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SUMMARY

On December 22, 1993, the National Institute for Occupational Safety and Health (NIOSH) received a request to evaluate worker exposure to contaminants and assess the efficiency of welding controls at the Johnson Controls Damper facility in Lexington, Kentucky. The joint union-management request indicated workers had experienced eye and throat irritation during production welding of galvanized metal. Although a previous industrial hygiene evaluation conducted by the Johnson Controls Risk Insurer found worker exposures to be below acceptable limits, the requestors were still concerned and asked NIOSH to conduct the HHE.

On February 23-24, 1994, NIOSH investigators conducted a site visit at the Damper facility. The purpose of this visit was to review manufacturing processes and work practices, conduct environmental monitoring to assess exposure to airborne contaminants, and evaluate the effectiveness of controls. Full-shift and activity-specific personal breathing zone and area air sampling was conducted for welding fume (both gravimetric and element-specific) at the Frame, Performance, and Value damper welding stations. Instantaneous sampling was conducted to assess airborne concentrations of carbon monoxide (CO), nitrogen dioxide (NO_2), and ozone (O_3) during metal inert gas (MIG) welding of galvanized steel. Quantitative evaluations of welding station ventilation systems were conducted to assess the effectiveness of these controls. Surface wipe sampling for zinc, copper, lead, cadmium, and cobalt was conducted to evaluate contamination levels.

Good housekeeping practices were found throughout the facility. However, it was observed that compressed air was used for cleaning work surfaces, a practice that can cause settled dust to become airborne. The facility has an established safety committee program. A respirator is used by one employee although a respiratory protection program has not been established.

The results of the air sampling showed that contaminant levels were below recommended exposure limits (RELs) for the substances monitored. Zinc oxide, manganese, and iron were detected in the welding fume samples. The highest measured concentrations of specific welding fume components were detected on a 143 minute afternoon sample obtained from the Value Line welder. A concentration of 1.71 milligrams per cubic meter (mg/m^3) of zinc oxide was measured on this sample. The NIOSH REL for zinc oxide is 5 mg/m^3 as a full-shift time-weighted average. A concentration of 0.75 mg/m^3 iron oxide, and 0.14 mg/m^3 manganese were also detected on this sample. The NIOSH REL for iron oxide and manganese is 5 mg/m^3 and 1 mg/m^3, respectively. NIOSH also recommends that exposure to welding fumes and gases be controlled to the lowest feasible concentration. No detectable levels of ozone or

nitrogen dioxide were found at the welding stations. Carbon monoxide concentrations of 1-2 parts per million (ppm) were measured at all welding stations. The NIOSH REL for carbon monoxide is 35 ppm as an 8-hour time-weighted average.

Surface sampling detected the presence of various metal residues, predominantly copper and zinc, on all samples collected. There are no standards regarding surface contamination levels. However, removable metal residue was found on surfaces used for food and beverage consumption, indicating additional cleaning is warranted.

The existing ventilation systems used to control welding fume were not being used as efficiently as possible. Canopy hoods used at the Performance and Frame Lines are not a recommended control method, as this type of ventilation system causes generated contaminants to pass through the worker's breathing zone prior to entering the hood. Observations indicated the movable fume extraction hood at the Value Line was not being positioned close enough to the weld spot to ensure efficient contaminant capture.

The ventilation systems used to control welding fumes were not operating or being used efficiently. However, personal air monitoring did not show an inhalation hazard during welding activities for the monitoring period. The measured surface contamination levels did not indicate an unusual housekeeping problem. Food and beverage consumption, however, should be restricted to non-manufacturing areas and additional attention to surface cleaning in the breakroom is warranted. Recommendations are offered with this report to improve the efficiency of the ventilation system, eliminate the use of compressed air and chlorinated cleaning solvents, and establish a respiratory protection program if respirators continue to be used.

KEYWORDS: SIC 3444 (Sheet Metal Work); welding fume, zinc, nitrogen dioxide, ozone, carbon monoxide, surface contamination, eye and throat irritation, galvanized steel, MIG welding.

INTRODUCTION

NIOSH received a joint union-management request on December 26, 1993, to evaluate worker exposure to contaminants generated during production welding of galvanized steel at the Johnson Controls Damper facility in Lexington, Kentucky. The requestors also asked NIOSH to assess the effectiveness of the facility ventilation system to control contaminants.

On February 23-24, 1994, NIOSH conducted a site visit to inspect the facility, review work practices, and collect personal breathing zone and area air samples during the damper manufacturing process. Quantitative assessments of local exhaust systems used to control contaminants were made. Facility safety and health programs were also reviewed.

BACKGROUND

Facility Description

The Johnson Controls Damper facility manufactures custom ventilation dampers from galvanized steel roll stock. The facility employs 35 workers, 26 of which are directly involved in the manufacturing process, with the remainder providing administrative support. The building is a single-story metal shell with a 30,000 square foot manufacturing area separated by a wall from the administrative support group. Ceiling height is approximately 20 feet. The business operates one shift (7:30 - 4:00), five days a week. Approximately 200 - 250 dampers are manufactured on an average day. Employees are represented by the Sheet Metal Workers International Association, Local 433. Johnson Controls has occupied this building, located in an industrial park in Lexington, Kentucky, since 1988. Smoking is not permitted in the manufacturing area. The facility is not air-conditioned; however, there are two roof fans which provide general ventilation. The plant also has a forced makeup air system which distributes air via straight, collapsible ductwork located just below the ceiling along one length of the building. The makeup air is used on an intermittent basis. Comfort fans are located in various areas and are used at employee discretion.

In 1991 management implemented a job rotation system consisting of three work teams with eight workers in each team. The teams rotate between the three process areas every four months. In addition, each team rotates all eight workers through the jobs at each process area.

On January 6, 1994, an industrial hygiene survey was conducted at the Johnson Controls Damper facility by the company's risk insurer. During this survey monitoring was conducted to assess worker exposure to metal fume at the production welding stations. All personal exposures during this evaluation were found to be well below (less than 10%) the applicable exposure limits established by the Occupational Safety and Health Administration (OSHA), and the American Conference of Governmental Industrial Hygienists (ACGIH).

Process Description

There are three (Frame, Value, and Performance) damper production lines at the Johnson Controls facility. After forming, cutting, and stamping the galvanized roll stock, the damper frames are welded. Each production line has a welding station requiring one full-time worker. Each galvanized steel damper frame requires four 2-inch welds (one at each corner of the frame). The weld size remains the same, even if the damper size varies. The welding process is metal inert-gas (MIG), using carbon dioxide as the inert gas shield. Welding parameters are standardized on all three welding lines. Local exhaust controls have been installed at the three production welding stations in the facility. The Value and Performance lines are manual welding stations, while the Frame Weld line uses a programmable automated welder. The Frame Weld and Performance welding stations utilize canopy hoods for control of welding fume. The Performance station is also equipped with a fume extraction welding gun, designed to capture fume at the point of generation. A flexible duct exhaust hood with an articulating arm is used for contaminant control at the Value line. The damper frames, which vary in size, are clamped in fixtures on a table prior to welding. At the Value line, the worker will position the hood opening over the frame assembly prior to welding. Exhaust air from the welding stations is recirculated back into the work environment after passing through an air-cleaning system (Aercology™ Inc. Industrial Precipitator). The air-cleaning system consists of a coarse filter and electrostatic precipitator. After welding, the frames are manually stacked for final assembly and packaging. Management has expressed interest in modifying the process to eliminate welding by using metal fasteners to manufacture the frames. A prototype system has been installed to test this process.

EVALUATION PROCEDURES

The NIOSH investigation consisted of the following elements:

1. A facility inspection to review manufacturing processes and chemicals used. Employee adherance to the use of personal protective equipment and housekeeping practices were also assessed.

2. Personal air monitoring to assess worker exposure to welding fume, and instantaneous area air monitoring for nitrogen dioxide, carbon monoxide, and ozone.

3. Surface monitoring to determine metal dust contamination levels on work surfaces and in the employee break room.

4. An assessment of the local exhaust ventilation systems used to control contaminants at the three production welding stations.

Air Sampling

On February 24, 1994, environmental air monitoring was conducted to assess personal exposures to welding fume, including zinc oxide, during the welding of damper frames. The monitoring was conducted utilizing established analytical protocols (NIOSH analytical methods).[1] Calibrated air sampling pumps were attached to selected workers and connected, via tubing, to sample collection media placed in the employees' breathing zone. Monitoring was conducted throughout the employees' work-shift. After sample collection, the pumps were post-calibrated and the samples submitted to the NIOSH contract laboratory (Data Chem, Salt Lake City, Utah) for analysis. Field blanks were submitted with the samples. Instantaneous air sampling was also conducted for carbon monoxide, nitrogen dioxide, and ozone, which were suspected gaseous contaminants potentially generated during MIG welding. Specific sampling and analytical methods used during this survey were as follows:

Welding Fume

Personal exposure to airborne welding fume was monitored using Gilian HFS 513A sampling pumps. Flow rates of approximately 2 liters per minute (L/m) were used to obtain the samples. All samples were collected with the sampling media positioned inside the worker's welding helmet. The samples were collected on 5 micrometer (µm) poly-vinyl chloride (PVC) filters 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 different metal species.

Nitrogen Dioxide

Sampling for nitrogen dioxide (NO_2) was conducted using direct-reading colorimetric indicator tubes (Dräger NO_2 tube 0.5/c CH30001) 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 this particular sampling method is 10-15%.[2] Samples were collected during the welding of galvanized steel.

Carbon Monoxide

A Metrosonics PM-7700 toxic gas monitor with a carbon monoxide (CO) sensor was used to measure CO during welding activities. The instrument was 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

Ozone (O_3) sampling was conducted using Dräger O_3 colorimetric indicator tubes (O.O5/b 67 33181) and a bellows pump. According to Dräger, the relative standard deviation for this method is 10-15%.[(2)]

Surface Sampling

Wipe samples were collected to determine the extent of metal dust surface contamination at certain work stations and in the employee break room. These samples were collected with Wash & Dri pre-moistened towlettes. 100 square centimeters (cm^2) of surface area, determined with a template, was wiped with each towlette. The samples were collected according to the surface sampling protocol described in the Occupational Safety and Health Administration (OSHA) Industrial Hygiene Technical Manual, and NIOSH method 0700 (Draft), Lead in Surface Wipe Samples.[(3)] After collecting the samples, the towlettes were placed in individually labeled plastic bags and submitted, with blanks, to the NIOSH Contract Laboratory for analysis.

Ventilation

A local exhaust ventilation assessment was conducted for those processes monitored that utilize ventilation for controlling worker exposure to contaminants. A comprehensive characterization of the facility's overall ventilation system was not conducted.

The ventilation assessment consisted of measuring the air velocity at the exhaust hood opening (face velocity). Critical dimensions were measured where necessary (hood size, duct diameters, distance from hood opening to point of contaminant generation). Work practices of employees regarding the use of these systems were observed (e.g., flexible duct placement, damper manipulation).

Air velocity measurements were obtained with a TSI VelociCalc 8360 anemometer. This instrument measures air velocity in feet-per-minute (fpm). For each system evaluated, multiple measurements were obtained and the results averaged to obtain the mean velocity.

EVALUATION CRITERIA

General

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff use established environmental criteria for the assessment of a number of chemical and physical agents. These criteria 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 should be noted, however, that not all workers will be protected from adverse health effects if their exposures are below the applicable limit. A small percentage may experience adverse health effects due to individual susceptibility, pre-existing medical conditions, and/or hypersensitivity (allergy).

Some hazardous substances or physical agents may act in combination with other workplace exposures or the general environment to produce health effects even if the occupational exposures are controlled at the applicable limit. Due to recognition of these factors, and as new information on toxic effects of an agent becomes available, these evaluation criteria may change.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Criteria Documents and recommendations, (2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and (3) the U.S. Department of Labor Occupational Safety and Health Administration (OSHA) standards.[4-6] Often, NIOSH recommendations and ACGIH TLVs may be different than the corresponding OSHA standard. Both NIOSH recommendations and ACGIH TLVs are usually based on more recent information than OSHA standards due to the lengthy process involved with promulgating federal regulations. OSHA standards also may be required to consider the feasibility of controlling exposures in various industries where the hazardous agents are found; the NIOSH recommended exposure limits (RELs), by contrast, are based primarily on concerns relating to the prevention of occupational disease.

Specific

Welding Fume

The composition of welding fume will vary considerably depending on the alloy being welded, the process, and the electrodes used.[5,7] 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.[7] 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.[7] 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.[7] The ACGIH TLV and

OSHA PEL for total welding fume, which applies only to manual metal-arc or oxy-acetylene welding of iron, mild steel or aluminum, is 5 milligrams per cubic meter (mg/m^3) as an 8-hour time-weighted average.[5,6]

The potential health effects and NIOSH RELs for elements of toxicological importance that were detected in the environmental samples are shown in the following table.

Element	NIOSH REL (mg/m^3)	Principle Health Effects[4,8]
Lead	<0.05*	Damage to blood-forming, nervous, urinary and reproductive systems. Symptoms include joint pain, metallic taste, anxiety, colic, tremors
Cadmium	LFC**	pulmonary edema, emphysema, pneumonitis, headache, muscle ache, nausea, vomiting, renal injury
Iron	5	benign pneumoconiosis (siderosis)
Zinc	5 (TWA), 10 (STEL)	metal fume fever (influenza-like illness), dry or irritated throat, metallic taste
Manganese	1 (TWA), 3 (STEL)	Central nervous system effects, manganese pneumonitis, headaches

* = The OSHA PEL is 0.05 mg/m^3. The NIOSH REL (0.1 mg/m_3) is currently under evaluation.

** = LFC = Lowest Feasible Concentration. NIOSH considers cadmium to be a potential human carcinogen and recommends controlling exposure to the LFC.

TWA = Time-weighted average concentration (10 hour)

STEL = Short Term Exposure Limit. A 15-minute TWA exposure that shall not be exceeded at any time.

Zinc

Zinc is a major component in galvanized coatings and may also be present in some paints. Welding of galvanized metal will generate zinc oxide fume. Exposure to zinc fumes can cause metal fume fever, an influenza-like sickness that usually begins several hours after exposure, and may last up to 24 hours.[8-10] Dryness or irritation of the throat, a sweet or metallic taste, dry cough, and chest constriction may be experienced by workers exposed to zinc oxide fume.[8] Only freshly formed (nascent) fume appears to cause metal fume fever, and attacks tend to be more severe on the first day of the workweek.[8]

Carbon Monoxide

CO is a colorless, odorless gas that is a product of incomplete combustion. Engine exhaust, tobacco smoking, inadequately ventilated combustion products from heaters that use hydrocarbon fuel are sources of exposure to CO. CO exposures can 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.[7] Overexposure to CO may cause initial symptoms such as headache, dizziness, drowsiness, and nausea. These symptoms may progress to vomiting, loss of consciousness, or collapse if high exposures are encountered.[11] The NIOSH REL for CO is 35 parts per million (ppm) as an 8 hour time-weighted average (TWA). NIOSH also recommends a ceiling level of 200 ppm for CO.[4]

Nitrogen Dioxide

Nitrogen Dioxide (NO_2) is a reddish/dark-brown gas, liquefying at 21°C, with a pungent, acrid odor. NO_2 is a respiratory irritant and can cause pulmonary edema.[8] Severe breathing difficulties attributable to exposure to NO_2 are usually delayed in onset and may cause death.[12] The NIOSH REL for NO_2 is 1 ppm as a 15 minute short-term excursion limit.[4] NO_2 has been detected as a by-product of oxyacetylene welding, although in lower concentrations than that found in other welding techniques (e.g., shielded arc welding).[7] Most reported cases of severe illness due to NO_2 have been due from accidental exposures to explosion or combustion of nitroexplosives, nitric acid, arc or gas welding (particularly in confined spaces), or entry into unvented agricultural silos.[8]

Ozone

Ozone (O_3) is an unstable short-lived gas that can be produced from atmospheric oxygen in the presence of ultraviolet radiation, welding arcs, and around high voltage electrical equipment. Gas metal arc welding (such as MIG welding) has been found to produce the highest ozone concentrations, especially when aluminum is used as a base metal.[7]

Exposure to ozone can cause irritation of the mucous membranes and lungs. Symptoms of exposure can include nose and throat irritation, cough, dyspnea, and chest pain.[8] The NIOSH REL for ozone is 0.1 ppm as a ceiling limit (should never be exceeded).[4]

Surface Sampling

Standards defining "acceptable" levels of surface contamination have not been established. However, wipe samples can provide information regarding the effectiveness of housekeeping practices, the potential for exposure to contaminants from other exposure routes (e.g., surface contamination on a table that is also used for food consumption), the potential for contamination of worker clothing and subsequent transport of the contaminant, and the potential for non-process related activities to generate airborne contaminants (e.g. custodial sweeping).

Ventilation

Local exhaust ventilation (LEV) is commonly used to control contaminants at the point of generation to reduce the potential for employee exposure. Ventilation assessments, in conjunction with exposure monitoring results, help determine the adequacy of controls at a workstation. This information also assists with deciding if additional controls, or modification of existing controls, is warranted. The principle design parameter for LEV systems is capture velocity. Capture velocity is the velocity necessary to overcome opposing air currents and capture contaminated air by causing it to flow into the exhaust hood. Recommended capture velocities will vary depending on contaminant toxicity and volatility, the manner in which the material is used (e.g., heated, agitated), and room conditions (e.g., air currents). Criteria commonly used for evaluating LEV systems is from the ACGIH publication, Industrial Ventilation: A Manual of Recommended Practice.[13]

RESULTS AND DISCUSSION

Workplace Observations/Industrial Hygiene Programs

Housekeeping practices appeared to be good throughout the facility. Work tables were clean and aisles were clear. However, it was observed that compressed air is used for cleaning work areas. Using compressed air to clean work surfaces can cause settled dust (e.g., welding fume) to become reentrained into the workroom air, possibly creating or exacerbating an inhalation hazard.

Although respirators are not required for any tasks at the Johnson Controls Damper facility, a disposable dust-fume respirator (3M 9920, TC-21C-202) has been provided to one employee who requested it. A formal respiratory protection program has not been developed, and no system to ensure workers who wear respirators are trained, medically cleared, and fit-tested has been established. Hearing protection devices are also available for employees to use and are required when the aluminum saw is in use. This saw was not operational during the NIOSH site visit. Hearing protection is not required for the general work area.

A commercially available solvent-based aerosol cleaner (Zep 45®) that contains 40% - 50% 1,1,1-trichloroethane (a volatile material also known as methyl chloroform) is used to clean fixtures and surfaces in the welding areas. Welding, open flame cutting of metal, or very hot metal in the presence of a volatile chlorinated compound can potentially liberate phosgene (carbonyl chloride), a combustion product of the chlorinated compound.[8,10] Phosgene is a colorless gas that is a potent respiratory irritant. Immediate irritation of the throat and eyes can occur at concentrations as low as 3 to 4 ppm; in some cases the onset of symptoms may be delayed up to 72 hours.[8]

A breakroom separate from the manufacturing area is available for employees to use. However, some food and beverage consumption was occurring at work stations. Some of these stations are potentially contaminated with toxic materials such as metal dust.

Air Sampling

The results of the personal breathing zone air sampling are shown in Table 1. All sample results showed that exposure to the contaminants sampled were below the applicable NIOSH REL for the sampling period. Manufacturing activity, however, was slower than normal during the monitoring period, as only about 150 frames were scheduled to be welded (a normal workday entails 200-250 frames). Not unexpectedly, worker exposure to zinc oxide fume was greater than that of the other contaminants (iron, manganese) detected. The highest zinc oxide concentration detected was 1.71 mg/m^3 on an afternoon sample obtained from the Value Line welder. The gravimetric results indicate overall exposure to total welding fume and other particulate that may have been present. As previously noted, NIOSH considers welding fume to be a potential occupational carcinogen, and recommends that exposures be controlled to the lowest feasible concentration.

Exposure levels at the Frame Line were lower than those detected at the other two stations. This was not unexpected, as the worker at this automated station stays outside the welding area and has less direct contact with the welding. One unusual finding was that the measured exposure levels at the Value Line were higher than those at the Performance Line, although only half as many frames were welded at the Value Line. Welding fume at the Performance Line is controlled with a ventilated canopy hood and a welding extraction gun. Ventilation at the Value Line consists of a movable fume extraction hood. Both of these systems are described in the *Ventilation Assessment* section of this report. Although only a very limited amount of data was collected, this finding may be due to the effectiveness of controls, work practices, or both. It was noted that at the Value Line, the movable fume extraction hood was typically placed in one location as each frame was welded. One observation was that with the short welding times for each frame corner, the previous weld was still visibly generating a contaminant plume as the worker welded another portion of the frame.

The area sampling results are shown in Table 2. All sample results were well below the respective NIOSH, OSHA, and ACGIH limits. Although no element-specific results are available from the sample obtained at the outlet of the Aercology™ air cleaning unit at the Performance Line (analytical problem), the gravimetric results show a very low concentration of particulate (0.09 mg/m^3).

No detectable concentrations of ozone or nitrogen dioxide were found at the Value or Performance Line stations. All measurements were obtained during welding. Carbon monoxide levels averaged 1-2 ppm at both the Value and Performance Line welding stations. As previously noted, the NIOSH REL for carbon monoxide is 35 ppm as an 8-hour TWA.

Surface Sampling

The results of the surface sampling (Table 3) indicate the presence of various metal residues on the surfaces sampled. With the exception of zinc (36 - 78 micrograms per 100 square centimeter surface area [µg/100 cm^2]) only very low levels (or below detectable limits) of metals were detected in the breakroom. Zinc and copper were the predominant elements detected; only trace or undectable levels of lead, cadmium, and cobalt were found. The highest contamination levels were found in the manufacturing area, including surfaces where food and beverage consumption occurs (work station table, drinking fountain surface). Although standards regarding surface contamination have not been established, and exposure can not be estimated from these results, the levels detected suggest that additional attention to surface cleaning in the breakroom would be prudent, and that eating and drinking should be confined to the breakroom to reduce the potential for cross-contamination and potential ingestion. The drinking fountain in the manufacturing area should be routinely wiped down. The practice of using compressed air for cleaning work surfaces could also increase the potential for generating airborne contaminants.

Ventilation Assessment

Performance Line

The Performance Welding Station was ventilated by a canopy hood over the welding table. Welding curtains, approximately 1.5 feet in length, were attached to the perimeter of the hood, ending 3 feet above the welding table. Exhaust air passes through an 8-inch round diameter duct and the Aercology™ air cleaner prior to discharge back into the plant next to the Performance Welding Area. A Hobart™ fume extraction gun with an exhaust hose 1.5 inches in diameter was also used in the Performance Welding Area. The extraction gun captures welding fumes at the point of generation and exhausts directly below the canopy hood's exhaust inlet. Thus, air captured by the fume extraction gun is also recirculated through the Aercology™ system. The welding area was partially enclosed from the plant by welding curtains.

Value Line

The local exhaust ventilation system for the Value Welding Station consisted of a movable, Nederman™ fume extraction hood. The hood had an oval-shaped opening, angled at 28 degrees from the horizontal, and was attached to a 7-inch diameter, flexible duct with an articulating arm. This allowed the hood to be positioned directly at the weld spot. Exhaust air from this unit is also recirculated through an Aercology™ filter system and discharged back into the plant. According to management, the Nederman™ system was installed in response to complaints regarding the canopy style ventilation system. Workers had complained that the fume extraction gun was bulky and heavy, and that the canopy hood was not working effectively to keep air contaminants out of their breathing zone.

Frame Line

The Frame Welding Station uses an automated programmable welder for large damper frames. A canopy hood was positioned over the welding table, and welding curtains surrounded the welding area. Exhaust air passes through a circular opening at the top of the hood and recirculates through an Aercology™ filtration system. The welder was responsible for positioning the frame on the welding table, and then entering the welding parameters at the computerized control panel which was located outside the welding area. Occasionally, the worker would need to manually perform spot welding. The automated welding system has been in use for approximately 5 years. An unused exhaust hose (1.5 inches in diameter) was observed hanging within the welding area. The air captured by this hose was exhausted to just below the canopy hood's exhaust inlet, so that it was also recirculated through the Aercology™ system.

Table 4 shows the results of ventilation measurements taken at the three welding stations. In general, the canopy hoods are not effective at removing welding fume from the worker's breathing zone. Canopy hoods should not be used if the material is toxic or if the worker must bend over the process, as is the case during manual welding at the Performance and Frame Lines.[13] The position of the canopy hood to the work results in the welding fumes passing directly into the welder's breathing zone before being exhausted.

The effectiveness of local exhaust ventilation is dependent in part on the proximity of the exhaust hood to the point of welding. As a general criteria, velocities necessary to capture and convey welding fumes into the hood should range between 100-200 fpm.[13,14] As shown in Table 5, the fume extraction hood used at the Value Welding Station is effective only when the hood is positioned within 6 inches of the welding area. At distances of 9 and 12 inches, the capture velocity decreases significantly. Capture velocities for the Performance Line canopy hood were almost negligible. In addition to capture velocity, a minimum duct velocity of 2000-2500 fpm for handling welding fumes is recommended.[13] Within the duct of the Value Line's fume extraction hood, the measured velocity was approximately 1650 fpm. The velocity within the Performance Line's fume extraction gun hose measured about 2600 fpm.

Table 6 shows that for the Performance and Frame Lines, the air volumes into the canopy hoods are much less than the air volumes exhausting out of the systems. This may be due to cracks or tears in the ductwork which can reduce the effectiveness of the ventilation systems. No measurements were made at the exhaust outlet of the Value Line.

Personal Protective Equipment

Speedglas™ welding helmets were used during welding for eye protection against UV radiation. These helmets automatically darken when the welder strikes an arc. The advantage of this is that the welder does not need to continually raise and lower the helmet. However, it was noticed at this plant that welders still raised and lowered the Speedglas™ helmet.

CONCLUSIONS

The personal air monitoring did not show an inhalation hazard for the employees sampled during the monitoring period. These results are consistent with those found in a previous industrial hygiene survey conducted by the company's loss control insurer. Although the measured contamination concentrations were below recommended levels for the specific compounds monitored, the ventilation systems used to control welding fume were not operating, or being used, efficiently. Ventilation measurements show that these engineering controls were not as effective as they could be in removing welding fumes from the worker's breathing zone. Improvements in the operation and use of the ventilation systems will help further reduce potential exposures to contaminants generated during welding. The area monitoring also indicated overall contaminant concentrations were below recommended limits for welding fume, nitrogen dioxide, ozone, and carbon monoxide.

Although there are no standards, the measured surface contamination levels did not indicate an unusual housekeeping problem. Food and beverage consumption, however, should be restricted to the non-manufacturing areas, and additional attention to surface cleaning in the breakroom is warranted.

Management attention to safety and health appears to be at a high level. A safety committee mechanism has been implemented, and efforts to improve safety and health were noted (e.g., welding ventilation modifications, collection of material safety data sheets, etc.). Efforts to replace the welding process by using mechanical fasteners should continue to be pursued, as this would eliminate exposure to welding fume.

RECOMMENDATIONS

1. The canopy hoods should be replaced with engineering controls that are more effective at removing air contaminants from the worker's breathing zone. The ACGIH Ventilation Manual should be used to obtain descriptions and specifications for welding fume ventilation systems.

2. To maximize efficiency, exhaust volumes need to be increased by using larger fans and improving the integrity of the ductwork. NIOSH researchers in the Engineering Control Technology Branch are currently studying engineering controls for reducing worker exposure to welding fumes. Upon completion of this study, additional technical recommendations for controlling welding fumes will be provided to Johnson Controls.

3. For the flexible duct system to be effective, the operator (welder) has to be conscientious and ensure the system is used properly. This entails positioning the hood as close as possible to the weld spot, and not moving the hood until the weld plume has been exhausted. Workers should be trained on how to properly use this Nederman™ system.

4. Cease using the Zep-45 aerosol cleaner at the welding stations. Do not use any chlorinated solvents in welding environments.

5. If the use of respirators is continued, even if the use is voluntary, a respiratory protection program (RPP) should be implemented. The elements of a comprehensive RPP include a written program, exposure monitoring, proper respirator selection, user training and fit-testing, medical clearance of users, and periodic program reviews. Federal and State Occupational Safety and Health regulations contain specific requirements for employee respirator programs.

6. Eliminate the use of compressed air for cleaning work surfaces to reduce the potential for generating airborne contaminants. One alternative cleaning method is to use a vacuum with an efficient particulate filter. Note that the use of comfort fans can potentially interfere with local exhaust systems, and these units should not be placed so they blow directly onto the welding area.

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1. Johnson Controls Damper Facility
2. Sheet Metal Worker International Association, Local 433
3. Department of Labor/OSHA Region IV.

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

Table 1
Personal Sampling Results: Elements
Johnson Controls Damper Facility, Lexington, Kentucky
February 24, 1994
HETA 94-0103

Task Monitored	Sample Number	Sample Time (min)	Contaminants Detected	Concentration (mg/m^3)	TWA (mg/m^3)
Welding Galvanized Steel, Value Damper Line	5050	09:01-11:59 (178) 30 frames welded	Iron Manganese Zinc Oxide	0.50 0.09 1.31	0.61 0.11 1.49
			Gravimetric[1]	2.3	2.7
	5064	12:40-15:03 (143)	Iron Manganese Zinc Oxide	0.75 0.14 1.71	
			Gravimetric[1]	3.1	
Welding Galvanized Steel, Performance Damper Line	5068	08:56-11:58 (185) 68 frames welded	Iron Manganese Zinc Oxide	0.30 0.05 0.85	0.26 0.04 0.78
			Gravimetric[1]	1.45	1.28
	5052	12:37-13:35 (58) 20 frames welded	Iron Manganese Zinc Oxide	0.15 0.03 0.55	
			Gravimetric[1]	0.73	
Welding Galvanized Steel, Frame Damper Line	5058	07:47-11:57 12:34-13:59 (335) 22 frames welded	Iron Manganese Zinc Oxide	0.08 0.02 0.20	0.08 0.02 0.20
			Gravimetric	0.46	0.46

NOTES:

1. Gravimetric = Total weight of contaminants detected on filter
2. mg/m^3 = milligrams of contaminant per cubic meter of air
3. TWA = time-weighted average concentration computed as follows:

$$TWA = \frac{(C_1)(T_1) + (C_2)(T_2) + \ldots (C_n)(T_n)}{T_1 + T_2 + \ldots T_n}$$

Where: C = Contaminant concentration
T = Corresponding sampling time

4. All samples were field blank corrected

Table 2
Area Sampling Results: Elements
Johnson Controls Damper Facility, Lexington, Kentucky
February 24, 1994
HETA 94-0103

Monitoring Location	Sample Number	Sample Time (min)	Contaminants Detected	Concentration (mg/m^3)
Outlet of Aercology™ Unit at Performance Welding Line	5056	07:58-14:36 (398)	No Results Available	
			Gravimetric[1]	0.09
Damper Assembly between Performance and Frame Line	5063	08:01-14:28 (387)	Iron Manganese Zinc Oxide	0.01 0.002 0.12
			Gravimetric[1]	0.11
Crankarm Assembly station, 15 feet from Frame and Value Line	5051	09:07-14:34 (327)	Iron Manganese Zinc Oxide	0.06 0.006 0.14
			Gravimetric	0.23

NOTES:

1. Gravimetric = Total weight of contaminants detected on filter
2. mg/m^3 = milligrams of contaminant per cubic meter of air
3. All samples were field blank corrected
4. No element-specific results are available from sample #5056 (analytical problem)

Table 3
Surface Sampling Results: Metals
Johnson Controls Damper Facility, Lexington, Kentucky
February 24, 1994
HETA 94-0103

Sample Number	Location	Contaminant Detected	Results (µg/100cm^2)
WS-1	Breakroom counter between coffee pot and the microwave oven	Zinc Copper Lead Cadmium Cobalt	78 0.07 ND ND ND
WS-2	Breakroom short counter between two microwave ovens	Zinc Copper Lead Cadmium Cobalt	36 0.27 ND (0.05) ND
WS-3	Breakroom lunch table adjacent soft drink vending machines	Zinc Copper Lead Cadmium Cobalt	22 0.4 (0.2) ND (0.05)
WS-4	Drinking fountain surface around nozzle, south wall of facility	Zinc Copper Lead Cadmium Cobalt	528 54.65 2.5 0.14 0.57
WS-5	Assembly work station table adjacent inner power scraper	Zinc Copper Lead Cadmium Cobalt	228 1.35 0.79 (0.08) ND
WS-6	Desk in shop office - in front of Keyboard	Zinc Copper Lead Cadmium Cobalt	88 0.42 (0.5) 0.17 ND

µg/100 cm^2 = micrograms of contaminant per 100 square centimeters surface area

() = Values in parentheses indicate the detected concentration was between the analytical limit of detection and the limit of quantification

ND = None detected (below analytical limit of detection)

Standards regarding surface contamination for the metals detected have not been established

Table 4.
Local Exhaust Ventilation Measurements
Johnson Controls Damper Facility, Lexington, Kentucky
February 24, 1994
HETA 94-0103

LOCATION	AREA (ft^2)	AVERAGE FACE VELOCITY (fpm)	EXHAUST VOLUME (cfm)
Performance - canopy hood exhaust inlet	0.35	1100	380
Performance - extraction gun exhaust inlet	0.01	2600	30
Performance - extraction gun exhaust outlet	0.01	1110	10
Performance - Aercology exhaust outlet	3.54	280	1000
Value - extraction hood inlet	0.65	690	450
Value - within flexible duct	0.27	1650	440
Frame - canopy hood face*	17	60	1040
Frame - unused exhaust hose inlet	0.01	1700	20
Frame - Aercology exhaust outlet	1.77	900	1600

* Measurements were taken at the rectangular canopy face (exhaust opening in the hood was inaccessible).

fpm = feet per minute

cfm = cubic feet per minute

Table 5.
Capture Velocities
Johnson Controls Damper Facility, Lexington, Kentucky
February 24, 1994
HETA 94-0103

LOCATION	DISTANCE FROM HOOD (in)	CAPTURE VELOCITY (fpm)
Performance - canopy hood**	18	10
Value - extraction hood	6	180
Value - extraction hood	9	70
Value - extraction hood	12	50

** Measurements were taken at the end of the welding curtains which hung from the hood. The curtains ended three feet above the welding table. Capture velocities taken at the level of the table were negligible.

Table 6
Air Volumes
Johnson Controls Damper Facility, Lexington, Kentucky
February 24, 1994
HETA 94-0103

LINE	AIR VOLUME INTO SYSTEM	AIR VOLUME OUT OF SYSTEM	UNACCOUNTABLE AIR VOLUME
PERFORMANCE	440 cfm	1000 cfm	+600 cfm
VALUE	450 cfm	-	-
FRAME	1060 cfm	1600 cfm	+540 cfm