, Titanium Dioxide

INTRODUCTION

On September 16, 1994, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a health hazard evaluation (HHE) at the Golden Valley facility of the Tennant Company in Minneapolis, Minnesota. The request was submitted by employees who worked in three different locations in the facility: an employee in a production area and two office workers, each in a different office area. The request concerned indoor environmental quality in the two administrative offices, and concerns about welding fumes in the production area. The requestors reported headaches, sneezing, burning eyes, fatigue, depression, and mood swings among office employees. One requestor was concerned about welding fume exposures resulting from welding mild steel, particularly in the assembly of larger sweeper frames. On November 17 and 18, 1994, NIOSH investigators conducted an HHE at the Tennant Company Golden Valley facility.

BACKGROUND

The Tennant Company is a manufacturer of floor sweepers, scrubbers, scarifiers, and floor coatings. Floor coatings are not manufactured at this facility. There are 35 welders, including 26 on the day shift and 9 on second shift. Seven of the first shift welders are frame welders. There are two robot welders located in the frame welding area. Frame welding is performed in two adjacent areas on the north side of the plant, with a ceiling height in the lower of the two areas of at least 18 feet. Most of the welding performed is gas metal arc welding (GMAW) (also known as metal inert-gas, or MIG, welding). A limited amount of gas tungsten arc welding (GTAW) (also known as TIG welding, for tungsten, inert-gas) work is also performed, along with one or two flux cored arc welding (FCAW) jobs. The shielding gas is a tri-mix of helium (He), argon (Ar), and carbon dioxide (CO_2). The bulk of the work is performed using an Ar-CO_2 shielding gas mixture. Wire electrodes used for carbon steel welding at the plant include E7053 (Arcalloy 85) and E7056 (Arcalloy 87). About 2,000 pounds (lbs) of the former and 250 lbs of the latter are used each month. Production rates vary, depending upon the size and complexity of, and demand for, the model being built. A stainless steel frame welding area, which was not part of this evaluation, is next to the mild-steel frame welding area. Smaller assemblies (i.e., shrouds) are welded in an area across the aisle from frame welding. There are four electrostatic precipitators mounted on the walls of the northernmost of the two frame welding areas. A variety of propeller fans, both wall- and pedestal-mounted, are used for air circulation. Portable local exhaust ventilation is reportedly available for "smokey" jobs and was observed in use in the stainless steel welding area. Welding stations evaluated during this HHE were typically separated by welding curtains. Welders working on mild steel are offered the use of supplied air respirators, which are required to be used by welders welding stainless-steel (the respiratory protection program was not evaluated).

Seven people work in the marketing department offices included in this request. The portion of the marketing department included in this evaluation consisted of a suite of offices across the corridor from document publishing. Mechanical ventilation in these offices is provided by air handling unit (AHU) 6, a constant volume air handler located in a penthouse mechanical room (penthouse 2), along with AHUs 5 and 7. There are two zones in these marketing department offices (zones 6-1 and 6-4). While zone 6-1 serves other office areas as well, zone 6-4 serves only these marketing department offices. Outdoor air enters AHU 6 directly through screened louvers and outdoor air dampers on the side of the penthouse, and mixes with return air from zone 6. The mixed air passes through 2-inch pleated filters and tempering coils (low-pressure steam heating, and air conditioning). The supply fan distributes the air past four reheat coils (one for each portion of zone 6) to the occupied space via the supply ducts above the ceiling and ceiling diffusers. Air is returned to the air handler via return grilles in the ceiling of the occupied space, return air ducts, and a return fan. Return air is either mixed with outdoor air or exhausted. Zone 6 shares no return air with either the chemistry department or any industrial area. The chemistry laboratory, which is nearby, is a single pass system. According to management representatives, the laboratory is sealed from floor to ceiling for fire protection. At outdoor air temperatures in excess of 75 degrees Fahrenheit (°F), the outdoor air dampers for AHU-6 are at their minimum setting. Between 40 and 60°F, the unit supplies 100% outdoor air. At temperatures between 60 and 75°F, the dampers modulate between the minimum and maximum positions.

Five people work in the plant manager's office area. This area is served by two Lennox package air handling units, AHU 87 and AHU 88, located in an area above the ceiling of the office, within the high bay production area. Unit 87 is equipped with a Space Guard™ "high efficiency air cleaner" on the return air duct. Unit 88 is equipped with an Aprilaire™ bypass wetted element humidifier, which uses tap water and a pad to humidify the air. Outdoor air for these AHUs (and the Heat Controller Inc. AHU serving the adjacent shop floor control offices) enters the building through an intake on the south side of the building and is ducted to the three AHUs. Outdoor air is mixed with return air, filtered, cooled as needed, and distributed via supply ductwork to diffusers in the office space. Return air enters return air grilles in the ceiling of the occupied space and is returned to the air handler serving that portion of the office space. These units are equipped with freon cooling coils. Only AHU 88 is equipped with electric reheat. The units are thermostatically controlled from within the space, the fans do not run constantly.

METHODS

Environmental

Five personal breathing zone (PBZ) full-shift samples for welding fumes were collected on welders welding large, mild-steel assemblies (i.e., sweeper frames) at the Tennant Company on November 18, 1994. None of the welders sampled were wearing respirators. Because the welding helmet reduces to some degree the amount of contaminant in the breathing zone, the cassettes were attached to the employees' collars so the sample would be collected inside the welding helmet when the helmet was in use. Samples were collected from the beginning of the work shift until lunch time. The sampling pumps were turned off during the welders' lunch break. The second sampling period began after the lunch break and ended at the end of the work shift. The samples were collected on 37-millimeter (mm) diameter, 5 micrometer (µm) pore-size polyvinyl chloride (PVC) filters in two piece cassettes, connected to a battery-powered personal sampling pump via a length of Tygon™ tubing. The pumps were calibrated to operate at a flow rate of 2 liters per minute (L/min). The PVC filters were analyzed according to NIOSH Method 0500 with modifications.[1] These modifications included: 1) the backup pads and filters were not vacuum desiccated; 2) the filters were stored in an environmentally controlled room (21 ± 3 °C and 50 ± 5% Relative Humidity), and subjected to the room conditions for at least several days duration prior to tare weighing for stabilization. This reduces the method's 8- to 16-hour time for stabilization between tare weighings to 5 to 10 minutes; and 3) the filters with dust were not vacuum desiccated 15 minutes prior to final weighing. The limit of detection of this method, 0.02 milligrams (mg), was based upon studies of the physical integrity of various PVC filters, which have shown that the weight of the filter may vary by as much as 0.02 mg.

Conclusions based on total fume concentration are generally adequate if no toxic elements are present in the welding rod, metal, or metal coating, and conditions are not conducive to the formation of toxic gases.[2] However, the composition and quantity of welding fume are dependent upon the alloy being welded and the process and electrodes used.[2] Therefore, the NIOSH investigators performed air sampling to test for the individual metallic constituents of the welding fumes as well. Five full-shift PBZ air samples for metals were collected and analyzed by inductively coupled plasma atomic emission spectroscopy (ICP-AES) according to NIOSH Method 7300, modified for microwave digestion.[1] The sampling was performed using 37 millimeter (mm) diameter, 0.8 micrometer (µm) pore-size mixed cellulose ester filters in three-piece cassettes, connected to a battery-powered sampling pump via a length of Tygon™ tubing. Samples were collected at a flow rate of 2 L/min. These sampling pumps were also turned off at lunch time, and like the total fume samples, these samples were collected inside the welders' helmets. Table 1 provides a list of the metals of concern which were analyzed by this method, along with the analytical LOD, analytical LOQ, MDC, and MQC. The MDC and MQC are based upon the maximum sample volume for this sample set of 839 L. This method does not distinguish Chromium (VI) from Chromium in other valence states.

Since concentrations of contaminants such as volatile organic compounds in office environments are typically low, thermal desorption tubes were used for this portion of the investigation. Thermal desorption tubes contain three sorbent beds in consecutive layers from front to back (Carbotrap C, Carbotrap, and Carboxen 569) which are used to capture organic compounds over a wide range of volatility. Substances such as acetone, toluene, pentane, and hexane will be trapped with this sorbent tube. This method is an extremely sensitive and a very specific screening technique; it will identify the compounds present on the sample in the parts per billion range. Nine general area samples were collected on November 18, 1994. Sampling locations are provided in Table 2. Samples were collected in the two "complaint areas", as well as the shop floor control office (adjacent to the plant manager's offices, a "complaint area"), an engineering office, outdoors, and in an industrial area near the shop floor control/plant manager's group of offices. The samples were collected in the "non-complaint" areas, outdoors, and in the industrial area for comparison with the "complaint" areas. The thermal desorption tubes were connected via Tygon™ tubing to battery-powered sampling pumps operating at a calibrated flow rate of 20 milliliters per minute (mL/min). Samples were collected for time periods ranging from about 3 to 4.5 hours. Samples were analyzed using an automatic thermal desorption system interfaced directly with a gas chromatograph and mass selective detector (GC-TD-MSD). Stock solutions in carbon disulfide containing known amounts of several common solvents were used to prepare spikes to estimate the concentrations of solvents collected on the air samples. Among the compounds in the stock solutions were ethanol, acetone, methylene chloride, 1,1,1-trichloroethane, toluene, butyl cellosolve, and decane. Other compounds present in this solution are not identified because they are not relevant to this sample set. Concentrations of the spikes ranged from 100 to 2700 nanograms (ng) per sample.

Seven GA samples on charcoal tubes were collected side by side with the thermal desorption tubes in order to quantify compounds identified during the analysis of those samples. The samples were collected on charcoal tubes in plastic holders connected via Tygon™ tubing to battery-powered sampling pumps operating at a flow rate of 20 mL/minute. Sampling times matched those of the thermal desorption tubes. Based upon the results of the analysis of the thermal desorption tubes, the charcoal tubes were quantitatively analyzed for toluene, xylene, and total hydrocarbons using NIOSH Method 1500.[1]

Inspections of the evaluated office areas and their HVAC systems were conducted to determine their current conditions. Drawings and records pertaining to the HVAC systems were reviewed as well.

In addition, indicators of occupant comfort were measured in the office environments. These indicators were temperature (T), and relative humidity (RH). Real-time temperature and humidity measurements were made using a Vaisala, Model HM 34, battery-operated meter. 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.

Medical

The NIOSH medical officer conducted confidential interviews with all seven frame welders and two spot welders from other departments. The interviews covered musculoskeletal problems, symptoms of metal fume fever, respiratory symptoms, skin and eye burns, electric shocks, chemical exposures, cleanliness of the work environment, and availability and use of personal protective equipment.

The Logs of Occupational Injuries and Illnesses (OSHA No. 200) were reviewed for the period January 1993 through October 1994. The review focused on reports for welders and office workers.

Questionnaires were distributed to employees working in the Marketing, Plant Management, Shop Floor Control, and Legal Departments who were present on the day of the NIOSH evaluation. The first section of the questionnaire explored whether the employee had experienced, while at work on the day of the survey, any of several symptoms (e.g., irritation, nasal congestion, headaches) commonly reported by occupants of "problem buildings." Questions in the second section dealt with the frequency of occurrence of these symptoms while at work in the building during the four weeks preceding the survey, and whether these symptoms tended to get worse, stay the same, or get better when the employee was away from work. The final section of the questionnaire addressed environmental comfort (e.g., too hot, too cold, unusual odors) experienced while the employee was working during the four weeks preceding the NIOSH evaluation.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially 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)[3], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs)[2], and (3) the U.S. Department of Labor, 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 .

Welding Fume

The composition of welding fume will vary considerably depending on the alloy being welded, the process, and the electrodes used.[2,5] Many welding processes also produce other hazards, including toxic gases such as ozone or nitrogen oxides, and physical hazards such as intense ultraviolet radiation. Of particular concern are welding processes involving stainless steel, cadmium- or lead-coated steel, and metals such as nickel, chrome, zinc, and copper. Fumes from these metals are considerably more toxic than those encountered when welding iron or mild steel. Epidemiological studies and case reports of workers exposed to welding emissions has shown an excessive incidence of acute and chronic respiratory diseases.[5] These illnesses include metal fume fever, pneumonitis, and pulmonary edema. The major concern, however, is the excessive incidence of lung cancer among welders. Epidemiological evidence indicates that welders generally have a 40% increase in relative risk of developing lung cancer as a result of their work.[5] Because of the variable composition of welding emissions, and epidemiological evidence showing an increased risk of lung cancer, NIOSH recommends that exposures to all chemical and physical agents associated with welding or brazing be controlled to the lowest feasible concentration. Exposure limits for each chemical or physical agent should be considered upper boundaries of exposure. The ACGIH TLV for total welding fume, which applies only to manual metal-arc or oxy-acetylene welding of iron, mild steel, or aluminum, is 5 mg/m^3 as an 8-hour time-weighted average. The OSHA PEL for total welding fume (as Particulates Not Otherwise Regulated [PNOR]) is 15 mg/m^3.[2,4] If the fume contains specifically regulated substances, the PELs for those substances would also apply.

Chromium

Chromium (Cr) exists in a variety of chemical forms. The toxicity varies among the different forms. For example, elemental chromium is relatively non-toxic.[6] Allergic dermatitis is one of the most common effects of chromium (III) and chromium (VI) toxicity among exposed workers. Chromium compounds in the +3 valence state are of a low order of toxicity.[7] In the hexavalent form (Cr [VI]), chromium compounds are corrosive, and possibly carcinogenic. Until recently, the less water-soluble Cr(VI) compounds were not considered to be carcinogenic. However, recent epidemiologic evidence indicates that soluble Cr (VI) compounds may be carcinogenic.[8-12] Based on this new evidence, NIOSH recommends that all Cr (VI) compounds be considered potential occupational carcinogens.

The NIOSH REL and OSHA PEL for Cr (II) and Cr (III) compounds (as Cr) is 0.5 mg/m^3.[3,4] The NIOSH REL for chromium metal is also 0.5 mg/m^3, while the OSHA PEL for chromium metal, which also applies to insoluble chromium salts, is 1 mg/m^3.[3,4] The NIOSH REL for chromic acid and chromates (Cr [VI] compounds) is 0.001 mg/m^3, as Cr.[3] The OSHA PEL for these compounds (as CrO_3) is a ceiling value of 0.1 mg/m^3.[4] The ACGIH TLVs are 0.5 mg/m^3 for chromium metal and Cr(III) compounds, 0.05 mg/m^3 for water-soluble Cr (VI) compounds, and

0.01 mg/m^3 for insoluble Cr (VI) compounds.[2] The ACGIH classifies both water-soluble and insoluble Cr (VI) compounds as confirmed human carcinogens.[2]

Manganese

Exposure to high concentrations of freshly formed manganese oxide fumes may cause metal fume fever.[6] An association between manganese exposure and pulmonary effects, including pneumonia and chronic bronchitis has been observed, but it is unlikely that manganese alone could be the agent responsible for serious pathologic changes in the lungs.[6] It may be that susceptibility to infection is increased by exposure to manganese.[6] The major concern of workers exposed to manganese is its effects on the central nervous system (CNS) following chronic exposure.[6] Manganese poisoning (manganism) was first reported in 1837.[13] The clinical effects of chronic manganese poisoning resemble symptoms of Parkinson's disease (expressionless face, rigidity, resting tremor, stooped posture, and a shortened gait).[6]

The NIOSH REL for manganese compounds is 1 mg/m^3 as a TWA, with a STEL of 3 mg/m^3.[3] The NIOSH REL is based upon prevention of CNS effects and manganese pneumonitis.[3] The OSHA PEL is 5 mg/m^3 as a ceiling.[4] The ACGIH TLV for manganese fume is currently 1 mg/m^3 as a TWA, with a STEL of 3 mg/m^3.[2] The ACGIH has announced that beginning with the 1995-1996 TLVs, the TLV for manganese and inorganic manganese compounds will be 0.2 mg/m^3 as a TWA.[14] This change is based upon epidemiological studies which indicate that TWA exposures to total manganese dust at approximately 1 mg/m^3 may lead to preclinical adverse pulmonary and CNS effects and adverse effects on the fertility of male workers.[13]

Titanium

Titanium dioxide is a mild pulmonary irritant and is generally considered to be a nuisance dust. In the lungs of three workers in titanium dioxide pigment processing, deposits of the dust resulted in findings that indicated that titanium dioxide is a minor pulmonary irritant.[6] Rats repeatedly exposed to concentrations of 10 to 328 million particles/cubic foot of air for up to 13 months showed small focal areas of emphysema, attributable to large deposits of dust.[6] There was no evidence that titanium dioxide produced any specific lesion.

A two year inhalation bioassay in which rats were exposed to 250 mg/m^3 of titanium dioxide resulted in the development of squamous cell carcinomas in 13 of 74 female rats and in one of 77 male rats, as well as an increase in bronchoalveolar adenomas, another type of tumor. No excess tumor incidence was noted at 50 mg/m^3. The authors of that study questioned the biologic relevance of these tumors to humans, given the extremely high exposure concentrations, the unusual histology and the location of the tumors, and the absence of metastases.[15]

The ACGIH TLV for titanium dioxide is 10 mg/m^3 as an 8-hour TWA.[2] The OSHA PEL is 15 mg/m^3 as an 8-hour TWA.[4] Based upon the animal inhalation study noted above, NIOSH considers titanium dioxide to be a potential occupational carcinogen and recommends that exposures be reduced to the lowest feasible concentration.[3]

Indoor environmental quality (IEQ)

Indoor environmental quality (IEQ) is affected by the interaction of a complex set of factors which are constantly changing. Four elements involved in the development of IEQ problems are:

- sources of odors or contaminants,
- problems with the design or operation of the HVAC system,
- pathways between contaminant sources and the location of complaints,
- and the activities of building occupants.

A basic understanding of these factors is critical to preventing, investigating, and resolving IEQ problems.

The symptoms and health complaints reported to NIOSH by non-industrial 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. Usually, 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 high prevalences of symptoms among occupants of office buildings.[16-20] Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints.[21,22] Among these factors are imprecisely defined characteristics of heating, ventilating, and air-conditioning (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.[23-28] 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 than any measured indoor contaminant or condition to the occurrence of symptoms.[29-31] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[31-34]

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 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, machines, structural components of the building and contents, tobacco smoke, microbiological contamination, and outside air pollutants; comfort problems due to improper temperature and relative humidity 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 Occupational Safety and Health Administration (OSHA), and the American Conference of Governmental Industrial Hygienists (ACGIH) have published regulatory standards or recommended limits for occupational exposures.[2-4] 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 been 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 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 temperature and relative humidity has proven useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems. The basis for measurements made during this evaluation are listed below.

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.[36]

Volatile Organic Compounds (VOCs)

The term "VOCs" describes a large class of chemical compounds which are organic (i.e., containing carbon) and have a vapor pressure sufficient to allow some of the compound to exist as a vapor at room temperature. There are literally thousands of unique chemical compounds which are VOCs, including formaldehyde and other aldehydes, which are emitted in varying concentrations from numerous sources, including, but not limited to, fabrics, adhesives, solvents, paints, cleaners, waxes, cigarettes, and combustion sources. There are no occupational exposure criteria for total VOCs.

RESULTS AND DISCUSSION

Environmental

The results of the air sampling conducted for total welding fumes and metals are presented in Tables 3 and 4. The results for total welding fume, shown in Table 3, were less than the OSHA PEL (for particulates not otherwise regulated) and the ACGIH TLV. NIOSH recommends that exposures to all chemical and physical agents associated with welding or brazing be controlled to the lowest feasible concentration. Exposure limits for each chemical or physical agent should be considered upper boundaries of exposure. Comparison of Table 1 and Table 4 illustrates that only a few of the metals for which the samples were analyzed were present in amounts greater than trace quantities. However, of those metals which were found in quantifiable concentrations, the results of air sampling revealed exposures to chromium compounds (as Cr), and manganese which are a cause for concern. The method used to identify chromium in the air samples NIOSH investigators collected at the Tennant Company does not distinguish between the various valence states of that element (for that reason, the evaluation criteria listed in Table 3 are for chromium metal). However, if all of the chromium collected on the samples was in the Cr (VI) valence state, the results would have exceeded the NIOSH REL of 0.001 mg/m^3 for chromic acid and chromates (Cr [VI] compounds), and would have equalled the ACGIH TLV for insoluble Cr (VI) compounds of 0.01 mg/m^3 at station 21, where a welder was welding a 528 main frame. These results indicate that the exposures to chromium should be characterized further to determine the nature of the chromium compounds to which these welders are potentially exposed. It should be noted that previous sampling for hexavalent chromium conducted by the company's insurance carrier in 1989 found a concentration of Cr (VI) of 0.00085 mg/m^3 in one 68 minute sample collected on a welder MIG and TIG welding on stainless steel with no local exhaust ventilation. This was the highest of three samples collected in the breathing zone of that individual (the other two were less than the LOD). No hexavalent chromium was found in a subsequent survey conducted in 1990. The results for manganese are below current evaluation criteria. The ACGIH has announced that the TLV for manganese for 1995-1996 will be 0.2 mg/m^3 for elemental manganese and inorganic compounds, as Mn. In two locations, the NIOSH investigators found exposures in excess of that value. The source of the manganese should be identified, and efforts should be made to control exposures, either through substitution (i.e., identification of a mild steel alloy which contains less manganese, but still meets Tennant's manufacturing requirements) or through other engineering controls, such as local exhaust ventilation. Results also indicated that titanium dioxide (as Ti) was present in excess of the NIOSH REL of lowest feasible level, but was well below the OSHA PEL and ACGIH TLV for that compound.

Analysis of the thermal desorption tubes showed that most samples contained C_3-C_4 alkanes, xylenes, and toluene as major compounds. Two of the samples, one collected on top of the secretary's divider in the plant manager's office, the other collected on top of the divider near the refrigerator in shop floor control, contained slightly different components than the rest of the samples. The different compounds included C_8 branched alkanes and methoxyethoxy ethanol. Other compounds present on some or all of the samples included isopropanol, ethanol, acetone, methyl ethyl ketone, tetrahydrofuran, propoxyethanol, 1,1,1-trichloroethane, hexanol, methyl propanol, trichloroethylene, 1-propanol, siloxanes, various C_6-C_{12} hydrocarbons, naphthalene, p-dichlorobenzene, limonene, and other terpenes. The Appendix of this report includes copies of the chromatograms from the TD-GC-MSD analyses of the samples and the standard spikes. Chromatograms are all scaled the same for comparison (same time and abundance axes). The Appendix also includes a table listing each peak number with its corresponding identification plus the concentration of solvents on the spiked tubes.

The relative amounts varied among samples, but, with few exceptions, concentrations for most compounds appeared to be less than 200 nanograms/sample (using the spiked standards for comparison). Higher amounts of C_3-C_4 alkanes, isopropanol, xylenes, and branched C_8 alkanes were present on a few samples. In these cases, the amounts were less than the 2 µg spikes of similar compounds. This means, for example, that the maximum concentration of isopropanol in these samples was less than 0.15 ppm. This value was calculated using a maximum sample volume of 5.4 L and the spiked amount of 2 µg/sample. Based upon these results, the charcoal tube samples were quantitatively analyzed for xylene, toluene, and total hydrocarbons. Because the results were so low, no detailed comparison was attempted between the various areas.

Quantitative analysis of the charcoal tubes collected side by side with the thermal desorption tubes revealed that concentrations of xylene (all isomers), toluene, and total hydrocarbons (as n-decane) were below the limits of detection for these compounds in every location except the administrative assistant's desk in the marketing department. The charcoal tube sample collected at that location was found to contain trace amounts of xylenes and total hydrocarbons, and 1 ppm of toluene. A trace amount is a quantity between the limit of detection and the limit of quantitation and should be viewed with limited confidence in its accuracy. One ppm of toluene is a very low concentration, and is well below concentrations where workers in an occupational environment usually experience health effects. The LOD for this set of sample was 3.0 µg/sample for both toluene and xylene (all isomers), and 2.0 µg/sample for total hydrocarbons (as n-decane). The MDCs for this set of samples, based upon these LODs and a maximum sample volume of 5.4 L, were 0.14 ppm for toluene, 0.13 ppm for xylene (all isomers), and 0.06 ppm for total hydrocarbons (as n-decane). The MQCs for this sample set, derived from LOQs of 9.0 µg/sample for toluene, 10.0 µg/sample for xylene (all isomers), and 7.0 µg/sample for total hydrocarbons (as n-decane), and a maximum sample volume of 5.4 L, were 0.44 ppm for toluene, 0.43 ppm for xylene (all isomers) and 0.22 ppm for total hydrocarbons (as n-decane). Thus, on the day of the survey the concentrations of these compounds in the office environments at the Tennant Company were well below the concentrations known to cause adverse health effects in exposed workers, and for the most part, were less than the limits of detection of the sampling method in use that day.

The temperature and relative humidity in marketing was 74°F and 24% in the morning and 72°F and 23% in the afternoon. In the plant manager's office, the temperature and relative humidity were 73°F and 22% in the morning and 72°F and 22% in the afternoon. In shop floor control, the temperature and relative humidity in the morning were 72°F and 22%, and 72°F and 23% in the afternoon. Outdoors at 2:00 p.m., the temperature was 41°F and the relative humidity was 18%. The values for the office spaces were outside of the thermal comfort guidelines for the winter months provided by ASHRAE in ANSI/ASHRAE 55-1992.[36] Low relative humidity is not uncommon in heated buildings in the winter months. Low relative humidity may be undesirable for reasons other than those based on thermal comfort. Low levels increase evaporation from the membranes of the nose and throat. Some medical opinions attribute an increased incidence of respiratory complaints to the drying of mucous membranes by low indoor humidities in winter. However, no well-documented evidence indicates a serious hazard to health resulting from exposure to low humidity.[38]

Inspection of the AHUs serving the plant manager's offices and shop floor control revealed that the filters in the two Lennox units were very dirty, and should be cleaned or replaced. Larger ductwork was installed in 1994 to improve airflow to these offices. The lining of the fan box of the AHU serving shop floor control was very dusty, which may indicate that the filter did not fit properly.

Inspection of AHU-6, which serves the portion of the marketing department included in the evaluation revealed no obvious deficiencies. Filters in the unit are changed based upon pressure drop across the filter, measured by a manometer on the side of the unit. The unit is checked weekly to ensure that it is in operation. Preventive maintenance inspections are performed quarterly. Control systems are inspected and calibrated twice a year.

At the time of the site visit, the roof of the plant was being replaced. While this work was being performed at night, when the AHUs were turned off, the roofing supplies were being stored directly in front of the outdoor air intake for penthouse 2. The exhaust stacks for the chemistry lab were being raised (the work began three weeks prior to the survey) because of problems with reentrainment of emissions into the chemistry department. These stacks were reportedly downwind of the air intake for penthouse 2, and in any case, any potential for reentrainment was addressed by raising the stacks. Other than the roofing material, the only emission source near the outdoor air intake for penthouse 2 was a sanitary sewer vent.

Review of drawings and a 1990 test and balance report of AHU 6 revealed that adequate outdoor air was provided to the marketing department at both minimum and maximum damper positions. According to the drawings, the maximum and minimum positions were designed to provide 4385 and 1100 cubic feet per minute (cfm) of outdoor air, respectively. The results of the final test in the 1990 test and balance report stated that the four diffusers in zone 6-4 and the one diffuser in zone 6-1 that is in the marketing offices provided a total of 1180 cfm of supply air. At 100% outdoor air, this results in a supply of 236 cfm of outdoor air for each of the five occupants. At the minimum damper position, the diffusers supply 25% of this amount (1100 cfm divided by 4385 cfm equals 0.25), or 59 cfm of outdoor air per occupant. This is almost three times the 20 cfm of outdoor air per person recommended by ASHRAE for office environments.[35] During the course of the survey, marketing department employees reported that the office carpet had been flooded on two occasions, once as the result of a roof leak about four years prior to the survey, and again approximately a year prior to the survey when a drain backed-up and overflowed in a nearby bathroom. Carpets which have been repeatedly wetted have been identified as growth media for microorganisms, and have thus been implicated as the cause of IEQ complaints.[37] However, the incidents of flooding are not temporally related with the onset of symptoms in these offices.

<u>Medical</u>

Seniority among the nine interviewed workers, all of whom were welders, ranged from 10 to 25 years (median=18 years). No remarkable health concerns in common to most of the workers were described. Nonetheless, most of those interviewed, however, reported occasional radiation burns of the neck through holes in their clothing. Most felt that the personal protective equipment provided by the company was adequate.

No instances of respiratory irritation or other respiratory illnesses or complaints were recorded in the OSHA 200 Logs for the 22-month period reviewed by the NIOSH medical officer. During this period, 14 entries were made for welders and non-technical office workers. Other than minor injuries (e.g., contusions, foreign body in eye), only upper extremity cumulative trauma was noted for more than one worker.

Questionnaires were completed by all seven workers in Marketing, all five workers in Plant Management, three of four workers in the Legal Department, and all four workers in Shop Floor Control. The respondents included 13 (68%) women and 6 (32%) men. The majority (13, 68%) ranged in age from 30 to 49 years. Nearly one-half of the respondents (9, 47%) had never smoked cigarettes. Only three individuals were current smokers. Respondents had worked in the building for an average of 13 years (range:<1 to 31). On average, they worked 42 hours per week (range: 30 to 50) and used a computer for 4 hours (range: 1 to 6).

The questionnaire results are shown in Table 5. The first column of Table 5 shows the percentage of the 19 respondents who reported the occurrence of symptoms while at work on the days of the survey. Dry/itching/irritated eyes (53%), headache (42%), stuffy nose (37%), and dry/itching skin (37%) are the most commonly reported symptoms.

The second column shows the percentage of employees who reported experiencing the respective symptoms once a week or more often while at work during the four weeks preceding the survey. The prevalence of most symptoms over the past four weeks was similar to the prevalence on the day of the survey.

The third column shows the percentage of employees who reported experiencing the respective symptom once a week or more often while at work during the four weeks preceding the survey and also reported that the symptoms tended to get better when they were away from work. This latter criterion has, in some studies of indoor air quality, been used to define a "building related" symptom, but it is possible that a symptom that does not usually improve when away from the building could also be due to conditions at work.

The reported "building related" frequent symptom prevalences shown in the third column are generally lower than the prevalences previously described. The most frequent "building related" symptoms were headache (42%), pain or stiffness in back/shoulder/neck (37%), dry/itching/irritated eyes (32%), and tired/strained eyes (32%). Overall, 58% of the respondents reported having one or more symptoms that had occurred at work one or more days a week during the preceding 4 weeks and tended to get better when away from work.

Table 6 shows results of employee reports regarding environmental conditions at their workstations on the days of the survey and during the four weeks preceding the survey. The first column shows the results for the days of the survey. It shows that 47% of respondents perceived that there was too little air movement, 42% felt that the air was too dry, and 37% felt that it was too hot during at least part of their work day. The second column shows the results for the four week preceding the survey. Adverse environmental conditions (too hot, too cold, odors, etc.) were considered "frequent" if they were reported to occur at least once a week. The results are generally higher than those reported for the day of the survey. Among respondents, 53% reported too little air movement, 37% reported that the temperature was too cold, 37% reported that the temperature was too hot, and 32% felt the air was too dry.

CONCLUSIONS

Results of air samples collected during mild steel welding indicate that these welders' potential exposures to hexavalent chromium should be evaluated. Air sampling results for manganese indicate a potential health hazard, due to the reduction in the ACGIH TLV next year. The reduction in the TLV is based upon epidemiological studies which indicate that TWA exposures to total manganese dust at approximately 1 mg/m^3 may lead to preclinical adverse pulmonary and CNS effects and adverse effects on the fertility of male workers. Efforts should be made to identify the source of manganese exposure and steps taken to reduce that exposure. Medical interviews revealed that employees in welding jobs reported remarkably few work-related health problems.

The questionnaire survey of office workers in several departments showed that many employees had frequently experienced symptoms (e.g., headache, eye irritation or strain) while at work. A substantial proportion of the symptomatic employees reported that their symptoms tended to get better when they were away from the building. Fifty-eight percent of survey respondents reported having frequently experienced one or more such "building related" symptoms during the four weeks preceding the NIOSH survey. Thermal comfort and lack of air movement were also of concern to a large percentage of employees. While no obvious cause was found to explain these health and comfort complaints, low relative humidity in the offices may play a role in complaints of eye and skin irritation. In addition, the fact that the fans in AHUs supplying air to the plant managers offices and shop floor control do not run continuously, and the presence of roofing materials and a sanitary sewer vent near penthouse 2 may also play a role in these complaints.

Reports of building related health complaints have become increasingly common in recent years; unfortunately the causes of these symptoms have not been clearly identified. As discussed in the criteria section of this report, many factors are suspected (e.g., volatile organic compounds, formaldehyde, microbial proliferation within buildings, inadequate amounts of outside air, etc.). While is 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.

RECOMMENDATIONS

Based upon the results of this evaluation, the following recommendations may improve the working environment at the Tennant Company.

Welding

1. Employee exposures to hexavalent chromium should be characterized among welders welding mild steel. Previous investigations by the company's insurance carrier indicate that these are likely to be less than applicable evaluation criteria. However, the results of the NIOSH sampling for total chromium indicate that potential exposure to hexavalent compounds should be evaluated.

2. The source of the welders' exposures to manganese should be investigated, and steps should be taken to control this exposure, either through the use of engineering (e.g., substitution, local exhaust ventilation) or administrative controls (e.g., work practices). Controls which reduce the welders' exposure to manganese in welding fumes should also reduce their potential exposures to titanium dioxide.

3. The use of welding curtains to enclose welding operations should be improved, thus shielding passersbye and welders at adjacent work stations from the welding arc.

4. The use of fastening guns to insert fasteners which hold-together assemblies to be welded should be evaluated. One of the welders remarked about the force required to use the fastener gun (particularly when the fastener holes in the work pieces are not machined properly) and the gun's effect on his hand.

5. The breathing air used to supply air to the welders respirators should be evaluated to ensure that it meets the requirements for grade D breathing air, as specified in the Compressed Gas Association Commodity Specification for Air, and required by the OSHA respiratory protection standard.[39,40] It is recommended that the respiratory protection program be evaluated to insure that it meets the requirements of the OSHA respiratory protection standard.[40]

Plant Managers Offices

1. The AHUs supplying this area and shop floor control should be modified so that they supply a minimum of 20 cfm of outdoor air per occupant on a continuous basis, in accordance with ASHRAE guidelines for offices.[35] This may require the provision of equipment to provide additional heating capacity.

2. The metal mesh and foam filters on the AHUs supplying the plant manager's offices should be included in the preventive maintenance schedule, and changed as needed. In addition,

the insulation on the inside of the AHU serving shop floor control should be vacuumed using a high efficiency particulate air-filtered vacuum cleaner. The cooling coils in these units should be cleaned at least annually, or more frequently, if required.

Marketing Offices

1. Roofing materials should not be stored near outdoor air intakes, and the sanitary sewer vent should be raised above the level of the outdoor air intake.

2. A U.S. Environmental Protection Agency engineering practice recommends that the top of stacks that emit "large quantities" of pollutants be 2.5 times the building height.[41] While experience has shown that no simple rule is available to determine safe stack heights for all situations, the height of the laboratory fume hood stacks should be evaluated to ensure that they were modified adequately.[41]

3. The humidity level that a given building is able to tolerate without serious concealed condensation may be much lower than indicated by visible condensation. Unless the building has been designed to effectively reduce or eliminate the possibility of concealed condensation, increasing humidification at the Tennant Company facility should be approached with caution.[38] Increasing the humidity to relieve symptoms of occupant comfort must be weighed against potential problems due to microbial growth as a result of condensation on building materials.

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Table 1
Analytical Limits for Analysis of Metals
Tennant Company
Minneapolis, Minnesota
November 18, 1994
HETA 94-0417

Analyte (elemental symbol)	LOD µg/filter	LOQ µg/filter	MDC mg/m^3	MQC mg/m^3
Aluminum (Al)	2	5.6	0.002	0.007
Arsenic (As)	3	8.2	0.004	0.01
Barium (Ba)	0.08	0.25	0.0001	0.0003
Beryllium (Be)	0.04	0.12	0.00005	0.0001
Cadmium (Cd)	0.2	0.35	0.0002	0.0004
Cobalt (Co)	0.4	1.2	0.0005	0.001
Chromium (Cr)	0.3	1.0	0.0004	0.001
Copper (Cu)	0.4	1.1	0.0005	0.001
Iron (Fe)	2	6.5	0.002	0.008
Lithium (Li)	0.2	0.42	0.0002	0.0005
Magnesium (Mg)	2	4.6	0.002	0.005
Manganese (Mn)	0.09	0.29	0.0001	0.0003
Molybdenum (Mo)	0.2	0.35	0.0002	0.0004
Nickel (Ni)	0.8	2.7	0.001	0.003
Lead (Pb)	2	4.0	0.002	0.005
Phosphorous (P)	4	13	0.005	0.02
Platinum (Pt)	3	7.7	0.004	0.009
Selenium (Se)	3	8.9	0.004	0.01
Silver (Ag)	0.09	0.28	0.0001	0.0003
Tellurium (Te)	2	6.4	0.002	0.008
Thallium (Tl)	3	9.4	0.004	0.01
Titanium (Ti)	0.2	0.61	0.0002	0.0007
Vanadium (V)	0.4	1.3	0.0005	0.002
Yttrium (Y)	0.07	0.21	0.00008	0.0003
Zinc (Zn)	0.9	2.9	0.001	0.003
Zirconium (Zr)	0.2	0.66	0.0002	0.0008

Notes:
LOD means limit of detection.
LOQ means limit of quantitation.
MDC is the minimum detectable concentration, based upon the LOD and a maximum sample volume of 839 liters for this sample set.
MQC is the minimum quantifiable concentration, derived from the LOQ and the 839 liter sample volume.
µg means micrograms.
mg/m^3 is the abbreviation for milligrams of analyte per cubic meter of sampled air.

Table 2
Locations of Area Samples for Volatile Organic Compounds
Tennant Company
Minneapolis, Minnesota
November 18, 1994
HETA 94-0417

Sample Number	Location	Duration (minutes)	Sample Volume (liters)
CX 54	Administrative Assistant's Desk, Marketing Department	270	5.4
CX 38	Administrative Coordinator's Desk, Marketing Department	267	5.3
CX 60	Marketing Support Rep's Desk, Marketing Department	263	5.3
CX 4	Assembly 07, 8400 machine	178	3.6
CX 26	Engineering Office, Zone S-2 (Office used by NIOSH investigators)	243	4.9
CX 10*	Outside Building	246	4.9
CX 12	Outside Building	183	3.7
CX 47	On top of room divider, near refrigerator, Shop Floor Control	251	5.0
CX 53	Top of desk-bookcase cabinet, secretary's area, Plant Manager's Office	247	4.9

*Sample CX 10, an outside "background" sample was found to have been blown to the ground, and was replaced by sample CX 12.

Table 3
Results of Personal Breathing Zone Air Samples For Total Welding Fumes
Tennant Company
Minneapolis, Minnesota
November 18, 1994
HETA 94-0417

Location	Welding Activity	Sample Duration (minutes)	Sample Volume (liters)	8-Hour Time Weighted Average Results (mg/m^3)
Station 22	530 Frame	432	886	1.1
Station 33	385 Frame	422	865	0.48
Station 20	550 Main Frame	389	778	1.6
Station 27	Building Shrouds	392	784	0.33
Station 44	W-2 Operator Stations for Model 800	385	809	1.1
			NIOSH Recommended Exposure Limit	LFL
			OSHA Permissible Exposure Limit	15
			ACGIH Threshold Limit Value	5

Notes:
mg/m^3 means milligrams of analyte per cubic meter of sampled air.
ND (not detected) indicates a result less than the analytical limit of detection
Trace indicates a value between the limit of detection and limit of quantitation, which should be regarded with limited confidence in its accuracy.
Exposure limits are for 8 or 10-hour time-weighted average exposures, unless otherwise noted.
STEL (short term exposure limit) is a 15 minute time-weighted average exposure that should not be exceeded during the work day.
C (ceiling) is an exposure limit which should not be exceeded at any time during the work day.
The 8-hour time weighted average exposures provided above were calculated assuming that no further exposures occurred during the unsampled portion of the work day. To obtain the time weighted average for the sampling period, multiply the result of interest (in mg/m^3) by 480 minutes and divide that product by the duration of that sample (in minutes).

Table 4
Results of Personal Breathing Zone Air Samples For Metals
Tennant Company
Minneapolis, Minnesota
November 18, 1994
HETA 94-0417

Location	Welding Activity	Sample Duration (minutes)	Sample Volume (liters)	8-Hour Time Weighted Average Results (mg/m^3)							
				Al	Cr	Cu	Fe	Mn	Ni	Ti	Zn
Station 24	510 Main Frame	277	554	trace	0.008	0.016	0.79	0.083	0.003	trace	trace
Stations 2 and 7	Main Frame W-1, W-2, WSS	412	824	0.009	0.003	0.039	2.2	0.27	trace	0.0007	0.003
Station 21	528 Main Frame	416	832	trace	0.01	0.062	2.2	0.22	0.005	trace	0.007
Station 8	Tack Welding W-1 Frames	430	839	trace	0.003	0.036	1.6	0.15	trace	trace	0.017
Station 3	8400 Frame	421	821	trace	0.003	0.021	1.0	0.10	trace	0.0009	trace
NIOSH Recommended Exposure Limit				5	0.5	0.1	5	1 TWA, 3 STEL	0.015	LFL	5 TWA, 10 STEL
OSHA Permissible Exposure Limit				15	1	0.1	10	5 C	1	15	5
ACGIH Threshold Limit Value				5	0.5	0.2	5	1*	1	10	5 TWA, 10 STEL
Minimum Detectable Concentration				0.002	0.0004	0.0005	0.002	0.0001	0.001	0.0002	0.001
Minimum Quantifiable Concentration				0.007	0.001	0.001	0.008	0.0003	0.003	0.0007	0.003

Notes:
mg/m^3 means milligrams of analyte per cubic meter of sampled air.
ND (not detected) indicates a result less than the analytical limit of detection
Trace indicates a value between the minimum detectable concentration and minimum quantifiable concentration, which should be regarded with limited confidence in its accuracy.
Exposure limits are for 8 or 10-hour time-weighted average exposures, unless otherwise noted.
STEL (short term exposure limit) is a 15 minute time-weighted average exposure that should not be exceeded during the work day.
C (ceiling) is an exposure limit which should not be exceeded at any time during the work day.
The 8-hour time weighted average exposures provided above were calculated assuming that no further exposures occurred during the unsampled portion of the work day. To obtain the time weighted average for the sampling period, multiply the result of interest (in mg/m^3) by 480 minutes and divide that product by the duration of that sample (in minutes).
The employee welding at station 24 did not return after lunch.
*The ACGIH will adopt a TLV of 0.2 mg/m^3 for elemental manganese and inorganic manganese compounds in the 1995-1996 TLVs.

Table 5
Symptoms Experienced by Employees at Work
Tennant Co.
Minneapolis, Minnesota
November 17-18, 1994
HETA 94-0417

Symptoms	% Experienced On Days of Survey at Work	% Frequently Experienced In Last 4 Wks at Work	% Have Frequent Symptoms that Improve When Away from Work
Dry, itching, or irritated eyes	53	53	32
Tired or strained eyes	42	42	32
Stuffy nose, or sinus congestion	37	42	26
Sneezing	32	26	26
Sore or dry throat	16	16	11
Dry or itchy skin	37	37	11
Unusual fatigue or drowsiness	32	32	26
Headache	47	47	42
Tension, irritability or nervousness	16	21	16
Difficulty with memory or concentration	11	5	5
Nausea or upset stomach	5	0	0
Feeling depressed	0	0	0
Pain or stiffness in back, shoulders, or neck	32	42	37
Dizziness or lightheadedness	5	5	5
Cough	11	21	5
Chest tightness	5	5	0
Wheezing	5	0	0
Shortness of breath	0	0	0

Table 6
Environmental Conditions Reported by Employees
Tennant Co.
Minneapolis, Minnesota
November 17-18, 1994
HETA 94-0417

Conditions	% Experienced On Days of Survey at Work	% Frequently Experienced In Last 4 Wks at Work
Too much air movement	11	16
Too little air movement	47	53
Temperature too hot	37	37
Temperature too cold	26	37
Air too humid	0	0
Air too dry	42	32
Tobacco smoke odors	0	0
Chemical odors	16	21
Other unpleasant odors	5	16

APPENDIX