In-Depth Survey Report:

Control Technology Assessment for the Welding Operations

at

United Air Specialists, Inc. Cincinnati, Ohio

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SUMMARY

The Engineering Control Technology Branch of the National Institute for Occupational Safety and Health is currently conducting a study of welding operations and workers' exposures to welding fumes The goal of this study is to identify, observe, and evaluate engineering control measures which may reduce the amount of fume a worker is exposed to during welding At the conclusion of this study, information on effective control technology will be disseminated to the welding community This report summarizes the results of sampling surveys of the welding operations at an air-cleaning equipment manufacturer in Cincinnati, Ohio The plant employs about 30 welders, and operates on a 4-day, 10-hour/day work schedule with optional overtime Workers in the metal fabrication area mainly weld galvanized and cold-rolled carbon steel (mild steel) Several portable local exhaust ventilation units are available in the metal fab area, however, they are used infrequently The only time a unit was observed to be in use was during a cutting operation Workers in the cab fabrication area mainly weld stainless and cold-rolled carbon steel Each welding booth in the cab fab area is equipped with a canopy hood over the worktable Each hood is connected to a SMOGHOG® air-cleaning unit, and the filtered air is exhausted back into the workplace

Air sampling measurements, collected on welders, a cutter, and a grinder, showed there to be no exposures in excess of the OSHA PEL for either total particulate (welding fume) or for any of the sampled fume constituents Overall, the cutting operation produced air contaminant levels higher than most of the other sampled tasks, the total particulate level on the cutter was just under the ACGIH TLV of 5 mg/m^3 Evidently, the use of a local exhaust system during cutting was not able to completely control the worker's exposures to dust and fume The grinding operation also resulted in several higher exposure levels when compared to the welding tasks The grinding exposures should decrease once the ventilation system currently being installed is operable Welders in the metal fab area averaged total particulate exposures more than twice that of the cab fab welders who used the canopy hoods to control the welding fume emissions Measured exposures for the metal fab welders also averaged between two and eight times higher than cab fab welders for various fume constituents, including chromium, iron, copper, manganese, and zinc In addition, one metal fab welder exceeded the ACGIH TLV for manganese and another exceeded the NIOSH REL for nickel

Although the canopy hoods appeared to effectively control the welding fume exposures, it is likely that short-term exposure peaks occurred which were not identified by the study's integrated sampling techniques In general, canopy hoods are not a recommended method for controlling worker exposures when the material is toxic or when the task requires the worker to bend over the process The main drawback of this type of ventilation system is that the position of the canopy hood to the part being welded on may result in the welding fume passing directly into the welder's breathing zone before being exhausted It is imperative that management stresses to the welders the importance of keeping their heads out of the welding plume at all times

INTRODUCTION

Over the past twenty years, the National Institute for Occupational Safety and Health (NIOSH) has recognized the importance of preventing potential health hazards associated with fumes and gases generated during welding operations (see Appendix A), however, no comprehensive study of control technology for welding operations has been conducted since the late seventies As such, the Engineering Control Technology Branch (ECTB) of NIOSH is currently conducting a study to evaluate the effectiveness of engineering control measures in reducing welding fume exposures This welding assessment study was initiated for several reasons First, even with advances in control technology, welders continue to be exposed to hazardous welding fumes and gases [1] Second, the continual development and implementation of new welding processes, techniques, and *materials can result in unidentified and uncontrolled health hazards* Third, many welding operations are small shops that may not have access to current technology for the control of welding emissions, this project responds to the NIOSH small business initiative which identifies welding shops as one of the top ten hazardous small businesses, in terms of occupational health risks [2] Finally, as it is likely that welding will be a high priority for OSHA over the next few years,[3] industry will need timely research on engineering technology for the control of welding fumes and gases

Many shops use a combination of ventilation and respiratory protection equipment to try and control the amount of fumes (and gases) the welder is exposed to during welding operations If the ventilation system does not adequately control the fumes, the welder often relies heavily on the respirator for protection against potential health hazards Ideally, respiratory protection should be used only as a last resort against welding fumes, and only when an excellent respirator protection program is in place It is unclear whether strong respiratory protection programs are common in welding shops Therefore, the goals of this assessment study are to identify effective ventilation systems, or other engineering control measures, that will protect the welder's health, and to disseminate this information to the welding community To determine which controls are most effective, various systems and processes must be evaluated in the field In this particular study, fume extraction guns were evaluated for their ability to exhaust welding fumes and gases away from the worker's breathing zone, at the point of generation

PLANT AND PROCESS DESCRIPTION

This plant manufactures air-cleaning equipment, both the electrostatic precipator and filter cartridge type Two of the products manufactured here include the SMOGHOG® and the DUSTHOG® which are sold to industrial and commercial customers The company has been in business for twenty years There are approximately 30 welders, most of whom work from 6 50 a m to 5 20 p m , with a 30-minute lunch break, 4 days a week Friday and Saturday are optional overtime days Four welders work at night Welding operations are performed in two main areas of the plant, known as the cab fabrication and metal fabrication areas All of the welding observed during the surveys consisted of the solid-wire gas metal arc welding (GMAW) technique During GMAW, a solid-core wire consumable is continuously fed through a welding gun while a shielding gas is supplied at the gun tip to prevent oxidation of the base metal Welders wear half-face North respirators during galvanized welding

In the metal fab area, welders primarily work on galvanized and mild steel The company would like to replace the galvanized steel with aluminized steel in the future to help protect the health of their welders This transition was in process at the time of the studies Ventilation equipment for the metal fab welders includes one stationary local exhaust unit and several portable local exhaust units, each with a movable arm and hood The units are each attached to individual SMOGHOG® units There are more welders than ventilated units in the metal fab area Plant management indicated they plan to move the metal fab welders to another area of the plant and that more fixed ventilated units may be installed for them at that time

In the cab fab area, welders work primarily on mild and stainless steels inside eight welding stations which are separated from each other by welding curtains Each station is ventilated by a large canopy hood situated over the welding table The welding tables are approximately 5 ft wide and 6 ft long The canopy hood is slightly larger than the table, at approximately 6½ ft wide and 7 ft long, with a round, 26-in diameter exhaust intake in the middle of the hood Each canopy hood is ducted to a SMOGHOG® air-cleaning unit located above the workstation on an overhead platform There is one air-cleaning unit for each canopy hood The exhaust filters on the air-cleaning unit are approximately 12 in by 16 in in frames that are 18 in by 20 in The filters on the SMOGHOG® units are changed every month, and are also subjected to semi-annual and annual checks The canopy hood system has been in use for about ten years

HAZARDS AND EVALUATION CRITERIA

The effect of welding fumes and gases on a welder's health can vary depending on such factors as the length and intensity of the exposure, and the specific toxic metals involved Welding processes involving stainless steel, cadmium- or lead-coated steel, or metals such as nickel, chrome, zinc, and copper are particularly hazardous as the fumes produced are considerably more toxic than those encountered when welding mild steel Mild steel consists mainly of iron, carbon, and small amounts of manganese, phosphorous, sulfur, and silicon, while stainless steel contains mainly iron, chromium, nickel, titanium, and manganese [4] The NIOSH criteria document identifies arsenic, beryllium, cadmium, chromium (VI), and nickel as potential human carcinogens that may be present in welding fumes Epidemiological studies and case reports of workers exposed to welding emissions have shown an excessive incidence of acute and chronic respiratory diseases Welder respiratory ailments can include occupational asthma, siderosis, emphysema, chronic bronchitis, fibrosis of the lung, and lung cancer Epidemiological evidence indicates that welders generally have a 40% increase in relative risk of developing lung cancer as a result of their work [4] Other cancers associated with welding include leukemia, cancer of the stomach, brain, nasal sinus, and pancreas Cadmium poisoning can affect the respiratory system and damage the liver and kidneys A common reaction to overexposure to metal fumes, particularly zinc oxide fumes, is metal fume fever, with symptoms resembling the flu Other health hazards during welding can include vision problems and dermatitis arising from ultraviolet radiation exposures, burns, and musculoskeletal stress from awkward work positions[4] See Appendix B for additional information on potential health hazards from welding

As a guide when evaluating hazards posed by workplace exposures such as those from welding, NIOSH field staff employ environmental evaluation criteria 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 if their exposures are maintained below these levels A small percentage may experience adverse health effects due to individual susceptibility, a preexisting 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 evaluation criteria These combined effects are often not considered in the evaluation criteria Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available

The primary sources of environmental evaluation criteria in the United States that can be used for the workplace are (1) NIOSH Recommended Exposure Limits (RELs), (2) the American Conference of Governmental Industrial Hygienists's (ACGIH) Threshold Limit Values (TLVs), and (3) the U S Department of Labor (OSHA) Permissible Exposure Limits (PELs) The OSHA PELs are required to consider the feasibility of controlling exposures in various industries where the agents are used, the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational disease ACGIH Threshold Limit Values (TLVs) refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects ACGIH states that the TLVs are guidelines The ACGIH is a private, professional society It should be noted that industry is legally required to meet only those levels specified by OSHA PELs

In 1989, the OSHA PEL for total welding fume was set at 5 mg/m^3 (5000 µg/m^3) as an 8-hour time-weighted average (TWA), however, this limit was vacated and currently is not enforceable Since 1989, OSHA has not reestablished a PEL for total welding fume, however, individual PELs have been set for the various constituents which can be found in welding fumes (see Appendix C)[5] OSHA has also set a PEL for total particulates not otherwise regulated (PNOR) at 15 mg/m^3 as an 8-hour time-weighted average (TWA) A TWA exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday Some substances have recommended short-term exposure limits (STEL) or ceiling values that are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures

The ACGIH has set a TLV-TWA for welding fumes-total particulate (NOC) at 5 mg/m^3 The ACGIH recommends 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 [6]

NIOSH indicates 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 suggests that the exposure limits set for each welding fume constituent should be met (see Appendix C) However, it was noted in the NIOSH criteria document that even when welding fume constituents were below the PELs, there was still excesses in morbidity and mortality among welders As such, NIOSH recommends that welding emissions should be controlled with current exposure limits considered to be upper limits [4]

METHODOLOGY

Conventional industrial hygiene air sampling was performed on the welders during the study Samples were collected on closed-faced, 37-millimeter (mm), polyvinyl chloride (PVC) filters, which were analyzed gravimetrically to determine the total welding fume concentration The analysis was conducted according to Method 0500 in the NIOSH Manual of Analytical Methods, 4th edition A known volume of air is drawn through the preweighed PVC filter The weight gain of the filter is then used to compute the milligrams of particulate per cubic meter of air The limit of detection (LOD), or lowest measurable amount, for total particulate for this study was 0 02 mg An element specific analysis was also performed on the filter samples, according to NIOSH Method 7300, to differentiate and quantify the different metal species in the welding fume The LOD and limit of quantitation (LOQ), the level at which the laboratory can confidently report precise results, for each element analyzed are given in Appendix D

Personal samples were collected in the worker's breathing zone using portable pumps set at a flow rate of 3 liters per minute (lpm) Filter cassettes were placed on the lapel of the welders' overalls just outside of their welding helmets, since the purpose of the study was to evaluate the control effectiveness of the ventilation, not the personal protective gear The samples collected represent only the workers' exposure while being observed, they are not full-shift samples It is likely, however, that the exposure data collected during the half day sampling periods is representative of full-shift data

The plant layout is depicted in Figure 1 Area samples were collected using portable sampling pumps set at a rate of 3 lpm The outside area sample was placed on a picnic table directly outside the door to the plant and the office sample was placed on a shelf in the hallway outside the nurse's station The metal fab area sample was located on a storage shelf about 10 ft away from any of the welders The cab fab area sample was placed on a break table in between two of the welding booths

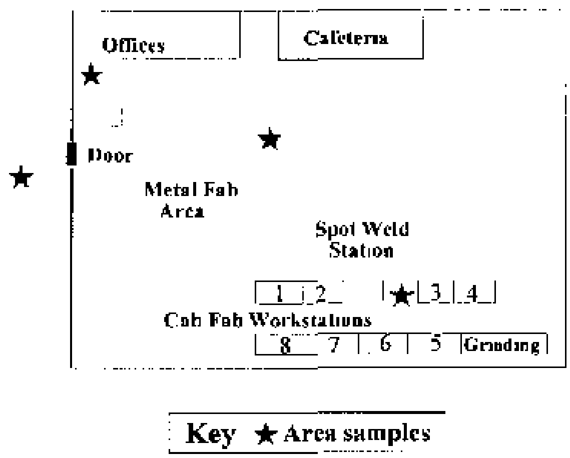

Figure 1 Plant Layout Diagram

The ventilation systems were assessed by measuring capture and face velocities with a hot wire anemometer This instrument measures air velocity in feet-per-minute (fpm) Capture velocities are measured to determine the ability of the system to remove welding fumes at certain distances away from the fume generation source The capture velocity is the velocity necessary to overcome opposing air currents and cause the welding fume to be exhausted Face velocities were measured to determine the systems air volumes Work methods regarding welding techniques and the use of the ventilation systems were also observed In addition, airflow patterns around the workers during welding were observed using smoke tubes and aspirators From this, an understanding of how air contaminants are transported into the worker's breathing zone can be developed

RESULTS AND DISCUSSION

Although the focus of this study was on welding fume exposures, plant management was also interested in determining exposure levels when grinding at the grinding station near the cab fab area As such, sampling data for the grinding operations were also collected and analyzed The grinding station was being redesigned to provide ventilation to that area During the first sampling survey, the ventilation system had not yet been incorporated into the grinding area During the second sampling survey, the grinding station was not in use as the ventilation system was being installed at that time

Also, the type of metal being welded on is an important parameter since different base metals can produce different types of fumes and dusts In the metal fab area, Workers A, B, F, and L welded on mild steel (otherwise known as low-carbon steel) and Worker D welded on aluminized and stainless steel Worker A also welded on aluminized and galvanized steel In the cab fab area, Workers H, I, K, and M welded on mild steel and Workers C and F welded on stainless steel Cutting and grinding samples were collected on Workers E and G, respectively, during mild steel welding, the spot welding sample on Worker J was collected during both galvanized and mild steel welding tasks

GRAVIMETRIC ANALYSIS (TOTAL WELDING FUME)

The results of the personal and sampling data for total welding fume concentrations can be found in Appendix E None of the samples exceeded the OSHA PEL or ACGIH TLV for welding fume, however, two samples did approach the TLV of 5 mg/m^3 These samples were collected during a cutting operation (Worker E) and a welding operation (Worker L), both performed in the metal fabrication area A local exhaust ventilation unit was used during the cutting operation, while no controls were used for the welding operation other than a man-cooling fan

The personal welding fume levels were analyzed to determine how the ventilation systems affected the average exposure to the workers (Table 1) All the welders in the cab fab area worked under canopy hoods, none of the metal fab welders used ventilation The grinder and the spot welder also did not use ventilation controls The data showed that the metal fab welders averaged more than twice the exposure levels of the cab fab welders To ensure the differences in base metals were not affecting these results, the welding data was then analyzed for only the mild steel welders Again, the metal fab welding exposures were found to be about twice that of the cab fab exposures Differences in stainless steel welding exposure data between the metal fab and cab fab welders were not analyzed due to there only being one data point for metal fab (0 96 mg/m^3) and 2 data points for cab fab (average of 0 025 mg/m^3)

Interestingly, the ventilated cutting and nonventilated grinding tasks resulted in even higher total particulate exposures than the welding operations The spot welding operation did not appear to generate much fume or dust during the surveys It is possible that the spot welder's proximity to the cab fab area may have resulted in higher exposures to this worker

Table 1 Average Personal Total Particulate Concentrations by Sample Location

Sample Location	Vent On/Off	N	Average (mg/m^3)	Std Dev (mg/m^3)
Cab Fab Welding	On	6	0 48	0 35
Metal Fab Welding	Off	9	1 07	1 34
Spot Welding	Off	1	0 36	0
Grinding	Off	1	1 77	0
Cutting	On	1	4 84	0

The area welding fume levels were analyzed to determine differences in background air contaminant levels (Table 2) The background level in both plant areas appeared to be roughly the same, while the office and outside levels were negligible

Table 2 Average Area Total Particulate Concentrations by Sample Location

Sample Location	N	Average (mg/m^3)	Std Dev (mg/m^3)
Cab Fab Area	2	0 09	0 06
Metal Fab Area	2	0 12	0 01
Outside	2	0 01	0 01
Office	2	ND	ND

ND = non-detected

ELEMENTAL ANALYSIS

The results of the elemental analysis are shown in Appendix F Two of the welders in the metal fab area were found to have overexposures Worker L was in excess of the ACGIH TLV for manganese which is set at 200 $\mu g/m^3$ and Worker D was in excess of the NIOSH REL for nickel which is set at 15 $\mu g/m^3$ Neither of these welders used ventilation during the sampling, although, as mentioned previously, Worker L had a man-cooling fan operating adjacent to his workstation Worker D was noted to perform some grinding as well as welding during the sampling period

In order to compare the effect of ventilation on the welding fume component exposure levels, the sampling data were analyzed by task location Personal sampling results are shown in Table 3 and area sampling results are shown in Table 4 Elements listed in the tables are those which were most likely to be present in the fume, or which were considered to be the most hazardous to the workers

Even with the use of a local exhaust ventilation unit, the cutting task presented the highest exposures for most of the sampled elements This is in agreement with the findings of the total particulate sampling data Grinding operations which were not ventilated were also fairly high compared to the average welding exposures When comparing the data from the workers in the cab fab area to those in the metal fab area, it is apparent that the canopy hoods are helping to keep worker exposures low The average cab fab welder's exposure levels for the elements listed in Table 3 are all 2-8 times lower than the metal fab welders exposures

Table 3 Workers' Average Exposures for Selected Elements by Sample Location (µg/m³)

Sample Location	N	Al $\bar{x}$ (SD)	Cr $\bar{x}$ (SD)	Cu $\bar{x}$ (SD)	Fe $\bar{x}$ (SD)	Mn $\bar{x}$ (SD)	Ni $\bar{x}$ (SD)	Pb $\bar{x}$ (SD)	Ti $\bar{x}$ (SD)	Zn $\bar{x}$ (SD)
Cab Fab Welding	6	2.0 (1.1)	0.49 (0.37)	3.5 (3.0)	184 (133)	16.8 (13.8)	ND (-)	ND (-)	0.07 (0.07)	3.8 (1.1)
Metal Fab Welding	9	6.8 (9.5)	2.7 (6.9)	12 (21.9)	429 (615)	55.1 (98.3)	1.8 (4.7)	0.18 (0.5)	0.14 (0.15)	30.2 (61.9)
Spot Welding	1	2.5	0.82	3.4	51.2	4.7	ND	ND	0.19	6.2
Grinding	1	11.4	0.66	5	698	10.4	1.04	ND	0.26	25.6
Cutting	1	21.7	1.4	12.1	1190	8.9	3.4	ND	1.1	85.4

$\bar{x}$ = average (µg/m³) SD = standard deviation (µg/m³) ND = non-detected

Table 4 Average Area Concentrations for Select Elements by Sample Location (µg/m³)

Sample Location	N	Al $\bar{x}$ (SD)	Cr $\bar{x}$ (SD)	Cu $\bar{x}$ (SD)	Fe $\bar{x}$ (SD)	Mn $\bar{x}$ (SD)	Ni $\bar{x}$ (SD)	Pb $\bar{x}$ (SD)	Ti $\bar{x}$ (SD)	Zn $\bar{x}$ (SD)
Cab Fab Area	2	0.78 (0.78)	0.38 (0.38)	0.56 (0.19)	21.7 (9.65)	1.8 (0.8)	ND (-)	ND (-)	0.09 (0.09)	13.2 (12.4)
Metal Fab Area	2	1.6 (0.3)	ND (-)	0.67 (0.12)	29.7 (7.1)	2.8 (0.8)	ND (-)	ND (-)	0.36 (0.19)	3.05 (0.79)
Outside	2	ND (-)	ND (-)	ND (-)	1.5 (0)	0.02 (0.02)	ND (-)	ND (-)	ND (-)	0.14 (0.14)
Office	2	ND (-)	ND (-)	0.04 (0.04)	2.7 (0.83)	0.17 (0.03)	ND (-)	ND (-)	0.12 (0.12)	0.32 (0.16)

$\bar{x}$ = average (µg/m³) SD = standard deviation (µg/m³) ND = non-detected

Since aluminized steel was welded in the metal fab area, it is not surprising that the highest aluminum exposures were during metal fab welding. The largest individual zinc exposure was found on the metal fab worker who welded galvanized steel. However, since the remaining metal fab welders did not weld galvanized steel during the sampling periods, the average zinc exposure for these welders fell to below that of the cutting operator.

The average area concentrations were approximately the same for the various elements throughout the plant area, except that zinc levels were found to be more than four times higher in the cab fab area than the metal fab area. Apparently, some of the dust/fumes from the plant were also making their way into the office area.

VENTILATION MEASUREMENTS

Multiple measurements were taken at each workstation in the cab fab area to determine the volume of air being moved by the canopy hood systems. Air velocity rates were measured at the face of the 26-in diameter exhaust intake, located at the center of each canopy hood. Each intake was calculated to be about 3.6 ft^2. The velocity rates and areas were then used to calculate the volume of air being pulled by each canopy hood system. Table 5 lists the results of these measurements. Information on the number of bends in the duct work leading to the overhead air-cleaning unit is also included.

Table 5. Canopy Hood Ventilation Measurements

Work Station	Average Intake Velocity (fpm)	Hood Airflow Rate (cfm)	No. of 90° Turns in Duct
1	1932	6955	1
2	1265	4554	2
3	922	3319	1
4	1124	4046	2
5	1532	5515	2
6	1647	5929	2
7	1494	5378	2
8	1535	5526	2

In addition to the air volumes, capture velocities were measured at the canopy hood plane in Booths 4 and 6. The highest velocities were found to be directly in the middle of the table below the exhaust opening. For Booth 4, this velocity was measured to be 270 fpm, for Booth 6, this velocity was 350 fpm. The average face velocity above the table was calculated to be about 130 fpm for Booth 4 and 180 fpm for Booth 6. The ACGIH Industrial Ventilation manual indicates that a velocity of 100-200 fpm should be used to capture welding fumes, with the higher values used for poor conditions such as disturbing room air currents, high toxicity contaminants, and high production/heavy use.[7] The manual indicates the capture velocities above 200 fpm may disturb the shielding gas. The manual also suggests that the minimum duct design velocities for welding fumes should be between 2000-2500 fpm to prevent settling and plugging of the duct. Duct velocities were not measured during this study.

Smoke tubes activated at various points around the welding tables showed the majority of the smoke was being captured by the canopy hood system. However, it was observed that the smoke was also influenced by nearby canopy hood systems if the curtains were open. The welders indicated that keeping the welding curtains closed helped to increase the capture efficiency of their workstation's ventilation system

CONCLUSIONS AND RECOMMENDATIONS

The filter sampling data showed very few instances of overexposures to total welding fume or the various fume constituents In fact, none of the samples exceeded the various OSHA PEL limits for the identified elements or for total particulate levels However, two samples, one on a metal fab welder, the other on the cutting operator, did approach the ACGIH TLV for total particulate In addition, one sample exceeded the ACGIH TLV for manganese, and one sample slightly exceeded the NIOSH REL for nickel Both of these samples were collected on welders in the nonventilated metal fab area The cutting and grinding operations produced air contaminant levels that were often greater than the average welding exposures In the future, the grinding operation will be performed using ventilation, the ventilated system was being installed at the time of the second sampling survey The cutting operation was already using ventilation to help reduce its fume and dust emissions Evidently, the local exhaust unit being used during the cutting task was not completely effective at controlling these emissions

From the data, it appeared as if the cab fab welders were adequately protected from welding fume emissions by the canopy hood systems However, while canopy hoods may be keeping the welder's overall exposures lower than if welding without ventilation, it may not be accurate to state that the welder's exposure levels are completely controlled by this ventilation system Canopy hoods often help to control air contaminants in the general vicinity of welders, however, in many instances, the fumes may enter the worker's breathing zone as the fumes rise from the workpiece to the hood This can result in occasional peak exposures to the welder, however, there were no actual observations that would support this hypothesis This theory is based on previous experience with real-time data sampling in other industries, which consistently shows that work methods and worker behavior often leads to short-term exposure peaks The only way to verify this theory would be to conduct real-time data sampling on the welding operations, a technique which was not performed during this study In general, the skill of the welder at keeping his or her head out of the weld plume can often make a great difference in the resulting welding exposures, especially when canopy hoods are used to control the fumes

In the case of the metal fabrication welders, it is unclear why the local exhaust ventilation units that are available are not being used Discussions with the welders suggested that the portable units are difficult to move and position, especially when welding on large parts Welders felt ventilation units with suspended arms might be of the most use to them, however, installing these units would be difficult due to the overhead crane system in the metal fab area In general, the welders should be trained on the proper use of the ventilated control measures and management should enforce their use to help further reduce fume exposures In addition, man-cooling fans should not be substituted for ventilation controls Depending upon where the fan is located in relation to the welder, generated air currents may cause fumes to be transported into the worker's breathing zone

In summary, although the results of the sampling did not show there to be many instances of overexposure to air contaminants during the surveys, there is still the potential for problems The metal fab welders should be trained on and required to use local exhaust ventilation systems Use of ventilation can help to further reduce these workers' exposures to welding fume and dust Welders throughout the plant should be trained to keep their heads out of the welding plume, especially when working under the canopy hoods Welding curtains should be closed when welding to improve the capture efficiency of the canopy hoods, as well as to protect surrounding workers from eye hazards

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APPENDICES

APPENDIX A NIOSH BACKGROUND

The National Institute for Occupational Safety and Health (NIOSH) is located in the Centers for Disease Control and Prevention (CDC), under the Department of Health and Human Services (DHHS) (formerly the Department of Health, Education, and Welfare) NIOSH was established in 1970 by the Occupational Safety and Health Act, at the same time that the Occupational Safety and Health Administration (OSHA) was established in the Department of Labor (DOL) The OSHAct legislation mandated NIOSH to conduct research and education programs separate from the standard and enforcement functions conducted by OSHA An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemicals and physical hazards

The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering (DPSE) has been given the lead within NIOSH to study and develop engineering controls and assess their impact on reducing occupational illness Since 1976, ECTB has conducted a large number of studies to evaluate engineering control technology based upon industry, process, or control technique The objective of each of these studies has been to evaluate and document control techniques and to determine the effectiveness of the control techniques in reducing potential health hazards in an industry or for a specific process

During the past twenty years, the National Institute for Occupational Safety and Health (NIOSH) has documented and reported on the need to control worker exposures to the fumes and gases generated during welding operations Much of the attention to welding has been in the form of Health Hazard Evaluations conducted at field sites, however, a few NIOSH reports have focused on control technology These reports are briefly discussed below and can be obtained through NTIS or the NIOSH Publications Office (1-800-35-NIOSH)

In 1974, a research contract report entitled "Engineering Control of Welding Fumes" was published, with the objective of developing design criteria for local ventilation systems to control welding fumes This report identified shielded manual metal arc welding on carbon and stainless steel and gas-shielded arc welding on carbon steel as processes constituting great health risks to welders A crossdraft table, free-standing hood, and low volume-high velocity fume extraction gun were evaluated to determine the minimum system operating point needed to reduce fumes below threshold limit values (TLVs) [1]

In 1978, the NIOSH booklet "Safety and Health in Arc Welding and Gas Welding and Cutting" included general information on dilution and local exhaust ventilation [2]

In 1979, NIOSH's Division of Physical Sciences and Engineering (DPSE) published the research report "Assessment of Selected Control Technology Techniques for Welding Fumes " This study considered the effect of dilution airflow direction on welder exposures in the field and evaluated a fume extraction gun [3]

In 1988, the NIOSH "Criteria for a Recommended Standard for Welding, Brazing, and Thermal Cutting" was produced In this document, NIOSH recommended that welding emissions be controlled to concentrations as low as feasibly possible using state-of-the-art engineering technology and work practices General guidelines were provided for selecting dilution and local exhaust ventilation systems [4]

REFERENCES

1 Astleford W [1974] Engineering Control of Welding Fumes Southwest Research Institute, San Antonio, Texas Contract No HSM 99-72-76 U S Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No 75-115

2 NIOSH [1978] Safety and Health in Arc Welding and Gas Welding and Cutting Cincinnati, Ohio U S Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No 78-138

3 Van Wagenen HD [1979] Assessment of Selected Control Technology Techniques for Welding Fumes Cincinnati, Ohio U S Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No 79-125

4 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

APPENDIX B: POTENTIAL HEALTH HAZARDS

Welding fumes are a product of 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 consumable [1] The size of welding fume is highly variable and ranges from less than 1-µm diameter (not visible) to 50-µm diam (seen as smoke) [2] Fume constituents may include minerals such as silica and fluorides (used as fluxes) and metals such as arsenic, beryllium (in high copper alloys), cadmium (often used as a rust inhibitor), chromium, cobalt and nickel (in stainless steel), copper (in copper-coated wire), iron, lead (in lead-based paint coatings), magnesium, manganese (in stainless steel, manganese steel), molybdenum, tin, vanadium, and zinc (used to galvanize steel) [3 4 5] Toxic gases such as ozone, carbon monoxide, nitrogen dioxide, and phosgene (formed from chlorinated solvent decomposition) can also be produced [3 4 5] Volatile hydrocarbons can be produced during welding if antispatter sprays, oils, or lanolin (often used during degreasing processes) are present [2]

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 The Welding Institute [1976] The Facts About Fume - A Welding Engineer's Handbook Abington, Cambridge, England The Welding Institute

3 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

4 American Welding Society [1987] Welding Handbook 8th ed , Vol 1, Welding Technology Connor LP, ed Miami, Florida American Welding Society, ISBN 0-87171-281-4

5 Rekus JF [1990] Health Hazards in Welding BodyShop Business *11* 66-77, 188

APPENDIX C SUMMARY OF SELECTED OCCUPATIONAL EXPOSURE LIMITS

Substance	OSHA PEL-TWA (µg/m³)	NIOSH REL-TWA (µg/m³)	ACGIH TLV-TWA (µg/m³)
Aluminum fume	15,000 (Total) 5000 (Respirable)	5000	5000
Arsenic	10	2 (Ceiling)	10
Barium	500	500	500
Beryllium	2	0 5 (Ceiling)	2
Calcium Oxide	--	2000	2000
Cadmium fume	5	LFC (Ca)	10 (Total) 2 (Respirable)
Cobalt	100	50	20
Chromium, Metal	1000	500	500
Copper fume	100	100	200
Iron Oxide fume	10 000 (as Fe)	5000	5000
Lithium	--	--	--
Magnesium Oxide fume	15000	--	10000
Manganese	5000 (Ceiling)	1000	200
Molybdenum	5000 (Soluble) 15 000 (Insoluble)	--	5000 (Soluble) 10 000 (Insoluble)
Nickel	1000 (change proposed)	15 (Ca)	1000 (change proposed)
Lead	50	100	50
Phosphorus	100	100	100
Platinum	2 (Soluble)	1000 (Metal) 2 (Soluble)	1000
Selenium	200	200	200
Silver	10	10	100
Sodium	--	--	--
Tellurium	100	100	100
Thallium	100	100 (Soluble)	100
Titanium Dioxide	15000	LFC (Ca)	10000
Vanadium Pentoxide fume	100 (Ceiling)	50 (Ceiling)	50
Yttrium	1000	1000	1000
Zinc Oxide fume	5000	5000	5000
Zirconium	5000	5000	5000
Welding fumes	-	LFC (Ca)	5000

LFC=lowest feasible concentration   Ca=NIOSH potential occupational carcinogen

APPENDIX D. ANALYTICAL DETECTION AND QUANTITATION LIMITS

Analyte	LOD (µg/filter)	LOQ (µg/filter)
Silver	0.04	0.13
Aluminum	0.5	1.6
Arsenic	1	3.1
Barium	0.02	0.040
Beryllium	0.02	0.064
Calcium	2	4.1
Cadmium	0.07	0.21
Cobalt	0.2	0.62
Chromium	0.4	1.2
Copper	0.05	0.16
Iron	0.6	1.9
Lithium	0.05	0.17
Magnesium	0.7	2.3
Manganese	0.03	0.091
Molybdenum	0.2	0.43
Sodium	5	17
Nickel	0.4	1.3
Phosphorus	4	11
Lead	0.6	1.8
Platinum	2	4.1
Selenium	0.9	3.0
Tellurium	0.7	2.3
Thallium	2	4.0
Titanium	0.06	0.19
Vanadium	0.2	0.39
Yttrium	0.02	0.041
Zinc	0.07	0.22
Zirconium	0.2	0.36

APPENDIX E GRAVIMETRIC AIR SAMPLING DATA

Date	Sample #	Welder or Area	Location	Base Metal	Mass (mg)	Flow (lpm)	Time (min)	Volume (l)	Conc (mg/m³)	Vent?
10/18	3176	A	Metal Fab	MS Galv	0 61	3	245	735	0 83	No
10/18	3175	B	Metal Fab	MS	0 26	3	198	594	0 44	No
10/18	3172	C	Cab Fab	SS	0 03	3	200	600	0 05	Yes
10/18	3183	D	Metal Fab	SS	0 83	3	288	864	0 96	No
10/18	3188	E	Cutting	MS	3 57	3	246	738	4 84	Yes
10/18	3063	Area	Cab Fab	-	0 11	3	234	702	0 16	N/A
10/18	3061	Area	Office	-	ND	3	228	684	0	N/A
10/18	3177	F	Cab Fab	SS	ND	3	242	726	0	Yes
10/18	3071	Area	Outside	-	0 02	3	231	693	0 03	N/A
10/18	3171	Area	Metal Fab	-	0 07	3	208	624	0 11	N/A
10/18	3189	G	Grinding	MS	1 24	3	234	702	1 77	No
10/18	3182	H	Cab Fab	MS	0 35	3	237	711	0 49	Yes
11/8	3095	Area	Outside	-	ND	3	274	822	0	N/A
11/8	3100	I	Cab Fab	MS	0 67	3	237	711	0 94	Yes
11/8	3092	J	Spot Weld	Galv MS	0 23	3	215	645	0 36	No
11/8	3098	Area	Metal Fab	-	0 09	3	236	708	0 13	N/A
11/8	3094	K	Cab Fab	MS	0 44	3	218	654	0 67	Yes
11/8	3091	L	Metal Fab	MS	1 99	3	141	423	4 70	No
11/8	3103	Area	Office	-	ND	3	270	810	0	N/A
11/8	3097	M	Cab Fab	MS	0 51	3	230	690	0 74	Yes
11/8	3102	Area	Cab Fab	-	0 02	3	216	648	0 03	N/A
11/8	3096	F	Metal Fab	MS	0 59	3	200	600	0 98	No
11/8	3101	B	Metal Fab	MS	0 31	3	235	705	0 44	No
11/8	3108	A	Metal Fab	MS Alum	0 10	3	236	708	0 14	No
11/8	3104	D	Metal Fab	Alum	0 53	3	152	456	1 16	No
11/8	3111	L	Metal Fab	MS	ND	3	71	213	0	No

APPENDIX F: ELEMENTAL AIR SAMPLING DATA

Sample #	Welder or Area	Vol (m^3)	Al $\mu g/m^3$	As $\mu g/m^3$	Ba $\mu g/m^3$	Be $\mu g/m^3$	Ca $\mu g/m^3$	Cd $\mu g/m^3$	Co $\mu g/m^3$	Cr $\mu g/m^3$	Cu $\mu g/m^3$	Fe $\mu g/m^3$	Li $\mu g/m^3$	Mg $\mu g/m^3$	Mn $\mu g/m^3$	Mo $\mu g/m^3$
3176	A	735	0.7	ND	0.9	0	35.4	0.2	ND	ND	3.0	190.5	ND	2.0	23.1	ND
3175	B	594	0.6	ND	0.4	ND	25.3	ND	ND	ND	3.9	185.2	ND	1.2	18.5	ND
3172	C	600	0.6	ND	0.2	ND	8.8	ND	ND	ND	0.2	15.2	ND	ND	1.2	ND
3183	D	864	0.9	ND	0.4	ND	33.6	ND	ND	22.0	3.5	277.8	ND	1.9	19.7	0.3
3188	E	738	0.7	ND	1.2	ND	73.2	ND	ND	1.4	12.1	1192.4	ND	2.9	9.0	0.5
3063	Cab Fab	702	0.7	ND	0.5	ND	28.5	ND	ND	0.8	0.8	31.3	ND	1.0	2.6	ND
3061	Office	684	0.7	ND	ND	ND	3.4	ND	ND	ND	ND	3.5	ND	ND	0.2	ND
3177	F	726	0.7	ND	0.4	ND	10.5	ND	ND	1.0	0.6	38.6	ND	N	2.3	ND
3071	Outside	693	0.7	ND	ND	ND	3.0	ND	ND	ND	ND	1.9	ND	ND	0.1	ND
3171	Metal Fab	624	0.6	ND	0.5	ND	10.7	ND	ND	ND	0.8	36.9	ND	ND	3.5	ND
3189	G	702	0.7	ND	0.7	ND	31.3	ND	ND	0.7	5.0	698.0	ND	1.3	10.4	ND
3182	H	711	0.7	ND	0.7	ND	13.5	ND	ND	ND	1.4	168.8	ND	1.6	6.6	ND
3095	Outside	822	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.1	ND	ND	ND	ND
3100	I	711	3.4	ND	0.9	ND	14.1	ND	ND	0.6	7.3	393.8	ND	1.8	28.1	ND
3092	J	645	2.5	ND	0.8	ND	12.6	ND	ND	0.8	3.4	51.2	ND	1.7	4.7	ND
3098	Metal Fab	708	1.3	ND	0.7	ND	11.0	ND	ND	ND	0.6	22.6	0.1	1.8	2.0	ND
3094	K	654	2.8	ND	1.0	ND	12.1	ND	ND	0.7	4.3	198.8	ND	2.1	26.0	ND
3091	L	423	6.1	ND	0.8	ND	17.7	0.4	ND	1.1	73.3	2127.7	ND	3.5	331.0	ND
3103	Office	810	ND	ND	0.0	ND	ND	ND	ND	ND	0.1	1.9	ND	ND	0.1	ND
3097	M	690	1.9	ND	0.4	ND	7.8	ND	0.3	0.7	7.4	289.9	ND	1.4	36.2	ND
3102	Cab Fab	648	ND	ND	0.6	ND	6.3	ND	ND	ND	0.4	12.0	ND	ND	1.0	ND
3096	F	600	2.7	ND	0.6	ND	13.0	ND	ND	0.8	6.8	436.7	0.1	1.7	36.7	ND
3101	B	705	1.7	ND	0.4	ND	8.9	ND	ND	ND	5.4	170.2	0.1	1.3	21.3	ND
3108	A	708	8.2	ND	0.3	ND	7.3	ND	ND	ND	0.6	41.0	ND	ND	30.2	ND
3104	D	456	32.9	ND	0.4	ND	16.4	ND	ND	ND	10.7	416.7	ND	2.0	39.5	ND
3111	L	213	0.0	ND	0.3	ND	11.7	ND	ND	ND	0.7	31.9	ND	ND	2.8	ND

APPENDIX F: ELEMENTAL AIR SAMPLING DATA (Continued)

Sample #	Welder or Area	Vol (m^3)	Ni $\mu g/m^3$	Pb $\mu g/m^3$	P_4 $\mu g/m^3$	Pt $\mu g/m^3$	Se $\mu g/m^3$	Ag $\mu g/m^3$	Na $\mu g/m^3$	Te $\mu g/m^3$	Th $\mu g/m^3$	Ti $\mu g/m^3$	V_2O_5 $\mu g/m^3$	Y $\mu g/m^3$	Zn $\mu g/m^3$	Zr $\mu g/m^3$
3176	A	735	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	204.1	ND
3175	B	594	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	23.6	ND
3172	C	600	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.5	ND
3183	D	864	15.1	ND	4.6	ND	ND	ND	10.7	ND	ND	0.2	ND	ND	18.5	ND
3188	E	738	3.4	ND	ND	ND	ND	ND	8.7	ND	ND	1.1	ND	ND	85.4	0.4
3063	Cab Fab	702	ND	ND	ND	ND	ND	ND	7.7	ND	ND	0.2	ND	ND	25.6	ND
3061	Office	684	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3	ND	ND	0.5	ND
3177	F	726	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.3	ND
3071	Outside	693	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3	ND
3171	Metal Fab	624	ND	ND	ND	ND	ND	ND	13.8	ND	ND	0.5	ND	ND	3.9	ND
3189	G	702	1.0	ND	ND	ND	ND	ND	52.7	ND	ND	0.3	ND	ND	25.6	ND
3182	H	711	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.1	ND
3095	Outside	822	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3100	I	711	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	3.9	ND
3092	J	645	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	6.2	ND
3098	Metal Fab	708	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	2.3	ND
3094	K	654	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.1	ND	ND	3.2	ND
3091	L	423	1.2	1.7	ND	ND	ND	0.2	ND	ND	ND	0.2	ND	ND	10.2	ND
3103	Office	810	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND
3097	M	690	ND	ND	ND	ND	ND	0.1	ND	ND	ND	0.1	ND	ND	1.6	ND
3102	Cab Fab	648	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND	0.8	ND
3096	F	600	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.1	ND	ND	4.5	ND
3101	B	705	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.1	ND	ND	3.4	ND
3108	A	708	ND	ND	ND	ND	ND	0.1	ND	ND	ND	0.1	ND	ND	1.2	ND
3104	D	456	ND	ND	ND	ND	ND	0.1	ND	ND	ND	0.5	ND	ND	4.6	ND
3111	L	213	ND	ND	ND	ND	ND	0.3	ND	ND	ND	ND	ND	ND	2.1	ND