HETA 2000-0185-2808
Thyssen-Dover Elevator
Middleton, Tennessee

Max Kiefer, MS, CIH
Richard J. Driscoll, Ph.D

PREFACE

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

HETAB also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Max Kiefer and Richard Driscoll of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies. Analytical support was provided by the Division of Applied Research and Technology. Desktop publishing was performed by Nichole Herbert and Pat Lovell. Review and preparation for printing were performed by Penny Arthur.

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Highlights of the NIOSH Health Hazard Evaluation

Evaluation of exposure to welding fume in selected departments

In May 2000, NIOSH investigators conducted a health hazard evaluation at Thyssen-Dover Elevator, Inc. We measured levels of air contaminants during welding. We evaluated work practices and collected information on health complaints.

What NIOSH Did

We collected air samples for welding fume.
We talked to employees about their health problems.
We collected samples of ceiling insulation for asbestos analysis.
We inspected the laser cutting machines.

What NIOSH Found

Welders have some health symptoms.
Welding fume levels were higher than recommended in Dept. 544.
The ventilation system was not working well.
There is no asbestos in the ceiling insulation.
The laser cutter may need shielding to prevent eye exposure to the beam.

What Thyssen-Dover Elevator, Inc. Managers Can Do

Design and install a better ventilation system.
Provide respirators for certain jobs.
Conduct additional monitoring.
Control emissions from fork lifts.
Review shielding and ventilation on the laser cutters

What the Thyssen-Dover Elevator, Inc. Employees Can Do

Wear and use welding shields properly.
Use welding ventilation properly.
Tell managers when and where there are problems.

CDC
CENTERS FOR DISEASE CONTROL
AND PREVENTION

What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513/841-4252 and ask for HETA Report # 2000-0185-2808

NIOSH
National Institute for Occupational Safety and Health

Health Hazard Evaluation Report 2000-0185-2808
Thyssen-Dover Elevator

Middleton, Tennessee
September 2000

Max Kiefer, MS, CIH
Richard J. Driscoll, Ph.D

SUMMARY

On March 14, 2000, the National Institute for Occupational Safety and Health (NIOSH) received a joint management/union request for a health hazard evaluation (HHE) at the Thyssen-Dover Elevator facility in Middleton, Tennessee. The request asked NIOSH to determine if workplace exposures are related to health problems that some employees have experienced. Specific areas of concern identified in the request included both traditional welding and laser metal cutting processes. Reported symptoms were muscle weakness, tingling fingers, weight loss, and diverticulitis.

On May 1-3, 2000, NIOSH researchers conducted a site visit at the Thyssen-Dover Elevator facility. During the site visit, integrated personal air sampling was conducted to evaluate employee exposure to welding fume during the first and second work shifts in Departments 544, 543, 591, 597, and at the Bystronic laser. Instantaneous air samples were collected for carbon monoxide (CO), oxides of nitrogen (NOx), and ozone (O_3) at various locations in the manufacturing area. Bulk samples for asbestos analysis were obtained from ceiling insulation and the Department 544 oven. Company accident and illness records were reviewed. Confidential interviews were conducted with 24 first and second shift employees. The laser cutting operation was reviewed.

The personal air sampling results showed that employees in Department 544 were exposed to total welding fume, above the American Conference of Governmental Industrial Hygienists (ACGIH)® threshold limit value (TLV) of 5 milligrams per cubic meter (mg/m^3). Full shift time-weighted average (TWA) exposures for the two employees in this department were 5.44 mg/m^3 and 6.10 mg/m^3. NIOSH recommends controlling welding fume to the lowest feasible concentration and meeting the exposure limit for each welding fume constituent. Element-specific analyses of the welding fume components showed that manganese exposure for the two Department 544 workers exceeded the ACGIH TLV of 0.2 mg/m^3 on the day of the monitoring. TWA concentrations measured were 0.23 mg/m^3 and 0.31 mg/m^3. The NIOSH recommended exposure limit (REL) for manganese fume is 1.0 mg/m^3. One sample from a Department 544 welder found exposure to lead in excess of the 30 micrograms per cubic meter Action Level established by the Occupational Safety and Health Administration. No other samples indicated the presence of lead above the limit of quantification. The source of the lead was not determined. In general, air contaminant concentrations were lower during the second (evening) work shift. General dilution ventilation is the primary ventilation control at this facility.

Carbon monoxide concentrations of 8-12 parts per million (ppm) were measured at various locations of the manufacturing area during the first shift. The NIOSH REL for CO is 35 ppm and the ACGIH TLV for CO is 25 ppm. The primary source of the CO is likely the propane-powered lift trucks. Low concentrations of NOx were measured at some welding stations and ozone was not detected in any of the samples. No asbestos was found in any of the bulk samples. A limited review of the laser cutting operation indicated that protective shielding to prevent eye exposure to beam radiation may not be adequate.

Worker complaints were grouped into three general categories; gastro-intestinal symptoms, neurological symptoms, and chronic sinusitis. Symptoms that were reported appeared to be associated with the work (i.e., symptoms appeared after reporting for work and improved or resolved after the employee left work). However, no work exposures could be found that would be the primary cause of chronic sinusitis or gastrointestinal symptoms. Welders complained of neurologic symptoms that were suggestive of manganese

poisoning. Manganese exposure levels measured during this site visit would not be expected to result in manganese poisoning, but higher past exposure levels, or chronic exposure to elevated manganese levels, may account for the symptoms described by welders at this plant.

Industrial hygiene monitoring found Department 544 worker exposure to total welding fume and manganese in excess of established criteria. One sample from this department showed lead exposure in excess of regulatory criteria. Because the facility is an open manufacturing environment, incorporates numerous processes, and relies on general dilution ventilation as the primary control, the worker exposure profile in the manufacturing area is complex. Contaminant concentrations were generally lower on the second shift. Shielding to prevent eye exposure to beam radiation on a high power laser cutter may have been altered. Workers reported gastro-intestinal symptoms, neurological symptoms, and chronic sinusitis. The temporal pattern for the gastrointestinal and chronic sinusitis was consistent with a workplace exposure, however, no workplace exposures were found that would explain these symptoms. Manganese levels measured at this site would not be expected to result in the neurologic symptoms observed and/or reported, however, higher past exposures or chronic exposures over time may account for these symptoms. Recommendations to provide respiratory protection as an interim measure, improve ventilation, conduct additional monitoring, utilize welding shields, review and modify the laser cutter, and reduce carbon monoxide emissions are in the Recommendations section of this report.

Keywords: 3534 (Elevators and Moving Stairways). Carbon Monoxide, Oxide, Nitrogen, Ozone, Welding, Laser cutting, Welding fume, Manganese, Lead, Asbestos, Ventilation, Gastro-intestinal symptoms, Neurologic symptoms, Sinusitis.

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INTRODUCTION

In response to a joint management-union request for a health hazard evaluation (HHE), National Institute for Occupational Safety and Health (NIOSH) investigators conducted a site visit on May 1-3, 2000, at Thyssen-Dover Elevator, Inc. in Middleton, Tennessee. NIOSH was asked to evaluate workplace exposures to welding and laser-cutting fume, determine if reported employee health complaints are associated with their work environment, and recommend appropriate control strategies for reducing employee exposure to workplace contaminants.

During the site visit, NIOSH researchers conducted environmental monitoring to evaluate worker exposure to total welding fume and welding fume constituents, carbon monoxide (CO), ozone (O_3), and oxides of nitrogen (NOx). Bulk samples of ceiling and process oven insulation were obtained for asbestos analysis. The ventilation system and laser cutting operations were reviewed. Confidential interviews were conducted with 24 employees on the first and second shift, and company accident and illness records were reviewed. An interim report describing our initial site visit, preliminary findings, and preliminary recommendations was mailed to management and employee representatives on June 29, 2000. A letter providing the results of the element-specific air sampling and control recommendations was mailed on July 7, 2000.

BACKGROUND

The Thyssen-Dover Elevator facility was constructed in 1968 and encompasses 512Kft^2 of manufacturing space, all of which is under one roof in an open, non-partitioned arrangement. The roof is slightly pitched, and ceiling height varies from approximately 25 to 30 ft. In 1991, the plant was restructured to manufacture in a cellular process flow, and operations from several facility closings at other sites were consolidated at the Middleton plant. The subplants and cells include machining, design, fabrication, painting, and shipping. In 1998, 166Kft^2 of manufacturing space was added, certain work areas were enclosed, and several air-handling units (AHUs) were installed to provide air conditioning to the manufacturing portion of the plant. Certain production processes previously conducted at other facilities or by contract were brought to the Middleton facility. At the time of the NIOSH visit, the Middleton facility employed 783 workers (664 hourly, 119 salaried) and operated (production) on a 3-shift basis; the second shift, however, only conducted selected manufacturing activities. Employees are represented by the Boilermakers Union, Local 251.

The production of hydraulic commercial and industrial elevators at the Middleton plant involves a number of process steps. A variety of metal working operations, including milling, lathe, punch, shear, and bending are conducted. Additional processes include painting, heat treating, woodworking, and formica installation. In addition to the elevator frame and body, the hydraulic system, including the pumps and engines, are manufactured and assembled. Raw materials typically include roll steel, stainless steel, and forged iron. Welding and laser cutting occurs in numerous process steps, both in manufacturing and assembly. The electronic components for the elevators are manufactured at a nearby Thyssen-Dover facility.

After adding manufacturing space and air conditioning in 1998, health concerns associated with exposures during welding activities and laser cutting were reported by some employees. The health complaints were thought by Thyssen-Dover management to be related to efforts to air condition the manufacturing area accompanied by an increase in recirculated air. In response to worker complaints, industrial hygiene surveys of welding and laser cutting activities were conducted in 1999 by the Thyssen-Dover insurance carrier. This monitoring found manganese exposure at certain welding processes to be in excess of the American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Value (TLV®) of 0.2 milligrams per cubic meter (mg/m^3).[1] Recommendations were made to control exposure to welding fume using flexible or fixed local exhaust ventilation, and some ventilation was installed in Department 544.

METHODS

Upon receipt of the HHE request, additional information regarding the reported health problems and suspect environmental contaminants was obtained. Information provided by Thyssen-Dover prior to our site visit included the results of previous investigations to evaluate exposures during welding, industrial hygiene and safety recommendations from the insurance carrier, and process information.

During the first shift (6:00 a.m. - 2:30 p.m.) on May 2, 2000, personal breathing zone (PBZ) air samples for welding fume were collected from welders in Departments 544, 597, and 591, and from a Machinist in Department 543. One area sample for laser cutting fume was collected adjacent the Bystronic Laser. During the second shift (3:00 p.m. - 11:00 p.m.) PBZ air samples for welding and laser cutting fume were collected from the Laser Cutter and two welders in Department 591. Instantaneous area samples were collected on both shifts in various areas for CO, O_3, and NOx. Additional activities included observing work practices, evaluating controls and the use of personal protective equipment (PPE), and reviewing reports of previous evaluations conducted to assess workplace conditions and exposures in these areas. On May 3, 2000, samples of sprayed-on ceiling insulation were obtained from several areas for asbestos analysis.

Analytical Methods

Welding and Laser Cutting Fume

Full shift PBZ exposures to airborne welding fume were monitored using SKC® Universal Samplers (PCXR4), Gilian® HFS 513A, and Gil-Air® sampling pumps. Flow rates of approximately 2 liters per minute (l/m) were used to obtain the samples. The sampling pumps were pre- and post-calibrated with a primary standard (BIOS®) to verify flow rate. The filters were placed as close as possible to the workers' breathing zone and connected via Tygon® tubing to the sampling pump. Welders were cautioned to maintain the filter under the welding hood shroud (when worn) during the monitoring. Management and employee representatives indicated that production activity was normal on the day of the sampling. Depending on the activity, some filters were replaced periodically throughout the work shift to avoid overloading. After collection, the samples were sent to the NIOSH contract laboratory (DataChem, Salt Lake City) for analysis. Time-weighted average concentrations were calculated using the following formula:

$$\text{TWA} = \frac{C_1T_1 + C_2T_2 + C_nT_n}{T_1 + T_2 + T_n}$$

Where: C= Concentration and T = Time

The samples were collected on tared 37 millimeter (mm), 5 micrometer (µm) pore size, poly-vinyl chloride (PVC) filters in the closed-face mode, and analyzed gravimetrically to determine the total welding fume concentration according to NIOSH Method 0500. An element specific analysis was also conducted on the samples, according to NIOSH Method 7300, to differentiate and quantify the following metal species: lead, iron, chromium, manganese, copper, zinc, cobalt, and titanium. With this technique, the sample filters are microwave digested in an acid mixture, and analyzed with an inductively coupled plasma emission spectrometer.[2]

Carbon Monoxide

A Metrosonics PM-7700 toxic gas monitor with a CO sensor was used to measure CO at various areas on the manufacturing floor. The instrument was zeroed and then pre-calibrated prior to use with a known concentration of CO. Instrument sensor repeatability is ± 2% at an operating temperature of -5 to 40° C.

Ozone and Oxides of Nitrogen

Sampling for O_3 and NOx was conducted using Dräger® Ozone 0.05/b and Nitrous Fumes 0.5/a (NO + NOx) direct reading colorimetric indicator tubes and a bellows pump. With this sampling technique, a known volume of air is drawn through the tube and the media inside the indicator tube will change color in proportion to the concentration of contaminant. According to the manufacturer, the relative standard deviation for these sampling methods is 10-15%.[3] Samples were collected during welding adjacent the welders wearing the PBZ monitors.

Asbestos

Bulk samples of ceiling insulation and the heat gasket on the Department 544 oven were collected and submitted to the NIOSH contract laboratory for analysis. Samples were collected because portions of the ceiling insulation were installed in 1969 (prior to the banning of asbestos for this use) and the lack of information regarding the insulation or oven gasket material. The samples were collected by first moistening the area to be sampled and then cutting the sample portion. The samples were analyzed by polarized light microscopy according to NIOSH Method 9002, which can detect asbestos in concentrations greater than 1% and identify the type of asbestos present.[2]

Medical

Company records (e.g., personnel records, Occupational Safety and Health Administration [OSHA] Accident and Illness [OSHA 200 Logs] records) for 1998-1999 were reviewed. In addition, a total of 24 workers from first and second shifts participated in confidential interviews. Interviewed workers were selected from a list of employees who had previously identified themselves to union and management representatives as workers with presumed work-related symptoms. During the interviews, workers were asked to describe their physical health and any health complaints they perceived to be the result of workplace exposures.

EVALUATION CRITERIA

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

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[4] (2) the ACGIH TLVs®,[1] and (3) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs).[5] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 95–596, sec. 5.(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

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

Background information on welding hazards and manganese is presented in Appendix A, information on welding fume control strategies and laser generated air contaminants (LGACs) is described in Appendix B and C.

RESULTS

Workplace Observations

Welding shields, to prevent ancillary exposure to welding flash, were not used consistently throughout the manufacturing plant. Observation of welding practices found that most welders do not wear their welding hood when performing the initial “tack” welds to fix components in place. Welders frequently used their hand to shield the flash from their eyes. During the actual weld, workers used the welding hoods. The use of respiratory protection is not required for welding at Thyssen-Dover, and none of the workers were observed wearing respiratory protection while welding.

A cafeteria and break room are provided for employees; however, some food and beverage consumption was observed in the manufacturing areas. Smoking is not permitted inside the building. Safety glasses and safety shoes are required to be worn on the manufacturing floor.

Ventilation of the manufacturing area is accomplished primarily through a series of heating, ventilating, and air-conditioning (HVAC) systems intended to air-condition (cooling and heating) the work area. These ground floor systems have both supply and return air grilles on the side wall. Particulate air filters have been placed on the return air grilles in an attempt to clean the recirculated air. The building is equipped with a number of large overhead doors that open to outside. Because of the effort to air-condition the plant, there is an incentive to keep the doors closed and prevent incursion of outside air. However, when outside conditions are favorable, the doors may be opened. During the NIOSH survey, some overhead doors were open; a noticeable breezeway was present in Department 591 (back of facility) because the doors were open.

Exhaust-only roof ventilators (axial fans) have been installed in various areas. Some of these ventilators were operational during the NIOSH visit. Some processes have direct ventilation to outside (paint booth and adhesive spray).

All welding observed was on mild steel using gas metal arc welding (GMAW). During GMAW, a consumable wire (0.045" diameter Lincoln L-50, or Holox Carbon Steel Welding Wire) is continuously fed through a welding gun. According to the material safety data sheet (MSDS), these electrodes contain approximately 1% manganese, <0.5% copper, with the balance composed of iron. Coalescence is achieved by the heat of an electric arc maintained between the end of an electrode and the work surface. The electrode is melted during this process and deposited as the weld metal. Shielding gas from a cylinder is supplied at the gun tip to prevent oxidation of the base metal during the GMAW process. Most processes used argon as the shield gas, although carbon dioxide was used on one process (Department 591) during certain welding tasks. Most welding is manual; however there are two automated stations using robot welders. According to Thyssen-Dover representatives, all welding is conducted by certified welders.

Figure 1: Welding Fume Exhaust

Most welding activities are conducted in the back portion of the manufacturing floor in an open environment with no local exhaust ventilation (LEV). Many of the welding processes require the welder to be mobile to complete the weld of large components. Except for Department 544, general dilution ventilation is relied on to disperse contaminants from the welding operations. Department 544 has two flexible exhaust ducts for use during welding. These exhaust ducts are connected to a fan which exhausts outside the building. Observation of work practices at Department 544 indicated that the LEV was not being used effectively, as the exhaust opening was not being placed close enough to the welding to be effective, and the exhaust flow rate may not be sufficient (Figure 1). Comfort fans were in use at most work stations. Informal discussions with workers indicated that the primary reason for using comfort fans is to disperse contaminants away from the worker; not for cooling.

Approximately 35 propane-powered forklifts are used to move product and raw materials in the manufacturing area. Other gasoline-powered vehicles (tractor) were also observed operating inside the facility.

A safety committee has been established at the Thyssen-Dover facility and cooperation with the union on safety has been good. Management has taken a number of actions (e.g., arranging for exposure monitoring, proposing ventilation designs) to address employee concerns regarding exposure to welding fume.

Air Sampling Results

Welding Fume - Gravimetric Sampling

The gravimetric, or total welding fume sampling results from the welding and laser fume monitoring are shown in Table 1. As shown in the table, both samples collected from first-shift welders in Department 544 exceeded the ACGIH TLV of 5 mg/m^3 TWA for total welding fume.[1] As noted in Appendix A, the ACGIH indicates that “conclusions based on total fume concentration are generally adequate if no toxic elements are present in the welding rod, metal, or metal coating and if conditions are not conducive to the formation of toxic gases.”[1] NIOSH has concluded that it is not possible to establish an exposure limit for total welding emissions since the composition of welding fumes and gases vary greatly, and the welding constituents may interact to produce adverse health effects. Therefore, NIOSH recommends controlling total welding fume to the lowest feasible concentration (LFC) and meeting the exposure limit for each welding fume constituent.[6]

All other total welding fume results were below the 5 mg/m^3 ACGIH criteria. The next highest sample was collected from a first shift Jackline welder from Department 591. Second shift samples were generally lower than first shift, possibly due to less production activity (e.g., Department 544 did not operate on the second shift). Additionally, a draft from open doors was present in Department 591, which could have resulted in dilution of generated contaminants and lower exposures to welding fume. Both the first-shift area sample and the second shift PBZ sample collected at the Bystronics laser indicated that exposure to total fume/dust were below applicable criteria. A sample collected from a machinist adjacent Department 544 showed a full-shift TWA exposure of 1.09 mg/m^3.

Welding Fume - Element-Specific Sampling

The results of the element-specific air sampling are shown in Table 2. The highest measured manganese concentrations were from the Department 544 MIG welders. Both workers in this department were exposed to a TWA manganese concentration in excess of the 0.2 mg/m^3 ACGIH TLV (0.23 mg/m^3, 0.37 mg/m^3). Manganese exposures in all other tasks monitored were below the ACGIH TLV.

Iron was the predominant metal found in all samples. This was an expected finding as iron is a primary component of mild steel. All measured concentrations were below the NIOSH REL of 5 mg/m^3 for iron oxide. Cadmium was only detected in one sample (0.00006 mg/m^3, Department 597 welder, first shift) at a trace (between the limit of detection [LOD] and limit of quantification [LOQ]) concentration. The highest nickel concentration was measured in the sample collected from the Department 591 first shift Jackline welder. A TWA concentration of 0.008 mg/m^3 was detected in this sample; most of this exposure occurred during the first portion of the shift as no nickel was detected on the sample collected during the latter portion of this worker’s shift. The NIOSH REL for nickel is 0.015 mg/m^3. Very low, non-detectable, or trace concentrations of zinc, cobalt, copper, chromium, and titanium were found in the air samples.

An unexpected result occurred in a sample collected from one of the first shift MIG welders in Department 544. Sample #1472, collected during the first portion of the work shift from this welder, showed a lead concentration of 0.0657 mg/m^3. The sample collected during the second portion of the work shift (sample # 1488) showed a concentration (0.002 mg/m^3) between the LOD and LOQ. The resulting TWA lead exposure (0.04 mg/m^3) for this worker exceeded the Action Level of 0.03 mg/m^3 established by OSHA.[7] Only very low trace concentrations of lead were detected in the samples obtained from an adjacent welder in Department 544 and most other samples were below the LOD for lead.

The source of lead contributing to this exposure was not determined. An inventory of welding materials during the site visit did not identify any lead-containing components. The type of steel (mild steel) used at Thyssen-Dover is composed primarily of iron with some other trace elements, and none of the material safety data sheets inspected indicated the presence of lead. Because an analytical error was a possibility, the NIOSH contract laboratory was requested to review this sample and determine the validity of the lead result; the sample was reanalyzed and the finding of lead was confirmed.

Carbon Monoxide, Ozone, Oxides of Nitrogen

The results of the instantaneous air sampling for CO, O_3, and NOx are shown in Table 3. During the day shift, CO concentrations of 8-12 parts per million (ppm) were detected in the manufacturing area. The higher concentrations were detected in the front portion of the manufacturing floor. The primary source of the CO is likely the propane-powered fork trucks. Night shift samples were much lower; this was an expected finding as there are fewer workers and fork trucks operating on the night shift. Low concentrations of NOx were detected at some of the welding stations. Ozone was not detected in any of the samples.

Asbestos Sampling

Four bulk samples of ceiling insulation were obtained from the following locations and analyzed for asbestos:

1968 ceiling insulation: Adjacent Column G-33, O-33,
1978 ceiling insulation: Adjacent Column C-34, between C-35 and C-36

A portion of the heat gasket on the Dept. 544 oven was also obtained and analyzed for asbestos. No asbestos (<1%) was detected in any of the samples.

Laser Cutting

The basic approach of most laser safety standards has been to use four hazard classifications (I - IV) that are based on the intensity of the emitted beam from the laser, or the laser system if the laser is a component within a larger system.[8,9] The laser is classified by the hazard it presents and specific control measures are required for each classification. The stringency of required controls are commensurate with the hazard classification. Class I denotes lasers or laser systems that do not, under normal operating conditions, pose a hazard. Class IV lasers or laser systems are powerful enough to produce a beam hazard not only from direct or specular reflections, but may also produce hazardous diffuse reflections.[9] Class IV lasers may also produce a skin and fire hazard and should only be operated within a sufficiently controlled and shielded area by trained personnel wearing appropriate protective eyewear.

The two (Bystronic and MAZAK) lasers used at Thyssen-Dover for cutting metal components are high power (Class IV, 1800-2000 Watts) carbon dioxide (CO_2) lasers designed to operate as Class I systems. That is, there should be sufficient controls (shielding, interlocks, enclosures, etc.) to prevent exposure to the beam. The CO_2 laser emits an invisible beam in the infrared region (wavelength = 10.6 micrometers). Both lasers are programable and operate in an open manufacturing environment. Although a comprehensive review of the laser operations was not conducted, it appeared that on the MAZAK laser some of the beam shielding had been removed, which would invalidate the Class 1 ranking.

During the NIOSH site visit, monitoring for LGACs was only conducted at the Bystronic laser. Employees had expressed concerns regarding potential exposure to LGACs from this laser. Concerns included fume from the base metal (stainless steel) and a polyethylene film with acrylic adhesive that is used to protect the steel. The MAZAK laser also cuts stainless steel, but the polyethylene film is removed prior to cutting. Appendix C contains information about LGACs and laser hazards.

The Bystronic laser was equipped with an exhaust system designed to capture contaminants and filter the air (at a filter bank behind the laser) prior to recirculation back into the facility. This system operates as a downdraft exhaust. A canopy hood was in place over the laser but was not operational.

Health Effects

Because the names of workers who participated in the confidential interviews were provided by management and union representatives, and specific symptoms (if fully described) could identify the workers, the number of workers who reported a symptom when less than 5 workers were affected has been omitted. Interviewed workers did not represent all departments at Thyssen-Dover Elevator, but were selected because of their symptoms, from among welders, laser operators, and machinists. Worker symptoms were grouped into three general categories, gastrointestinal symptoms, neurological symptoms, and chronic sinusitis.

Gastro-intestinal symptoms: Nine of 24 workers reported gastrointestinal symptoms, which included diarrhea, bloating, and vomiting. Both welders and machinists reported these symptoms. Symptoms were severe enough in some workers that their physicians evaluated them for heart disease and ulcers. Generally, workers indicated that these symptoms began after arriving at work and improved when they were away from work. Several workers indicated that their gastrointestinal symptoms resolved after transferring out of their original departments.

Neurologic symptoms: Two welders reported gait disturbances (stumbling, unsure footing), mood swings, speech impairment, and one welder appeared to have slight facial paralysis. In addition, some of the welders interviewed indicated frequent headaches and muscle aches, and several noted that their spouses had complained that they had become unusually irritable. The welders with headaches reported that headaches begin within hours of reporting to work and resolve gradually after being away from work. Gait disturbances and mood swings persisted after leaving work in the evenings.

Sinusitis: Ten machinists and welders reported chronic sinus infections. A number of the workers noted that sinus infections persisted despite the use of antibiotics. These sinus infections were reported to resolve when the workers were on vacation or away from work for an extended period.

A review of the company's OSHA 200 log did not indicate any common source exposures or exposure incidents that involved more than one person.

DISCUSSION

The worker exposure profile in the manufacturing area is mixed and complex, consisting of vehicle emissions, gases and fume from welding, dust from grinding, laser-generated air contaminants, solvent vapors, and metal-working fluids (MWF). Although there is some LEV available for certain processes, general dilution ventilation is relied on as the primary control. The effort to air condition the building and the resulting recirculation of building air, climatic conditions that affect decisions about opening the overhead doors, the use of comfort fans, and the roof ventilators will impact the extent of exposure. Capturing contaminants at the source via LEV is the preferred method for controlling contaminants.

This HHE focused on exposure to welding fume in certain departments with reported problems. However, not all welding activities were evaluated and a comprehensive exposure survey was not conducted. Because of the many sources of contaminant exposure, a comprehensive approach to improving workplace conditions is recommended. A well designed LEV system that can accommodate the constraints (e.g., different size structures, worker mobility) of the welding processes should be implemented to control exposure to welding emissions. Because welding emissions contain both a gaseous and particulate fraction, and because of the limitations of recirculating filtered air, the exhaust system should ventilate contaminants outside. It is likely that a sufficiently flexible system will encompass several of the designs described in Appendix B.

Welders working in Department 544 were found to have exposures exceeding the ACGIH criteria for total welding fume and manganese, and controls to reduce exposure are necessary. The results of the NIOSH evaluation are consistent with previous industrial hygiene surveys that have identified exposures to manganese above recommended guidelines. Until effective engineering controls or work modifications are implemented, workers at this station should use appropriate respiratory protection to reduce their exposure to welding fume. NIOSH recommends that respiratory protection be used for worker protection only when engineering controls are not technically feasible, during the interim while the controls are being installed or repaired, or when an emergency or other temporary situations arise.[10] Respirators are the least preferred method of worker protection against air contaminants because the burden of protection is on the worker. Respirator use requires implementation of an effective respiratory protection program to increase the reliability of the protection, and the cooperation of the workers to adhere to the elements of the program is critical for respirators to afford adequate protection.

There are two general classes of respiratory protection, air-purifying respirators which remove contaminants from the ambient air before it is inhaled, and air-supplied respirators which deliver an independent source of respirable air (other than the surrounding atmosphere).[13] Both types of respirators can be further classified based on the type of inlet covering (facepieces, helmet/shroud, suit, etc.) and the mode of operation. Regardless of the subclassification, air-purifying respirators only remove contaminants from the air; air-purifying respirators must not be used in oxygen deficient atmospheres. It is essential to fully characterize the hazardous atmosphere that respirators will be used in, including the identity and concentration of the air contaminants.

Additionally, one first shift Jackline worker monitored in Department 591 and a welder in Department 597 had full-shift exposures to total welding fume exceeding ½ of the ACGIH TLV. Note that these sampling results are only representative of exposures during the monitoring period. In general, an exposure profile will vary due to changes in work and production schedules and the inherent variability in most environmental sampling. Studies have indicated that exposure concentrations among welders who performed the same task can vary significantly.[6] Action should be taken to reduce exposures at these stations and additional monitoring performed to evaluate the efficacy of the controls.

The finding of lead in the Department 544 air sample was not expected and further investigation is necessary to better characterize the potential for lead exposure. An initial review of materials conducted during the site visit did not identify any lead-containing components, and it does not appear that an analytical error occurred. Because the exposure occurred during the first portion of the shift, and lead was not detected to any extent in other samples, it is likely that this was a unique event associated with an unusual source or a single welding activity.

Lead is a bluish-gray heavy metal with no characteristic taste or smell that serves no useful function after absorption in the body. Although lead is a naturally occurring element, most exposures to lead occur from human activities.[11] Lead is ubiquitous in U.S. urban environments due to the widespread use of lead compounds in industry, gasoline, and paints during the past century. Exposure to lead generally 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.

Lead can adversely affect numerous body systems. Skin absorption does not occur except for certain organo-lead compounds such as tetraethyl lead and inhalation is considered to be the most important occupational exposure route. Lead is a systemic poison, the health consequences of which can occur after periods of exposure as short as days or as long as several years.[7] Absorbed lead can damage the kidneys, peripheral and central nervous systems, and the blood forming organs (bone marrow).[1,11] These effects may be felt as weakness, tiredness, irritability, digestive disturbances, high blood pressure, kidney damage, mental deficiency, or slowed reaction times. Damage to the central nervous system in general, and the brain (encephalopathy) in particular, is one of the most severe forms of lead poisoning. Although the hazards of lead have been known for some time, occupational exposure to lead is still a significant problem in some industries.

Under the OSHA general industry lead standard (29 CFR 1910.1025), the permissible exposure limit (PEL) for airborne exposure to lead is 50 µg/m^3 (8-hour TWA).[7] 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 blood lead level (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. ACGIH has proposed a TLV for lead of 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.[1]

The primary source of the CO detected was likely the propane-powered fork trucks and other fuel driven vehicles. CO is a colorless, odorless gas that is a product of incomplete combustion. Engine exhaust, tobacco smoking, and inadequately ventilated combustion products from heaters that use hydrocarbon fuel are sources of CO. CO exposures can also result from the reduction of carbon dioxide used for shielding in gas metal arc welding, and has been reported during flame cutting of primed steel in confined spaces.[6] Overexposure to CO may cause initial symptoms such as weakness, confusion, headache, dizziness, drowsiness, and nausea. More serious effects such as loss of consciousness, or collapse can occur if high exposures are encountered.[12] The NIOSH REL for CO is 35 ppm as a TWA for up to 10 hours per day. NIOSH also recommends a ceiling level of 200 ppm for CO.[4] The ACGIH TLV for CO is 25 ppm.[1] Although the CO concentrations were below recommended guidelines, the best practice is to maintain concentrations of all contaminants as low as practical.[1] Action could be taken to reduce levels from these sources.

A wide variety and complex composition of LGACs can be produced from the interaction of high power CO_2 laser energy with various substrates, including metal and the polyethylene coating. The composition of the LGACs can vary significantly depending on the material being cut. Many of these compounds can have toxic and irritating effects if exposure concentrations are high enough, and this confirms the need to provide sufficient ventilation to capture the emissions. Because of the highly variable nature of laser decomposition, precisely defining the composition and relative amounts of degradation products which could be produced is difficult. This uncertainty provides additional justification that sufficient ventilation to control emissions is warranted.

Preliminary review of the laser cutting operation indicates that some of the laser shielding to prevent eye exposure to beam radiation may not be in place on the MAZAK laser. High power lasers in open manufacturing environments should only operate as a Class I system. Diligent investigation and consultation with the laser manufacturer is warranted to ensure all beam controls are in place.

In general, employees who were interviewed reported symptoms that began after arriving at work and improved when the employee left work, suggesting that work exposures may be associated with these symptoms. Compelling accounts of possible work related illness were described by welders who had worked in the same department at separate times and had endured prolonged gastrointestinal symptoms that completely resolved when they transferred out of the department. Similarly, workers who complained of chronic sinusitis reported that the infection cleared after they were away from the work site on vacations. Despite the temporal association between work and symptoms, there were no exposures found at this work site that could account for the gastrointestinal symptoms or the number of workers who reported chronic sinusitis. Both gastrointestinal illness and chronic sinusitis are conditions that are commonly reported in the general community and are usually the result of an infection. Furthermore, sinusitis is not generally considered to be an occupationally related illness but exposure to dusts, welding fumes, and allergens can aggravate symptoms among those with chronic sinusitis.

On interview, welders reported neurologic problems such as gait disturbances, headaches, muscle aches, and mood changes. These symptoms are suggestive of manganese toxicity.[13] Given that the welding electrodes used at Thyssen-Dover Elevator contain manganese, there was concern that welders could be showing signs of manganese poisoning. Personal air sample results for manganese (Table 2) showed that some welders were exposed to manganese fumes above the ACGIH TLV of 0.2 ppm. The exposure levels measured, however, would not be expected to cause the severity of symptoms reported by welders at this job site, although they do not rule out the possibility that exposures have been higher in the past and the effects reported by workers are the result of these higher exposures and/or chronic exposures over time.

CONCLUSIONS

Measured exposures to manganese and total welding fume exceeded applicable guidelines in Department 544, and welders in Departments 591 and 597 had exposures exceeding ½ of the ACGIH welding fume TLV. Interim exposure controls of respiratory protection are necessary until adequate engineering controls can be implemented. An unexpected finding of lead in one sample from Department 544 warrants further investigation to verify this finding and ensure lead exposure is not occurring. Not all welding activities were evaluated and a comprehensive exposure survey was not conducted. Other processes, including machining (with metal working fluids), painting, laminating, and woodworking were not evaluated.

Because of the reliance on general exhaust ventilation as a primary control, the number of different processes, and the open manufacturing environment, the exposure profile in the manufacturing area is complex. Climatic conditions that affect decisions about opening the overhead doors, the use of comfort fans, and the operation of roof ventilators will impact the extent of exposure. Capturing contaminants at the source via local exhaust ventilation is the preferred method for controlling contaminants.

Instantaneous area air sampling found elevated levels of CO throughout the manufacturing area during the first shift. The primary source of the CO appears to be the propane-powered lift trucks and action should be taken to reduce emissions from these sources.

RECOMMENDATIONS

1. A comprehensive safety review with vendor representatives should be conducted to ensure that both the Bystronic and MAZAK laser operate in the Class I mode during normal production. Manufacturer installed shielding and interlocks should not be removed or defeated as this could invalidate the safety classification and potentially create beam hazards. Protective laser goggles should be worn whenever maintenance is conducted, the laser is fired with the shielding removed, or when interlocks are defeated. When the laser is operating in the Class IV mode, protective curtains should be in place to prevent ancillary exposure to beam hazards, and a warning lamp or sign should be in place to indicate that testing is in progress.

2. LEV at the Department 544 welding station should be implemented. Several options could be considered, including adjustable/flexible articulating exhaust shrouds, vacuum nozzles, or a combination of both. A bench hood with side baffles would be an optimum ventilation design (information on this design was provided at the opening conference).

3. Until engineering controls (ventilation) or work practice changes to reduce exposure are in place, workers conducting tasks where exposures were found to exceed the ACGIH criteria should use respiratory protection. Because measured exposures were less than 10 times the ACGIH TLV, a particulate respirator with an assigned

protection factor (APF) of 10 will provide sufficient protection. A half-mask air-purifying respirator equipped with a high efficiency particulate air (HEPA) filter certified under 42 CFR Part 84 should be used as the minimally protective respirator. Respirators should only be used within the constraints of a comprehensive respiratory protection program (29 CFR Part 1910.134). Users must be clean shaven, medically cleared, trained, and fit-tested for their assigned respirator.

4. Sampling to evaluate worker exposures to welding fume should be conducted every 6 months. The sampling strategy should focus on workers that are expected to have the highest exposures (high production areas, etc.). Area sampling can help augment the personal exposure monitoring. The objectives of an environmental monitoring program are to evaluate the effectiveness of work practices and engineering controls, ensure that exposures are below the applicable criteria, and identify areas where further reduction in exposures is possible.

5. A more comprehensive ventilation system should be implemented in areas where welding is concentrated (e.g., there are 23 welding stations in Department 597). Ventilation design parameters should include flexibility, appropriate capture velocity, material flow and handling considerations, and worker considerations. A combination of LEV, work practice controls, vacuum nozzles, and general dilution exhaust is likely necessary. Target capture velocities should be 140-150 feet per minute for welding fume; higher velocities are necessary when turbulence or cross drafts are present. Preventing drafts and turbulence is essential to good ventilation control. Shields, baffles, and a reduction in the use of comfort fans will be necessary. Exhaust ventilation should be to outside. Recirculating filtered air from welding operations back into occupied spaces is not recommended. Additional general dilution ventilation may be necessary.

6. Welding electrodes that are manganese-free or have lower manganese concentrations should be evaluated and used if feasible. As noted in Appendix A, a substantial portion of the welding fume is believed to originate from the electrode.

7. Fork trucks and other propane/gas powered combustion engines should be equipped with controls to reduce carbon monoxide generation. Information regarding exhaust controls was provided to Thyssen-Dover management.

8. Welding shields should be used properly by welders to prevent exposure of ancillary personnel to weld flash. Welders should wear appropriately shaded eye protection when conducting the tack welds.

9. Evaluate all materials in use in Department 544 and determine if any lead-containing materials that may be welded are used. All sources of lead should be removed from service if feasible, and alternative lead-free materials should be used. Additional air monitoring of tasks in Department 544 should be conducted for lead. If lead-containing materials are used, it may be necessary to establish a lead program as described in the OSHA comprehensive lead standard (29 CFR 1910.1025).[7]

10. Welders who continue to experience mood changes, gait disturbances, muscle weakness, or slurred speech should be sent by the company to an occupationally trained physician for a complete medical evaluation and toxicologic assessment.

REFERENCES

1. ACGIH [2000]. 2000 Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists

2. Eller PM, ed. [1994]. NIOSH manual of analytical methods. 4th ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94-113.

3. Leichnitz, K [1989]. Detector tube handbook: air investigations and technical gas analysis with dräger tubes. 7th. ed. GmbH, Lübeck: Graphische Werstätteb GmbH.

4. NIOSH [1992]. 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 and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

5. CFR [1997]. 29 CFR 1910.1000. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

6. NIOSH [1988]. Criteria for a recommended standard: occupational exposure to welding, brazing, and thermal cutting. Cincinnati, Ohio: 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. 88-110.

7. CFR [1997]. 29 CFR 1910.1025. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register

8. ANSI [1993]. ANSI Z136.1-1993, American national standard for safe use of lasers. American National Standards Institute, New York, New York.

9. Sliney, D, ed. [1993]. LIA laser safety guide, 9th ed. Laser Institute of America. Orlando, FL.

10. NIOSH [1987]. NIOSH respirator decision logic. 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. 87-108.

11. ATSDR [1999]. Toxicological profile for lead: update. U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry.

12. NIOSH [1996]. Alert: preventing carbon monoxide poisoning from small gasoline-powered engines and tools. Cincinnati, OH: U.S. Department of Health, and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 96-118.

13. Mergler, D.; Baldwin, M.; [1997] Early manifestations of manganese neurotoxicity in humans: an update. Environ Res 73 (1-2) 92-100.

Table 1
Gravimetric Sampling Results
Thyssen-Dover Elevator, HETA 2000-0185-2808
May 2, 2000

Sample #	Location/Task	Time (min)	mg/m^3	TWA (mg/m^3)
1481	Plunger Welder, Dept. 591, 2nd shift	15:01-19:14 (253)	1.15	1.6
1471		20:06-21:35 (89)	2.87	
1486	Casing Welder, Dept 591, 2nd shift	15:28-21:41 (389)	0.45	0.79
1494		20:05-21:35 (90)	2.26	
1484	Bystronics Laser Op. 2nd shift	15:13-19:17 (244)	0.37	0.37
1474	Jackline, Dept. 591, 1st shift	05:55-13:00 (425)	4.28	4.03
1482		13:00-14:15 (75)	2.63	
1478	MIG, Dept 544, 1st shift	05:57-10:43 (286)	4.34	**5.44**
1491		10:43-14:08 (205)	**6.98**	
1472	MIG, Dept 544, 1st shift	05:58-10:34 (276)	**5.33**	**6.10**
1488		10:34-14:09 (215)	**7.08**	
1473	Dept. 597 Welder, 1st shift	06:01-12:50 (409)	1.34	1.35
1495		12:50-14:20 (97)	1.37	
1477	Dept 597 Welder, 1st shift	06:04-12:52 (408)	3.03	2.96
1489		12:52-15:21 (149)	2.79	
1492	Machinist, Dept. 543	06:08-12:11 (363)	1.09	1.09
1493	Area, Bystronics Laser	06:50-15:32 (522)	0.29	0.29
ACGIH TLV-TWA for Total Welding Fume			**5.0**	

mg/m^3 = milligrams of contaminant per cubic meter of air sampled.
Bolded = exceeds criteria
TWA = time-weighted average concentration calculated as follows:

$$\text{TWA} = \frac{C_1T_1 + C_2T_2 + C_nT_n}{T_1 + T_2 + T_n}$$

Where: C = Concentration, T = Time

Table 2
Elemental Sampling Results
Thyssen-Dover Elevator, HETA 2000-0185-2808
May 2, 2000

Task	Sample #	Concentration (Mg/m^3)									
		Mn	**Ni**	**Fe**	**Pb**	**Cd**	**Zn**	**Co**	**Cu**	**Cr**	**Ti**
Plunger Welder, Dept. 591, 2nd shift	1481	0.06	(0.001)	0.53	<0.001	<0.0001	<0.001*	<0.0004	0.004	(0.001)	<0.0001*
	1471	0.17	(0.005)	2.67	<0.01	<0.0005	<0.006*	<0.002	<0.02	0.004	<0.001*
	TWA	0.09	(0.002)	1.06	<0.003	<0.0002	<0.002*	<0.0008	0.008	0.002	<0.0003*
Casing Welder, Dept. 591, 2nd shift	1486	0.02	<0.0003	0.16	<0.001	<0.00005	<0.0006	<0.0003	0.0009	<0.0004	<0.0001
	1494	0.04	<0.001	1.18	<0.005	<0.0002	<0.003	<0.001	0.007	<0.002	<0.001
	TWA	0.02	<.0004	0.35	<0.002	<0.00008	<0.001	<0.002	<0.001	<0.0005	<0.0003
Byst. Laser Op. 2nd shift	1484	0.008	<0.0004	0.13	<0.002	<0.00009	<0.001	<0.0004	0.002	(0.0009)	0.0005
Jackline Welder, Dept. 591, 1st shift.	1474	0.09	0.009	2.01	<0.001	<0.00005	<0.0006*	(0.0002)	0.008	0.001	0.0006
	1482	0.10	<0.001	1.31	<0.006	<0.0003	<0.003	0.001	0.006	<0.002	<0.0006*
	TWA	0.09	0.008	1.91	<0.002	<0.00008	<0.001	0.0003	0.008	0.001	0.0006
MIG Welder, Dept. 544, 1st shift	1478	**0.2**	(0.0007)	1.68	<0.002	<0.00009	<0.001*	<0.0005	0.03	(0.002)	<0.0002*
	1491	**0.27**	(0.0007)	2.67	<0.002	<0.0001	<0.001*	<0.0005	0.04	0.002	<0.0002*
	TWA	**0.23**	(0.0007)	2.09	<0.002	<0.0001	<0.001	<0.0005	0.03	0.002	<0.0002
MIG Welder, Dept. 544, 1st shift	1472	**0.27**	(0.0007)	2.55	**0.0657**	<0.00007	0.002	<0.0004	0.04	0.002	<0.0002*
	1488	**0.37**	(0.0009)	3.49	(0.002)	<0.00009	<0.001*	<0.0004	0.06	0.003	<0.0002*
	TWA	**0.31**	(0.0008)	2.96	**0.04****	<0.00008	0.0001	<0.0004	0.05	0.002	<0.0002
Dept. 597 Welder, 1st shift	1473	0.08	(0.0006)	0.49	<0.001	<0.00005	0.005	<0.0002	<0.0004	(0.0008)	<0.0001*
	1495	0.08	(0.001)	0.53	<0.005	<0.0002	<0.003*	<0.001	<0.0004	<0.002	<0.0005

Table 2
Elemental Sampling Results
Thyssen-Dover Elevator, HETA 2000-0185-2808
May 2, 2000

Task	**Sample #**	**Concentration (Mg/m^3)**									
		Mn	**Ni**	**Fe**	**Pb**	**Cd**	**Zn**	**Co**	**Cu**	**Cr**	**Ti**
	TWA	0.08	(0.0007)	0.5	<0.002	<0.00008	0.005	<0.0004	<0.0004	(0.0008)	<0.0002
Dept. 597 Welder, 1st shift	1477	0.18	0.001	1.12	(0.001)	(0.00005)	0.015	(0.0004)	0.006	0.001	0.0004
	1489	0.03	(0.002)	0.69	<0.003	<0.0001	<0.002	(0.0007)	0.01	(0.001)	<0.003*
	TWA	0.14	0.001	1.01	(0.001)	(0.00006)	0.01	(0.0005)	0.007	0.001	0.0001
Machinist, Dept. 543	1492	0.02	0.002	0.34	(0.003)	<0.00006	<0.0007	<0.0002	0.02	(0.0007)	0.001
Area, Byst. Laser, 1st shift	1493	0.007	(0.0007)	0.10	<0.0009	<0.00004	<0.0005	<0.0002	0.002	0.001	0.0002
NIOSH REL		1.0$^+$	0.015	5	0.1**	LFC	5	0.05	0.1	0.5	NE

Note:
mg/m^3 = milligrams of contaminant per cubic meter of air sampled
< = less than
Values in parentheses indicate the contaminant concentration was between the analytical limit of detection (LOD) and the limit of quantification (LOQ).
All results are blank corrected.
* = element was detected above the LOQ but below the level detected on the field blank
LFC = Lowest Feasible Concentration
NE = Not Established
TWA = time-weighted average concentration calculated as follows:

$$\text{TWA} = \frac{C_1T_1 + C_2T_2 + C_nT_n}{T_1 + T_2 + T_n}$$

Where: C = Concentration, T = Time

Tasks without a TWA category were sampled for the full shift and the results reported represent the TWA.
** The regulatory Action Level for lead is 0.03 mg/m^3 established by OSHA (29 CFR 1910.1025). The OSHA Permissible Exposure Limit for lead is 0.05 mg/m^3.
+ The ACGIH TLV for manganese is 0.2 mg/m^3.
Mn = manganese, Ni = nickel, Fe = iron, Pb = lead, Cd = cadmium, Zn = zinc, Co = cobalt, Cu = copper, Cr = chromium, Ti = Titanium
Bolded numbers indicate evaluation criteria was exceeded.

Table 3
Direct Reading Monitoring Results
Thyssen-Dover Elevator, HETA 2000-0185-2808
May 2, 2000

Location	Time	CO (ppm)	NOx (ppm)	O_3 (ppm)
Bystronics Laser	0935	9	0.75	ND
Bystronics Laser	2030	5	Trace	ND
Dept. 597	0945	10	0.5	ND
Dept. 597	0955	3	0.4	ND
Dept. 591	1005	3	0.4	ND
Dept 591 (plunger weld)	2010	1	Trace	ND
Dept. 591 (casing)	2020	1	Trace	ND
Dept. 544	1015	8	0.5	ND

Note:
ppm = parts of gas or vapor per million parts air
Trace = concentration detected was between the limit of detection and the limit of quantification (a discoloration on the tube was noted but below the quantification limit.
ND = none detected, limit of detection = 0.05 ppm

Appendix A: Welding Fume

The effect of welding fumes on an individual's health can vary depending on such factors as the length and intensity of the exposure and the specific metals involved. The content of welding fumes depends on the base metal being welded, the welding process and parameters (such as voltage and amperage), the composition of the consumable welding electrode or wire, the shielding gas, and any surface coatings or contaminants on the base metal. It has been suggested that as much as 95% of the welding fume actually originates from the melting of the electrode or wire.[1] The flux coating (or core) of the electrode/wire may contain up to 30 organic and inorganic compounds. The primary purpose of the flux is to release a shielding gas to insulate the weld puddle from air, thereby protecting against oxidation.[2] The size of welding fume particulate is highly variable and ranges in diameter from less than 1-micrometer (µm) (not visible) to 50-µm (seen as smoke).[3]

In general, welding fume constituents may include minerals, such as silica and fluorides, and metals, such as arsenic, beryllium, cadmium, chromium, cobalt, nickel, copper, iron, lead, magnesium, manganese, molybdenum, tin, vanadium, and zinc.[3,4,5] Low-carbon steel, or mild steel, is distinguished from other steels by a carbon content of less than 0.30%. This type of steel consists mainly of iron, carbon, and manganese, but may also contain phosphorus, sulphur, and silicon. Most toxic metals, such as nickel and chromium which are present in stainless steel, are not present in low carbon steel.

A PEL for total welding fumes has not been established by OSHA; however, PELs have been set for individual welding fume constituents (e.g., iron, manganese), and the PEL for total particulates not otherwise regulated is 15 milligrams per cubic meter (mg/m^3) as an 8-hour time-weighted average (TWA).[6] The ACGIH has established a TLV of 5 mg/m^3 TWA for welding fumes.[7] The ACGIH suggests that "conclusions based on total fume concentration are generally adequate if no toxic elements are present in the welding rod, metal, or metal coating and if conditions are not conducive to the formation of toxic gases."[7] The ACGIH also recommends that arc welding fumes be tested frequently to determine whether exposure levels are exceeded for individual constituents.[7] NIOSH has concluded that it is not possible to establish an exposure limit for total welding emissions since the composition of welding fumes and gases vary greatly, and the welding constituents may interact to produce adverse health effects. Therefore, NIOSH recommends controlling total welding fume to the lowest feasible concentration (LFC) and meeting the exposure limit for each welding fume constituent.[8] The potential health effects and NIOSH RELs for the metals measured in the environmental samples during this survey are shown in the following table. Evaluation criteria for manganese are presented separately.

Element	NIOSH REL (mg/m^3)	Principle Health Effects[9,]
Chromium	0.5*	skin and mucous membrane irritation, possible lung cancer
Iron	5	benign pneumoconiosis (siderosis)
Manganese	1 TWA 3 STEL	central nervous system effects, pneumonitis, headaches
Copper	0.1 (fume) 1 (dust/mist)	upper respiratory irritation, metal fume fever
Nickel	0.015	lung and nasal cancer, skin effects
Zinc oxide fume	5 TWA 10 STEL	metal fume fever

* Chromium can occur in various oxidation states. Certain hexavalent chromium compounds (chromic acid and chromates) have been shown to be carcinogenic. NIOSH recommends controlling exposure to the LFC for these compounds. Hexavalent chromium compounds have been detected in stainless steel welding processes.[4]

In addition to welding particulate (known as fume), many other potential health hazards exist for welders. Welding operations can produce gaseous emissions such as ozone, carbon monoxide, nitrogen dioxide, and phosgene (formed from chlorinated solvent decomposition).[3,4,5] Welders can also be exposed to hazardous levels of ultraviolet light from the welding arc if welding screens or other precautions are not used. Ergonomic problems are also a consideration due to various contorted positions welders assume for some welding tasks.

References

1. Stern RM [1979]. Control technology for improvement of welding hygiene, some preliminary considerations. Copenhagen, Denmark: The Danish Welding Institute, The Working Environment Research Group, ISBN 87-87806-18-5, p. 2.

2. Burgess, WA: Recognition of Health Hazards in Industry. A Review of Materials and Processes. Industrial Operations, Welding. Ed: John Wiley & Sons, New York.

3. The Welding Institute [1976]. The facts about fume - a welding engineer's handbook. Abington, Cambridge, England: The Welding Institute.

4. NIOSH [1988]. Criteria for a recommended standard: occupational exposure to welding, brazing, and thermal cutting. 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. 88-110.

5. Rekus JF [1990]. Health hazards in welding. Body Shop Business *11*:66-77, 188.

6. CFR. Code of Federal Regulations [1994]. Occupational Safety and Health Administration: OSHA Table Z-2. 29 CFR 1910.1000. Washington, D.C.: U.S. Government Printing Office, Federal Register.

7. ACGIH [2000]. 2000 Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

8. NIOSH [1994]. NIOSH pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94-116.

9. Hathaway GJ, Proctor NH, Hughes JP [1996]. Chemical hazards of the workplace, 4th. Ed. New York: Van Nostrand Reinhold Company.

Manganese

Manganese (Mn) is an abundant and ubiquitous element present throughout the environment including soil, water, air, vegetation, and food items. Manganese is an essential trace element necessary for the formation of connective tissue and bone as well as the metabolism of carbohydrates and lipids; for these reasons, adult humans require 2 to 3 milligrams (mg) of dietary Mn per day.[1] Elemental Mn is a light gray metal that does not occur naturally. Manganese is a very reactive metal that exists in numerous oxidation states and it is a component in over 100 minerals. One of the most common and commercially important Mn-containing ores is pyrolusite, a black mineral typically containing approximately 60% MnO_2.[2,3] There are many important industrial uses for Mn; it is used in the steel and metal alloy industries to improve hardness and strength; it is also used in ceramic and glass products, in rubber and wood preservatives; and it is also used in dry-cell batteries. The health effects of excessive occupational Mn exposure are primarily neurological and respiratory (including irritation, pneumonitis, and chronic bronchitis). Metal fume fever has also been reported with exposure to Mn fume. Most notably, occupational exposure to Mn dust is known to cause *manganism*, a Parkinsonian-like syndrome with well recognized characteristics. This condition has also been referred to as Mn poisoning and chronic Mn toxicity.

Adverse health effects have been associated with heavy occupational exposures to Mn as early as 1837, when Couper reported a neurologic syndrome found in workers who had been grinding MnO_2 for several months.[4] Further reports of Mn poisoning did not appear in the medical literature until 1901.[5,6] Most of the affected workers reported from 1901 to 1919 were MnO_2 grinders and the rest processed or handled Mn ore.[5-13] The findings in the affected workers resembled those of Parkinsonism and subsequent studies have shown that Mn affects the extrapyramidal system of the brain.[14] More recent reports or studies of chronic Mn toxicity have been described and studied in the mining, ore processing, and smelting industries.[2]

Manganism is a progressive occupational disease. The symptoms of early disease, such as fatigue, somnolence, and irritability, are nonspecific and may be related to any of a number of factors. Advanced disease, however, is characterized by more specific symptoms such as slow or minimal speech or movement (brady- or hypokinesia); increased muscle tone (rigidity) especially of the limbs; a smooth and expressionless face; tremors; disturbed gait; postural instability (with difficulty in turning around, difficulty stopping when stepping forward [propulsion] or backward [retropulsion]); increasingly small handwriting (micrographia), and possibly psychological disturbance such as hallucinations, compulsive behavior, and emotional instability. The condition may develop insidiously after months or years of Mn exposure. Although the condition may be reversible after early removal from exposure, it is often unrecognized until the worker is severely and irreversibly affected.

Chronic Mn toxicity has been found in workers exposed to Mn during operations in which high concentrations of dust or fume were generated. Such operations have included mining, ore processing, purification processes, metallurgical and manufacturing processes, and welding of Mn alloys or use of welding rods containing Mn.[15] Inhalation is the primary route of occupational exposure, but most inhaled Mn dust is mobilized from the lungs and swallowed.[16] Thus, the gastrointestinal tract is an important route of absorption for inhaled as well as ingested Mn dust. An experimental study of adult humans showed that 3% of ingested Mn is absorbed by healthy subjects, 3 to 5% by subjects with chronic Mn toxicity, and up to 10% by unexposed anemic subjects.[16]

In 1837, Couper reported that the neurologic findings reversed in workers who were promptly removed from exposure when early signs of toxicity were recognized.[4] Because of the irreversible nature of the disease, Edsall, et al., recommended preventive measures, such as elimination of dust from the work environment.[13] They also recommended medical surveillance of exposed workers and removal of symptomatic workers from exposure.[13]

The NIOSH REL for Mn dust is an 8-hour time-weighted average (TWA) of 1.0 milligram per cubic meter (mg/m^3) total Mn, with a short term exposure limit (STEL) of 3.0 mg/m^3 based on central nervous system (CNS) effects and pneumonitis.[17,18] The OSHA PEL for Mn dust is a ceiling criteria of 5.0 mg/m^3.[19] The ACGIH TLV® for Mn dust and fume is an 8-hour TWA of 0.2 mg/m^3 based on adverse pulmonary effects, CNS effects, and male infertility.[20] Reports of Parkinsonian-like symptoms have been reported for high Mn dust (and fume) exposures, but the significance of lower dust exposure levels for producing neurological effects is uncertain.

References

1. WHO [1981]. Environmental Health Criteria 17: Manganese. Geneva, Switzerland. World Health Organization.

2. ACGIH [1992]. Documentation of threshold limit values and biological exposure indices for chemical substances and physical agents. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

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

4. Couper J [1837]. On the effects of black oxide of manganese when inhaled into the lungs. Brit Ann Med Pharm 1:41-45.

5. Von Jaksch R [1901]. Ueber gebäufte diffuse erkrankungen des gehirns und rückenmarks, an den typus der multiplen sklerose mahnend, welebe durch eine besondere aetiologie gekeunzeichnet sind. Wien klin Rundschau 15:729-733.

6. Embden H [1901]. Zur kentniss der metallischen nervengifte. Deutsche med Wochenschr 27:795-796.

7. Friedel [1903]. Manganvergiftung in braunsteinmühlen und gesundheitspolisciliche mamregein su threr verhütung. Ztschr Med-Beamte 16:614.

8. Sieffer H [1904]. Manganvergiftung. Berl klin Wochenschr 41:370.

9. Von Jaksch R [1907]. Ueber mangantoxikosen und manganophobie. München med Wochenschr 54:969-972.

10. Von Jaksch R [1910]. Vergiftung und mangensalzen. In: Nothnagel CWH (ed.). Specielle pathologie und therapie. Vienna: Alfred Holder. Vol. 1, pp. 231-238.

11. Casamajor L [1913]. An unusual case of mineral poisoning affecting the nervous system: Manganese? JAMA 60:646-647.

12. Seelert H [1913]. Ein fall chronischer manganvergiftung. Monatschr Psychiat Neurol 34:82-92.

13. Edsall DL, Wilbur FP, Drinker CK [1919]. The occurrence, course and prevention of chronic manganese poisoning. J Industrial Hygiene 1:183-193.

14. Canavan MM, Cobb S, Drinker CK [1934]. Chronic manganese poisoning: report of a case, with autopsy. Arch Neurol Psychiatr 32:501-513.

15. Tanaka S [1993]. Manganese and its compounds. In: Zenz C, Dickerson OB, Horvath E (eds.). Occupational medicine: Principles and practical applications, 3rd ed. Chicago: Year Book Medical Publishers, Inc.

16. Mena I, Horiuchi K, Burke K, Cotzias GC [1969]. Chronic manganese poisoning: individual susceptibility and absorption of iron. Neurology 19:1000-1006.

17. NIOSH [1988]. NIOSH testimony on OSHA's proposed rule on air contaminants. 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, NTIS No. PB-90-115-337.

18. NIOSH [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.

19. OSHA [1989]. Final rule: PEL project update. (29 CFR 1910.1000) Washington, DC: Occupational Safety and Health Agency, U.S. Department of Labor, U.S. Government Printing Office. Federal Register, January 19, 1989. 54 FR 2641.

20. ACGIH [2000]. 2000 Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

Appendix B: Control of Welding Fume

To reduce the hazard of welding fume exposures, the following hierarchy of controls should be considered: automation, substitution, isolation, ventilation.

! Partial or complete automation so the welder is less exposed to welding fumes.

! Implement process changes to limit hazards. For example, determine if different joining process other than welding can be used, if lower fume-producing welding processes, such as submerged arc welding or gas tungsten arc welding (GTAW or TIG) are feasible; or if low-fume electrodes can be substituted for the electrodes currently used.

! Isolate or enclose the welding process to limit the hazard to workers.

! Utilize ventilation to remove the fumes and gases from the welder's breathing zone.

A number of ventilation systems are commercially available to help control fume emissions during welding operations. Local exhaust ventilation (LEV) controls capture the air contaminants directly at the point of generation and are generally positioned no more than 12 inches away from the source. LEV systems are more effective than general ventilation systems since the air contaminants can be captured and removed before they can reach the welder's breathing zone. However, the effectiveness of the LEV system is often dependent on how the welder positions the hood; if the hood is placed too far from the welding operation it may not adequately capturing the air contaminants, depending on the capture velocity. LEV systems used during industrial welding operations can include: fixed movable hoods, portable movable hoods, fume extraction guns, and, to some extent, canopy hoods.

Movable Hoods

OSHA 29 CFR 1910.252 recommends that "(movable hoods) should be placed as near as practicable to the work being welded and provided with a rate of airflow sufficient to maintain a velocity in the direction of the hood of 100 fpm in the zone of welding when the hood is at its most remote distance from the point of welding." To maintain a capture velocity of 100 fpm, OSHA provides the following values when using a 3" wide, flanged hood.

OSHA GUIDELINES FOR MOVABLE HOOD AIRFLOW RATES

Distance from Arc to Hood (in)	Airflow (cfm)	Duct Diameter (in)
4-6	150	3
6-8	275	3.5
8-10	425	4.5
10-12	600	5.5

The ACGIH Ventilation Manual also provides guidelines on the use of movable exhaust hoods for welding operations.[1] The airflow rates suggested by ACGIH are more conservative than those recommended by OSHA.

ACGIH GUIDELINES FOR MOVABLE HOOD AIRFLOW RATES

Distance from Arc to Hood (in)	Plain Duct Airflow (cfm)	Flange or Cone Hood Airflow (cfm)
up to 6	335	250
6-9	755	560
9-12	1335	1000

Fume Extraction Guns

Fume extraction guns are high vacuum, low volume controls. Two types of fume extraction guns are available. One type of gun incorporates the ventilation directly into the gun design. Lines for the shielding gas and exhausted air are encased in a large, single line leading from the gun. The second type of gun uses a conventional, nonventilated model with a suction attachment connected to the gun nozzle. On this model, the shielding gas and exhausted air lines remained separate. The type of gun used often depends on the welder's personal preference. Welders who find the all-in-one fume extraction gun bulky and cumbersome may prefer to use a conventional gun with the suction attachment. One manufacturer gives the following comparison of air flow rates for fume extraction guns and suction devices.[2]

APPROXIMATE AIRFLOW RATES FOR LEV SYSTEMS

Suction Device	Approximate Airflow Requirement (cfm)
Fume Extraction Gun	20-60
Small Suction Hood	40-80
Large Suction Hood	80-160

Although local exhaust ventilation can be very efficient at reducing worker welding fume exposures, there are many impediments to the successful implementation of this type of ventilation control in the shipbuilding industry:

1) Controls must be usable in confined or enclosed spaces, or in awkward positions.
2) Controls must be usable by a mobile workforce and may require extensive reaches.
3) Controls must be able to be moved out of the way of overhead cranes and hoists when necessary.
4) Duct work for controls must be tough enough to endure misuse and abuse.
5) Controls must be able to effectively filter exhaust air before releasing it back into the welding area, or must exhaust air to the outside (preferrable)
6) Controls must be flexible enough to adjust to changes in unit size and configuration, or changes in the process layout.

There can be additional drawbacks to using the various types of local exhaust ventilated controls. For example, welders may resist using fume extraction guns if they consider them to be too cumbersome or if they believe the ventilation is exhausting the shielding gas in addition to the fumes. Movable hoods are only effective if welders continually position the hood close to the point of fume generation. Portable ventilated units may be too large to maneuver through the work in progress on the Factory floor.

If local exhaust ventilation controls cannot be implemented, general exhaust ventilation (GEV) controls should be considered. A drawback to a GEV system is that, although it may help to reduce overall fume levels in the facility, it may not have a significant impact on reducing the exposure levels of the welder. OSHA 29CFR1910.252 recommends a minimum exhaust ventilation rate of 2000 cfm per welder when welding in a space of less than 10,000 ft^3 per welder, or when in a room with a ceiling height of less than 16 ft, or when in confined spaces or where the welding space contains structural barriers to the extent that they significantly obstruct cross ventilation. The ACGIH Ventilation Manual suggests the following general ventilation airflow rates: (1) for open areas where welding fume can rise away from the breathing zone the airflow required (cfm) = 800 x lb/hour of rod/wire used (2) for enclosed areas or positions where fume does not readily escape the breathing zone the airflow required (cfm) = 1600 x lb/hour of rod/wire used. Examples of general exhaust ventilation controls include: suspended air filtration units and roof ventilators.

Other Welding Fume Controls

In addition to engineering controls, other factors such as work practices, personal protective equipment, and administrative controls should be investigated to help reduce worker exposures to welding fumes. Examples of work practices that may help to lower worker fume exposures include: educating welders to keep their heads out of the weld plume and to remain aware of air currents to ensure welding is performed upwind of the fumes as much as possible. Examples of personal protective equipment include: proper use of respirators, use of welding glasses/goggles/hoods by welders and workers in the vicinity, and availability of welding screens to place around weld operations. Examples of administrative controls include: job rotation to limit welders' exposures, training and education of welders on hazards and controls associated with their jobs, ensuring welders use ventilation and other control measures supplied to them.

References

1. ACGIH [1992]. Industrial ventilation: a manual of recommended practice. 21st Ed. Cincinnati, Ohio. American Conference of Governmental Industrial Hygienists.

2. Lincoln Electric [1994]. Lincoln Environmental Systems. High-Vacuum Solutions. Fume X-Tractor™ Products. Product Literature, E13.10. Cleveland, OH

Appendix C: Laser Generated Air Contaminants

During the intense interaction of laser energy with a target, a wide variety and complex mixture of LGAC can be formed. The quantity and composition of the LGAC will vary greatly depending on the beam irradiance (power per area) and material undergoing the lasing action.[1,2,3] Although research on the products of polymer pyrolysis and combustion has been conducted, this data may not be applicable to the products generated when materials are irradiated with high power laser energy. Information concerning LGAC formation is much less complete, although some data is available.(4,5,6,7,8) Predicting the composition and quantity of LGACs that may be generated during any laser situation is not possible. However, it is known that toxic airborne contaminants can be liberated from materials such as plastics, composites, metals, wood, etc., when the target irradiance (power per area) reaches a given threshold, beginning at about 10^3 Watts per square centimeter (W/cm^2).[1] These can be generated from certain Class 3b and 4 lasers.

Industrial hygiene evaluations of emissions from cutting both carbon and stainless steel with high power CO_2 lasers have been conducted. One study assessed contaminants generated while cutting metal with an 1800 W CO_2 laser identified both iron oxide fume and hexavalent chromium fume.[9] The study authors concluded that fume formation was of the same order as metal inert gas (MIG) welding and that good ventilation was necessary.

Emissions from laser interaction with matter can include both a gaseous or vapor fraction (aldehydes, benzene, carbon monoxide, hydrogen cyanide, etc.), and a particulate component (fumes, dust, re-condensation products). Information and guidelines for the control of LGAC have been developed and are found in the American National Standards Institute (ANSI) *Safe Use of Lasers standard, Z136.1-1993*.[1] This consensus standard contains information concerning LGAC formation and hazard control methods. The primary method for controlling exposure to LGAC is local exhaust ventilation that captures contaminants at the point of generation.

References

1. ANSI [1993]. ANSI Z136.1-1993, American national standard for safe use of lasers. American National Standards Institute, New York, New York.

2. Kokosa, J [1994]. Hazardous chemicals produced by laser materials processing. J. Laser Appl. 6:195-200.

3. Hitchcock T, ed. [1999]. LIA guide to non-beam hazards associated with laser use. Laser Institute of America, Orlando, FL.

4. Busch, H. [1989]. Aerosol formation during cutting of fibre reinforced plastics. J. Aerosol Sci. 20:1473-1476.

5. Doyle DJ, Kokosa JM [1986]. Chemical by-products of laser cutting of kevlar. Polymer Preprints 27:206-207.

6. Kokosa J, Doyle D [1985]. Condensed phase pyrolysates produced by CO_2 laser processing of polymers I: polycyclic aromatic hydrocarbons obtained from polyvinyl chloride. Polym. Preprints 26:255.

7. Kiefer M, Moss CE [1997]. Laser generated air contaminants released during laser cutting of fabrics and polymers. Journal of Laser Applications. 9(1):7-13.

8. Steiner H, Windelberg D, Georgi B [1988]. Aerosol generation during cutting of various materials with plasma, laser and consumable electrode. J. Aerosol Sci. 20:1381-1384.

9. Hietanen M, Honkasalo A, Latitnen H, Lindroos L, Welling I, von Nandelstadh P [1992]. Evaluation of hazards in CO_2 laser welding and related processes. Ann. Occup. Hyg. 36(2):183-188.

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