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INDUSTRIAL HYGIENE SERVICES

TITLE

EMPLOYEES' EXPOSURE TO OZONE, METAL FUMES, GRINDING DUSTS AND NITROGEN DIOXIDE DURING VARIOUS WELDING AND GRINDING OPERATIONS, FABRICATION SHOP, 593 BUILDING, MICHIGAN DIVISION, JULY - AUGUST, 1988

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DESCRIPTIVE SUMMARY WITH CONCLUSIONS

Air monitoring studies were conducted at the Michigan Division Fabrication Shop, 593 Building, to determine welders' exposures to metal fumes, nitrogen dioxide, grinding dusts, and total fumes generated during various types of welding operations. Both area concentrations and personal exposures to welding fumes were evaluated.

Survey results indicated that calculated employee Time Weighted Average (TWA) exposures to all expected individual heavy metals were well within the current Industrial Hygiene Guidelines (IHGs) with the exception of one sample. Survey results also indicated that twenty three out of twenty six calculated TWA exposures to total welding fumes were within the current IHG of 5 mg/m^3. The three samples in excess of the IHG for total fumes were collected during flux core arc welding, plasma arc cutting, and gas tungsten arc welding.

Twenty work area samples were taken for individual heavy metal and total welding fumes. The highest welding fume concentrations were measured during plasma arc cutting operations.

Employees' exposures to iron and total dust during hand-held grinding operations were excessive for both excursion and calculated 8-hour TWAs.

Excursion sampling results indicate that workplace concentrations of ozone were well within the current IHG of 0.6 mg/m^3. Survey results show concentrations of nitrogen dioxide to be relatively high. Ozone and nitrogen dioxide were sampled simultaneously during welding processes that were expected to generate the highest gas concentrations.

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PURPOSE

Since 1981, the last time a welding survey was conducted in 593 Building, many of the welding operations have changed. A survey was initiated to determine current employee exposures to welding fumes, ozone, oxides of nitrogen, grinding dust, and total fumes generated during various welding and grinding operations.

INTRODUCTION

This study was conducted to determine the potential hazard posed to welders by metal fumes, ozone, oxides of nitrogen, and grinding dusts during various welding and grinding processes. Eight types of welding processes were analyzed: plasma arc cutting, gas metal arc welding, gas tungsten arc welding, synergic pulse welding, flux core arc welding, shielded metal arc welding, hardfacing, and welding inside an enclosed vessel. These welding processes were performed on seven different types of surfaces: aluminum, carbon steel, stainless steel, nickel, inconel, monel, and hastelloy.

Employee breathing zone exposures to welding fumes were measured inside the employee's welding hood. Area samples were often taken simultaneous with breathing zone samples at approximately 2-4 feet from the welding operation. The use of local exhaust ventilation was compared to natural ventilation with regard to the workers' exposure. During welding in a ventilated vessel,the general atmosphere of the vessel was sampled downstream of the welder, as well as in the welder's breathing zone.

CONCLUSIONS

1. Employee 8-hour TWA exposures to concentrations of tin oxide, lead, copper, molybdenum, manganese, iron oxide, aluminum oxide, titanium dioxide, zinc oxide, nickel, and chromium were all shown to be well within the current exposure guidelines, with the exception of one sample. This particular sample was collected when an employee performed flux core arc welding on carbon steel inside a vessel without ventilation. The exposure concentration to manganese was 1.14 mg/m^3, (IHG 1 mg/m^3). All 8-hour TWA concentrations were calculated from data based on short term samples.

2. Short term work area welding fume concentrations near the welder were measured. Concentrations for tin oxide, lead, copper, molybdenum, manganese, aluminum oxide, titanium dioxide, zinc oxide, nickel, and chromium were relatively low. Iron oxide concentrations however, can be excessive. The amount of total fumes generated can also be excessive, especially during plasma arc cutting.

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3. Excursion samples taken during 10-15 minute sampling periods showed that ozone was well within the Short Term Exposure Limit (STEL) of 0.6 mg/m^3 for all 8 welding processes surveyed.

4. Excursion sample results also indicated that levels of nitrogen dioxide during plasma arc cutting were relatively high, within 70-90% of the current STEL of 5 ppm. The results ranged from 2-4 ppm for a 15 minute sampling duration.

5. Employees' exposures to dusts during hand-held grinding operations were excessive for iron and total particulates. Tin, lead, copper, molybdenum, manganese, aluminum, titanium, zinc, nickel, and chromium concentrations were determined to be at acceptable levels. Results indicate that calculated 8-hour TWA exposures to total particulates were close to or in excess of the current exposure guideline in four out of seven samples.

6. The position of the welder influences fume concentrations in the breathing zone. As expected, breathing zone concentrations were highest when the welder leaned over the work and into rising fumes.

7. Local exhaust ventilation units are an effective means of reducing welders exposure to welding fumes.

8. A comparison was made of metal fume concentrations inside versus outside the welding hood. Results show that concentrations outside the welding hood are 2-4 times higher than inside the welding hood. These results are supportive of previous findings (1).

RECOMMENDATIONS

1. When welders are performing hand-held grinding operations, it is recommended that local exhaust ventilation be utilized. When this is not practical, respiratory protection should be used.

2. Proper precautions must always be taken when working in confined spaces. Concentrations of fumes, gases, and toxic substances can build up quickly. The atmosphere can be depleted of oxygen and replaced by asphixiant gases.

3. Personal protective equipment such as aprons of leather or other flame resistant material should be worn during welding operations to withstand radiated heat sparks. All welders and welders attendants should have adequate eyesight to avoid positioning themselves too close to the arc - thus increasing exposure to gases and fumes. Helpers or attendants should also wear proper eye protection.

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4. Future Industrial Hygiene efforts should include:
   a. Personal noise monitoring utilizing audiodosimeters to evaluate sound pressure levels experienced by welders performing air carbon arc cutting.

   b. Further evaluation of fumes generated while welding on chemical contaminated or painted material.

   c. Evaluation of any process or equipment changes that might significantly affect employee exposure potential.

   d. Fume studies should be conducted using local exhaust ventilation positioned at typical distances from the work and operating at representative exhaust flowrates to determine if air flowrates are adequate to capture and remove welding fumes at their source.

5. Floor fans, if used, should be located at an angle to the welder as not to create a vortex of fume under the welding hood. Use of fans is, without doubt, the oldest and poorest method for dealing with welding fumes. It is inexpensive, but does not begin to solve the problem. It has been determined that if a fan is placed in front of or behind the welder, actual fume exposure increases versus not using a fan (2). Fans simply dilute the fume by spreading it around the entire plant eventually to be inhaled by other workers.

6. Local Exhaust ventilation should continue to be emphasized and utilized during welding operations.

POTENTIAL HEALTH EFFECTS [3,4,5]

Iron Oxide Fume

Inhalation of iron oxide fumes can cause pockets of accumulated material to form which are dense enough to show up on chest x-ray films. This mottling of the lungs, called siderosis, is considered to be a mild lung disease because it does not lead to the proliferation of lung fibrosis and loss of respiratory function or other severe lung diseases.

Nickel

Fine nickel dust introduced into the pleural cavity, muscle tissue, and subcutaneous tissue of animals has been shown to cause cancer. Skin contact may cause a dermatitis called "nickel itch". Nickel and its compounds are also irritants to the conjunctiva of the eye and the mucous membrane of the upper respiratory tract.

Symptoms of dermatitis usually begin with a sensation of burning and itching in the hand, followed by erythema (reddening of the skin) and a nodular eruption on the web of fingers, wrists, and forearms.

Copper

The fumes and dust from copper cause irritation of the upper respiratory tract, metallic tastes in the mouth, nausea, metal fume fever, and in some instances discoloration of the skin and hair to a greenish-black color. Inhalation of dusts, fumes, and mists of copper salts may cause congestion of the nasal mucous membranes, sometimes of the pharynx, and on occasions, ulceration with perforation of the nasal septum. If the salts reach the gastrointestinal tract, they act as irritants producing salivation, nausea, vomiting, gastric pain, hemorrhagic gastritis, and diarrhea. In chronic exposures, the liver, kidneys, and spleen may be injured and anemia may develop.

Aluminum

The effects on the human body caused by the inhalation of aluminum dust and fumes are not known with certainty. Present data suggest that pneumoconiosis might be a possible outcome. In the majority of cases investigated, however, it was found that exposure was not to aluminum dust alone, but to a mixture of aluminum, silica fume, iron dusts, and other materials.

Chromium

In some workers, chromium compounds act as allergens which cause dermatitis to exposed skin. Acute exposures to dust or mist may cause coughing and wheezing, headache, difficult or labored breathing, pain on deep inspiration, fever, loss of weight, ulceration, and perforation of the nasal septum.

Lead

Inhalation, the most important route of lead exposure, and ingestion result in damage to the nervous, urinary, and reproductive systems. Lead inhibits synthesis of the molecular heme, which is responsible for oxygen transport in living systems. Damage to the central nervous system in general, and the brain (encephalapathy) in particular, is the most severe clinical form of lead intoxication.

Symptoms of severe lead intoxication include loss of appetite, metallic taste in the mouth, nausea, pallor, weakness, insomnia, headache, irritability, fine tremors, dizziness and colic.

Zinc Oxide

The syndrome of metal fume fever is the only important effect of exposure to freshly formed zinc oxide fumes and zinc oxide dusts of respirable particle size. Typically, the syndrome begins four to twelve hours after sufficient exposure to zinc oxide. The worker first notices the presence of a sweet or metallic taste in the mouth, accompanied by dryness and irritation of the throat. Cough and shortness of breath may occur, along with general malaise, a feeling of weakness, fatigue, and pains in the muscles and joints. Fever and shaking chills then develop. Profuse sweats develop and the fever subsides. The entire episode runs its course in 24 to 48 hours.

Manganese

Manganese dust and fumes are only minor irritants to the eyes and mucous membranes of the respiratory tract. In chronic exposure, manganese dusts or fumes enter the respiratory tract and are absorbed into the blood stream. Manganese is then deposited in major body organs with a special predilection for the liver, spleen, and certain nerve cells of the brain and spinal cord. Chronic manganese poisoning is not a fatal disease although it is extremely disabling.

Ozone

Ozone is irritating to the eyes and all mucous membranes. In human exposures, the respiratory signs and symptoms in order of increasing ozone concentrations are: dryness of upper respiratory passages; irritation of mucous membranes of nose and throat; choking, coughing, and severe fatigue; bronchial irritation, substernal soreness, and cough. Pulmonary edema may occur, sometimes several hours after exposure has ceased. In severe cases, the pulmonary edema may be fatal.

Symptoms and signs of subacute exposure include headache, malaise, shortness of breath, drowsiness, reduced ability to concentrate, slowing of heart and respiration rate, visual changes, and decreased desaturation of oxyhemoglobin in capillaries.

Nitrogen Dioxide

Nitrogen dioxide vapors may cause severe irritation to the eyes with corneal injury which may result in permanent impairment of vision, even blindness. Excessive vapor concentrations are readily attainable and may cause severe irritation to upper respiratory tract, lungs, and emphysema-like effects.

Titanium Dioxide

Titanium dioxide is, for the most part, virtually inert and not highly toxic to man. Extremely high concentrations of titanium dioxide dust can, however, lead to breathing difficulty because of the deposition within the lungs.

Molybdenum

Signs of molybdenum poisoning are loss of appetite, listlessness, diarrhea, and reduced growth rate. Anemia is characteristic of molybdenum toxicity because of low hemoglobin concentrations and reduced red cell counts.

Excessive exposure may cause edema and joint pains in the knees, hands and feet, articular deformities, and erythema.

Tin

When inhaled as a dust or a fume, tin oxides lead to a benign pneumoconiosis without symptoms of interference with pulmonary function.

WELDING PROCESS [6]

All welding processes monitored involved electric arc welding. Arc welding is essentially an electric circuit in which the current passes from a generator, through a metal rod, to the metal object being welded and then into the ground. Heat is generated when the electric current jumps across the air gap between the end of the electrode and the base metal being welded. This heat melts the tip of the metal rod and a portion of the base metal. Welding current is provided by an AC or DC generator using line current at 220 or 440 volts.

Shielded Metal Arc Welding (Stick Welding)

Shielded metal-arc welding, sometimes referred to as stick welding, is widely used in industry. The electrode is a metal rod having approximately the same composition as the metal to be welded. Shielded electrodes have heavy coatings of various substances such as cellulose sodium, cellulose potassium, and iron oxide. The purpose of the coatings are 1) to act as a cleansing and deoxidizing agent, 2) to release an inert gas to protect the molten metal from oxides and 3) to form a protective slag over the deposited metal until the metal cools.

Gas Metal Arc Welding (MIG)

Gas metal-arc welding is a process which uses continuous consumable wire as the electrode. Shielding of the arc and molten weld metal is obtained from an inert gas, or a gas mixture, which is fed through the torch at pre-set controlled rates.

Gas Tungsten Arc Welding (TIG)

Gas tungsten-arc welding uses a nonconsumable thoriated-tungsten electrode. Shielding of the arc and the molten metal is obtained from an inert gas or gas mixture. Oftentimes the gas used is either 100% argon or helium. The inert gas is provided from compressed gas cylinders suitably reduced in pressure and fed to the welding torch.

Maximum temperatures in the arc itself are estimated to be 12,000-15,000 degrees Kelvin, a short distance below the tungsten electrode. Temperatures close to the workpiece are approximately 10,000 degrees Kelvin, sufficient to melt all metals.

Hardfacing

Hardfacing, or hard surfacing is a process in which a hard resistant layer of metal is applied to surfaces or edges of metal objects. Hardfacing differs from shielded metal arc welding in that the finished weld is harder. There are three different types of electrodes that can be used: severe abrasion-resistant, moderate abrasion and impact resistant, and severe impact and moderately severe abrasion-resistant. Either the shielded metal arc or carbon arc method can be used for hardfacing. This study monitored shielded metal arc welding using severe abrasion-resistant electrodes.

Pulse Welding

Pulse welding is a variation of arc welding in which short, but effective, programmed bursts of power are utilized. The power pulses can be varied to allow for stabilization of the weld puddle.

Plasma Arc Cutting

Plasma arc cutting closely resembles gas tungsten arc welding. However, the arc between the tungsten electrode and the workpieces is constricted by forcing the arc to pass through a small orifice in a water cooled copper nozzle. This constriction of the arc, together with increased gas flow rate through the orifice, causes the arc to become more intense and develop a higher temperature than with gas tungsten arc welding and with a more powerful arc force. The high temperature, forced plasma jet is used to melt and remove material placed in its path providing an effective welding or cutting tool.

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Flux Core Arc Welding

This process may be considered to be a continuous version of the shielded metal arc welding process. The electrode has the flux on the inside instead of the outside. Since, the electrode now has steel on the outside, it may be fed through a welding torch in a continuous manner from a spool, similar to that used in gas metal arc welding. This process may be used with or without an external gas shield. Some cored electrodes are designed with materials in the core that provide large quantities of gas by vaporization in the arc and therefore, do not need external shielding.

COLLECTION AND ANALYSIS OF AIR SAMPLES

Welding Fumes

Personal breathing zone excursion samples for metal fumes were collected on open face membrane filters. The filters were preweighed 47 millimeter, 0.8 micron porosity metricel membrane filters. The sample air was collected using portable, battery operated vacuum pumps connected to an open-faced filter cassette using flexible tubing. Air flow rates were calibrated using a rotometer before and after sampling, and were set at approximately 2 liters per minute (lpm). A modified welder's helmet was used for sample collection. A hole was drilled in the helmet and, the filter in its holder was placed in the welding hood. Positioning the filter in the welding hood allowed an accurate evaluation of employee exposure. When the operator was grinding, the sample holder was placed on his lapel. After the sample collection period, the samples were transported to the laboratory to equilibrate at the same temperature and relative humidity at which they were preweighed. The samples were then postweighed on a Metteler AE240 Analytical Balance. Metal fumes were analyzed by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) in the Michigan Division Analytical Laboratories, 1897 Building and reported by Craig Cerbus in AL 88-041082. Total fumes were calculated gravimetrically. The preweight was subtracted from the postweight to determine the total mass of particulates.

Ozone

Air was drawn through a midget impinger containing a mixture of 1% potassium iodide in 1 normal sodium hydroxide, in accordance with a NIOSH validated method (7). The air was collected using a portable battery operated pump connected to "Tygon" flexible plastic tubing. The pumps were calibrated before and after each sample with a rotometer. Flow rates were set at approximately 2 lpm. After sampling, the impingers were sealed appropriately for shipment to the Michigan Division Analytical Laboratories. The analysis was completed by the addition of phosphoric-sulfamic acid reagent, which liberates the iodine. The yellow iodine color absorbance was determined by spectrophotometry. Analysis was conducted by Craig Cerbus and reported in AL 88-041082.

Ozone grab samples were collected by drawing air through Draeger #67-33181 ozone detector tubes and Sensidyne #18 ozone detector tubes. Nitrogen dioxide samples were collected by drawing air through Sensidyne #9 nitrogen dioxide detector tubes. The concentration (ppm) was read directly off the detector tubes at the interface between the stained-to-unstained colorimetric reagent. This particular method was very imprecise and difficult to decipher the accuracy of the color change.

EMPLOYEE EVALUATION CRITERIA

Industrial Hygiene Guideline (IHGs) are concentrations of airborne substances to which it is believed nearly all employees may be repeatedly exposed throughout a working lifetime without known adverse health effects. IHGs are established by health professionals of the Dow Industrial Health Board for chemicals (raw materials, intermediates, by-products, wastes, and products) handled within Dow Chemical. Published exposure criteria are available for many industrial chemicals; examples include the Threshold Limit Values (TLVs) of the American Conference of Governmental Industrial Hygienists (ACGIH), the ANSI standards of the American National Standards Institute, and the Permissible Exposure Levels (PELs) set by the Occupational Safety and Health Administration (OSHA). For most of these chemicals, the Industrial Health Board has adopted the published exposure criteria as the Dow IHGs. In a few instances, the Dow IHGs differ from the published exposure criteria. In establishing IHGs for chemicals which lack published exposure criteria, the Industrial Health Board considers toxicological information, occupational exposure data, and medical experience.

IHGs do not represent fine lines between safe and dangerous exposures. As the name indicates, IHGs are properly used as guides for plant design and for evaluation of occupational exposures. IHGs for gases and vapors are usually expressed in parts per million (ppm, volume/volume); for dusts, mists, fumes and aerosols, IHGs are usually expressed in milligrams of contaminant per cubic meter of air (mg/m3).

Most IHGs are time-weighted average (TWA) concentrations for an 8-12 hour workday and a 40 hour work week. Limited excursion exposures to concentrations exceeding the IHG are permitted, provided that the TWA exposure for the entire workday is acceptable and the consequences of exposure, within the excursion limits, are minimal and reversible. For most most chemicals, excursion limits are calculated from the IHGs or TLVs and the excursion factors recommended by the ACGIH. Ceiling IHGs are assigned to those materials which cause significant or irreversible effects at concentrations exceeding the IHG. For these chemicals, no excursion exposures are allowed.

The following exposure criteria applies to airborne contaminants and physical agents measured in this survey:

Material	IHG	Excursion Limits (mg/m^3)
FUME		
Iron Oxide	5.0 mg/m3	-
Nickel Fume	1.0 mg/m3	-
Copper Fume	0.2 mg/m3	-
Aluminum Oxide	5.0 mg/m3	-
Lead Fume	0.05 mg/m3	-
Chromium	0.5 mg/m3	-
Zinc Oxide	5.0 mg/m3	10 mg/m3
Titanium Dioxide	10.0 mg/m3	-
Tin Oxide	2.0 mg/m3	-
Manganese	1.0 mg/m3	-
Molybdenum	5.0 mg/m3	-
Total Welding Fume	5.0 mg/m3	-
Nitrogen Dioxide	3 ppm	5ppm
Ozone	0.1 ppm	1.3 ppm
DUST		
Tin	10.0 mg/m^3	-
Lead	0.15 mg/m^3	-
Copper	1.0 mg/m^3	-
Molybdenum	10.0 mg/m^3	-
Manganese	5.0 mg/m^3	-
Iron	10.0 mg/m^3	-
Aluminum	10.0 mg/m^3	-
Titanium	10.0 mg/m^3	-

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Zinc	10.0 mg/m^3	-
Nickel	10.0 mg/m^3	-
Chromium	10.0 mg/m^3	-
Nuisance Particulate Dust	10.0 mg/m^3	-

When the results of an industrial hygiene survey indicate a need to reduce exposure, control measures should be implemented. Traditional engineering control methods include containment, isolation, substitution, local exhaust ventilation, general ventilation, sound enclosures, and change of operating procedures. Administrative control, limiting exposure time through remote control or job rotation, may also be effective. Personal protective equipment may be used to protect employees only as a last alternative when none of the preceding control measures are feasible or until control measures can be effective.

QUALITY ASSURANCE

Standard quality control procedures including equipment calibration were followed. Sample blanks and spikes were submitted with actual survey samples in order to evaluate background interferences and possible storage losses before analysis. These efforts indicated minimal interferences and good recovery.

DEFINING EMPLOYEES EXPOSURE

An industrial hygiene survey was conducted at the Michigan Division Fabrication Shop, 593 Building to determine welders' exposures to metal fume components, grinding fume components, nitrogen dioxide, ozone, and total fumes generated during welding, grinding, and cutting of various metals. Fume samples were taken in the breathing zone of the welder, inside the welding hood. Each sample was begun when the welder struck the arc. Most samples were simulated and lasted approximately 10-15 minutes. Grinding samples were taken on the lapel of the welder; face shields were worn during grinding operations. Each sample was activated when the welder began grinding operations, and continued for approximately 15-20 minutes. Work area concentrations were taken 2-4 feet from the welding process.

No attempt was made to sample eight hour TWA exposures of the welders because of the varied nature of their work. In many cases, prewelding preparation (set up, measuring, checking drawings, etc.) occupies the majority of their time. Total arc time usually varies but was approximately 2 hours per day.

Total grinding time is estimated to be 1 hour a day. Airborne concentrations of metal fumes were determined from the sample analytical results (micrograms) and the specific volume of air collected for each sample. Airborne metal fume concentrations of tin, aluminum, iron, titanium, and zinc (oxides) were based on analytical results (micrograms), and were calculated into their corresponding metal oxide. Airborne concentrations of the metal oxide were determined, based on the sample volume of air collected for each of the individual samples.

The building in which all samples were collected (593 Building) was 100,000 ft.^{2} and the ceilings were 48 ft. high. Because the area of the building is so large, fumes are easily dispersed throughout. Since collection of samples was in the summer, many floor fans were in operation. This may have caused fume concentrations to be higher or lower than winter concentrations, depending on air flow patterns.

DISCUSSION OF RESULTS

Welding fume samples were analyzed for fifteen metals by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Eleven of these metals were present at concentrations high enough to quantify: tin, lead, chromium, zinc, manganese, molybdenum, aluminum, copper, iron, titanium, and nickel. Four metals, vanadium, cadium, cobalt, and beryllium were at non-detectable levels for all the air samples collected.

Table 2 lists the results of breathing zone samples for airborne concentrations of total fumes and individual heavy metal fumes that were present when various types of welding processes were performed. The samples were taken in the welders hood for approximately 10-15 minute sample periods. Based on an approximation of two hours of welding time per day, an 8-hour TWA was calculated. All twenty six calculated 8-hour TWA concentrations were well below the current IHGs except for one instance in which a welder was exposed to a calculated 8-hour TWA of 1.14 ppm of manganese. This exposure can be attributed to the fact that welding was performed inside an enclosed vessel without ventilation. In addition, calculated TWA exposures to total fumes exceeded exposure guidelines during flux core arc welding, plasma arc cutting, and gas tungsten arc welding where local exhaust ventilation was not utilized. The concentrations involved were 8.86, 7.65, and 7.0 mg/m^3 respectively.

Table 1 summarizes the results from employee calculated TWA exposures to metal fume during various types of welding. The eight different types of welding are represented with a corresponding range of the lowest detected concentration to the maximum concentration level found. The table includes the seven heavy metals that were found at significant concentrations. The highest concentrations of total fumes found were in plasma arc cutting and flux core arc welding, both on carbon steel.

Table 4 lists the individual work area concentrations of metal fumes during various types of welding. The samples were taken 2-4 feet from the location of the weld, while monitoring the employee exposures listed in tables 1 and 2. These samples are representative of a 10-15 minute sampling duration. The concentrations were judged to be relatively high for iron oxide, based upon the fact that concentrations present were two times greater than the 8-hour TWA-TLV. Total fume concentrations were in excess of the IHG (5.0 mg/m^3) during 3 samples taken during plasma arc cutting on both on carbon and stainless steel.

Table 3 summarizes the work area concentration of metal fumes during various types of welding. The six different types of welding are represented with a corresponding range of the lowest detected concentration to the maximum concentration level found. Represented in the table are the seven heavy metals that were found at significant concentrations.

Table 6 lists employee exposures to dust during hand-held grinding operations. Samples were collected while grinding on stainless steel, carbon steel and aluminum. Results for individual metal and total dust are reported on 2 different criteria. The concentrations of individual metals were reported for 10-15 minute sampling durations. However, concentrations of total particulate were calculated for an 8-hour, TWA workday. It was assumed in the TWA calculations that grinding operations took place for an hour per day, and the rest of the workday involved zero exposure. Elevated levels of total particulate were found when grinding on carbon and stainless steel, 16.0 and 14.2 mg/m^3 respectively. These levels exceeded the IHG for nuisance dust or 10 mg/m^3. Iron oxide concentrations were also judged to be relatively high, based upon the fact that the concentrations found were 2 times greater than the 8-hour TWA-TLV.

Table 5 summarizes and highlights the results of employees' short term exposure to dust during hand-held grinding operations. The worst case exposure scenarios were chosen to depict the highest concentrations.

Table 7 depicts a comparison of metal fume concentrations inside versus outside the welding hood. The sampling durations were 10-15 minutes. Most samples showed the concentration outside the welding hood to be 2-3 times that inside the welding hood. In some instances the concentration was higher inside than outside the hood. This is due to the positioning of the welder, or to air movement.

Table 8 compares the results between employee exposure to metal fumes and a simultaneous work area concentration measured 2-4 feet away. As was expected, the personal exposure concentration was slightly higher than the area sample. Air movers and local exhaust ventilation were both used, and are an effective means of reducing area concentrations.

Seven sets of impinger samples were taken during typical welding operations. No ozone was detected in five of the samples, with a detection limit of 0.01 mg/m^3. The current IHG STEL for ozone is 0.6 mg/m^3. Results are listed in table 9. A trace of ozone, 0.075 mg/m^3, was detected in two of the samples during plasma arc cutting.

Four grab samples were collected by drawing air through Sensidyne nitrogen dioxide detector tubes during plasma arc cutting. Breathing zone samples, taken during 10-15 minute sampling periods showed that levels of nitrogen dioxide ranged from 2-4 ppm. Ozone was an interferent on the nitrogen dioxide detector tube. Therefore, ozone and nitrogen dioxide were collected simultaneously on seperate detector tubes to determine the validity of the measurement.

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TABLE 1. SUMMARY OF EMPLOYEE CALCULATED 8-HOUR TIME WEIGHTED AVERAGE EXPOSURES* TO METAL FUMES DURING VARIOUS TYPES OF WELDING, MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING, JULY-AUGUST, 1988 (summarization of data in Table 2)

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SAMPLE NUMBER	DESCRIPTION OF PROCESS		RESULTS IN mg/m^3 Pb	Cu	Mn	Fe_2O_3
1.	SMAW[a]					
	on:	Stainless Steel	ND-0.006	ND-0.007	0.02-0.44	0.06-2.09
		Carbon Steel	ND	ND	0.02	0.31
		Nickel	ND	0.006	ND	0.04
2.	GMAW[b]					
	on:	Stainless Steel	0.004	ND	0.05	0.16
		Carbon Steel	ND	0.01-0.04	0.04-0.12	0.30-1.22
3.	PAC[c]					
	With:	Air	ND	0.007-0.04	ND-0.14	0.03-2.17
		Gas	ND	ND-0.10	ND-0.19	0.10-2.89
4.	FCAW[d]					
	on:	Stainless Steel	ND	ND-0.01	0.02-0.15	0.08-0.26
		Carbon Steel	ND-0.01	ND-0.01	0.03-1.14	0.45-3.65
5.	SPW[e]					
	on:	Stainless Steel	ND	0.004	0.07	0.21
		Nickel	ND	ND	ND	0.03
6.	GTAW[f]					
	on:	Stainless Steel	ND	ND	0.003	0.05
		Carbon Steel	0.003	0.003	ND	0.17
7.	Hardfacing					
	on:	Carbon Steel	ND	ND	0.74	1.03
8.	Metal Spraying					
	on:	Carbon Steel	0.01	ND	ND	0.05
		IHG =	0.05	0.2	1.0	5.0

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TABLE 1. (con't.) SUMMARY OF EMPLOYEE CALCULATED 8-HOUR TIME WEIGHTED AVERAGE EXPOSURES* TO METAL FUMES DURING VARIOUS TYPES OF WELDING, MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING, JULY-AUGUST, 1988 (summarization of data in Table 2)

HEH2.1-1-1-64(11)

RESULTS IN mg/m^3

SAMPLE NUMBER	ZnO	Ni	Cr	TOTAL FUME
1.	ND-0.13	0.005-0.01	0.007-0.04	0.92-4.09
	ND	ND	0.006	1.17
	ND	0.02	ND	1.17
2.	0.005	0.02	0.04	0.73
	ND-0.03	ND-0.03	ND-0.01	1.25-3.58
3.	ND	0.14-0.09	0.007-0.17	2.46-4.88
	ND	0.03-0.19	0.02-0.19	0.21-7.65
4.	ND	0.008-0.02	0.02-0.10	2.74-3.13
	ND-0.01	ND-0.03	ND-0.04	1.67-8.86
5.	0.005	0.02	0.04	1.13
	ND	0.01	ND	1.88
6.	ND	0.005	0.003	0.85
	0.01	0.009	0.004	7.0
7.	0.005	0.02	0.03	4.13
8.	0.008	0.01	ND	-
IHG =	5.0	1.0	0.5	5.0

[a]SMAW = Shielded Metal Arc Welding
[b]GMAW = Gas Metal Arc Welding
[c]PAC = Plasma Arc Cutting
[d]FCAW = Flux Core Arc Welding
[e]SPW = Synergic Pulse Welding
[f]GTAW = Gas Tungsten Arc Welding

Pb = Lead
Cu = Copper
Mn = Manganese
Fe_2O_3 = Iron Oxide
ZnO = Zinc Oxide
Ni = Nickel
Cr = Chromium

IHG = Industrial Hygiene Guideline

ND = Non-detectable at typical analytical sensitivity of 0.004 mg/m^3

* Actual sample duration of 5 to 30 minutes; time weighted average based on assumed 2 hour exposure at measured concentration, 6 hours at zero concentration.

TABLE 2. (Page A) INDIVIDUAL EMPLOYEE CALCULATED 8-HOUR TIME WEIGHTED AVERAGE EXPOSURES* TO METAL FUMES DURING VARIOUS TYPES OF WELDING, MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING, JULY - AUGUST, 1988

HEH2.1-1-64(11)

SAMPLE NUMBER	DESCRIPTION OF PROCESS	TIME IN MINUTES	RESULTS IN mg/m^3 SnO	Pb	Cu	Mo	Mn	Fe_2O_3
1.	SMAW[a] on 316 Stainless Steel No Vent. MN 63355 7/18	15	ND	ND	ND	0.006	0.02	0.06
2.	SMAW on Carbon Steel No Vent. MN 63355 7/18	15	0.006	ND	ND	ND	0.02	0.31
3.	GMAW[b] Solid Wire on Mild Carbon Steel No Vent. MN 63355 7/18	7	ND	ND	0.01	ND	0.04	0.30
4.	PAC[c] With Air on Hastelloy With Vent. MN 64815 7/25	15	ND	ND	0.007	0.80	ND	0.03
5.	FCAW[d] on Carbon Steel With Vent. MN 64815 7/25	15	ND	0.01	ND	0.0008	0.05	0.45
6.	FCAW on Stainless Steel No Vent. MN 64815 7/25	10	ND	ND	0.01	ND	0.15	0.26
7.	Synergic Pulse Welding on Stainless Steel No Vent. MN 63355 7/26	20	ND	ND	0.004	ND	0.07	0.21
8.	PAC With Gas on Inconel No Vent. MN 63355 7/26	12	0.006	ND	ND	ND	ND	0.10
9.	FCAW Inside Vessel on Mild Steel With Vent. MN 63355 7/26	10	ND	ND	ND	ND	0.03	0.66
10.	GMAW Using Solid Wire Inside Vessel With Vent. MN 64838 7/26	15	ND	ND	0.01	ND	0.09	0.59
11.	SMAW on Stainless Plate No Vent. MN 63355 7/26	17	ND	ND	ND	ND	0.05	0.09
12.	Silver Soldering on Copper Tubes No Vent. MN 68895 7/27	13	ND	ND	0.01	ND	ND	0.05

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TABLE 2. (Con't.) (Page A) INDIVIDUAL EMPLOYEE CALCULATED 8-HOUR TIME WEIGHTED AVERAGE EXPOSURES* TO METAL FUMES DURING VARIOUS TYPES OF WELDING, MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING, JULY - AUGUST 1988 HEH2.1-1-64(11)

SAMPLE NUMBER	RESULTS IN mg/m^3 AL_2O_3	TiO_2	ZnO	Ni	Cr	TOTAL FUME
1.	ND	0.02	ND	0.005	0.01	0.92
2.	ND	0.01	ND	ND	0.006	1.17
3.	ND	0.02	ND	ND	ND	2.5
4.	ND	0.008	ND	0.09	0.007	2.46
5.	ND	0.03	ND	ND	ND	1.67
6.	ND	0.12	ND	0.02	0.10	3.13
7.	ND	0.007	0.005	0.02	0.04	1.13
8.	0.04	ND	ND	0.03	0.02	0.21
9.	ND	0.02	ND	0.03	0.04	2.38
10.	ND	0.01	0.12	0.03	0.01	1.25
11.	ND	0.04	0.005	0.009	0.04	1.55
12.	ND	ND	0.06	0.008	ND	0.09

TABLE 2. (Con't.) (Page B) INDIVIDUAL EMPLOYEE CALCULATED 8-HOUR TIME WEIGHTED AVERAGE EXPOSURES* TO METAL FUMES DURING VARIOUS TYPES OF WELDING, MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING, JULY - AUGUST, 1988

HEH2.1-1-64(11)

SAMPLE NUMBER	DESCRIPTION OF PROCESS	TIME IN MINUTES	RESULTS IN mg/m^3 SnO	Pb	Cu	Mo	Mn	Fe_2O_3
13.	SMAW on Stainless Steel Plate No Vent. MN 64838 7/26	11	ND	0.006	0.007	ND	0.44	2.09
14.	FCAW on Carbon Steel Inside Vessel No Vent. MN 63386 8/1	15	ND	ND	0.01	0.005	1.14	3.65
15.	FCAW on Carbon Steel No Vent. MN 64838 7/28	15	ND	ND	ND	ND	0.16	0.74
16.	GTAW** on Stainless Steel No Vent. MN 64458 8/1	25	ND	ND	ND	ND	0.003	0.53
17.	PAC With Gas on Stainless Steel No Vent. MN 63355 8/2	14	ND	ND	0.10	0.13	0.19	2.89
18.	SMAW on Nickel Based Monel No Vent. MN 54954 8/1	15	ND	ND	0.006	ND	ND	0.04
19.	GTAW on Carbon Steel No Vent. MN 68895 8/10	30	ND	0.003	0.003	0.009	ND	0.17
20.	FCAW Inside Vessel on Stainless Steel No Vent. MN 63386 8/11	15	ND	ND	ND	ND	0.02	0.08
21.	PAC With Air on Stainless Steel No Vent MN. 63355 8/2	10	ND	ND	0.04	0.01	0.14	2.17
22.	GMAW on Stainless Steel No Vent. MN 64272 8/4	24	0.003	0.004	ND	0.005	0.05	0.16
23.	GMAW Using Copper Coated Solid Wire on Carbon Steel No Vent. MN 68895 8/10	15	ND	0.03	0.04	ND	0.12	1.22

TABLE 2. (Cont.) (Page B) INDIVIDUAL EMPLOYEE CALCULATED 8-HOUR TIME WEIGHTED AVERAGE EXPOSURES* TO METAL FUMES DURING VARIOUS TYPES OF WELDING, MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING, JULY - AUGUST, 1988 HEH2.1-1-64(11)

RESULTS IN mg/m^3

SAMPLE NUMBER	Al_2O_3	TiO_2	ZnO	Ni	Cr	TOTAL FUME
13.	ND	0.10	0.01	0.01	0.007	4.09
14.	ND	0.21	0.01	0.02	0.007	8.86
15.	ND	0.04	0.01	0.02	ND	2.81
16.	ND	0.005	ND	0.005	0.003	0.85
17.	ND	0.008	ND	0.19	0.19	7.65
18.	ND	ND	ND	0.02	ND	1.17
19.	ND	0.005	0.01	0.009	0.004	7.0
20.	ND	0.02	ND	0.008	0.02	2.74
21.	ND	ND	ND	0.14	0.17	4.88
22.	ND	ND	0.005	0.02	0.04	0.73
23.	ND	ND	0.03	ND	ND	3.58

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TABLE 2. (Con't.) (Page C) INDIVIDUAL EMPLOYEE CALCULATED 8-HOUR TIME WEIGHTED AVERAGE EXPOSURES* TO METAL FUMES DURING VARIOUS TYPES OF WELDING, MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING, JULY - AUGUST, 1988

HEH2.1-1-64(11)

SAMPLE NUMBER	DESCRIPTION OF PROCESS	TIME IN MINUTES	RESULTS IN mg/m^3 SnO	Pb	Cu	Mo	Mn	Fe_2O_3
24.	Hardfacing on Carbon Steel No Vent. MN 68895 8/10	10	ND	ND	ND	ND	0.74	1.03
25.	Synergic Pulse Welding on Nickel No Vent. MN 68895 8/10	10	ND	ND	ND	ND	ND	0.03
26.	Metal Spraying Using PROXON 21021 on Carbon Steel With Vent. MN 41517 8/16	10	0.01	0.01	ND	ND	ND	0.05
		IHG =	2	0.05	0.2	5.0	1.0	5.0

TABLE 2. (Con't.) (Page C) INDIVIDUAL EMPLOYEE CALCULATED 8-HOUR TIME WEIGHTED AVERAGE EXPOSURES* TO METAL FUMES DURING VARIOUS TYPES OF WELDING, MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING, JULY - AUGUST, 1988

HEH2.1-1-64(11)

RESULTS IN mg/m^3

SAMPLE NUMBER	Al_2O_3	TiO_2	ZnO	Ni	Cr	TOTAL FUME
24.	ND	0.01	0.005	0.02	0.03	4.13
25.	ND	ND	ND	0.01	ND	1.88
26.	ND	ND	0.008	0.01	ND	-
IHG=	10.0	10.0	5.0	1.0	0.5	5.0

[a]SMAW = Shielded Metal Arc Welding
[b]GMAW = Gas Metal Arc Welding
[c]PAC = Plasma Arc Cutting
[d]FCAW = Flux Core Arc Welding
**GTAW = Gas Tungsten Arc Welding

IHG = Industrial Hygiene Guideline

ND = Non-detectable at a typical analytical sensitivity of 0.004 mg/m^3

MN = Master number

SnO = Tin Oxide
Pb = Lead
Cu = Copper
Mo = Molybdenum
Mn = Manganese
Fe_2O_3 = Iron Oxide
Al_2O_3 = Aluminum Oxide
TiO_2 = Titanium Dioxide
ZnO = Zinc Oxide
Ni = Nickel
Cr = Chromium

* Actual sample duration of 5 to 30 minutes; time weighted average based on assumed 2 hour exposure at measured concentration, 6 hours at zero concentration.

TABLE 3. SUMMARY OF WORK AREA CONCENTRATIONS OF METAL FUMES DURING VARIOUS TYPES OF WELDING, MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING, JULY-AUGUST, 1988. (Summarization of data in Table 4)

HEH2.1-1-64(11)

Description of Process	RESULTS IN mg/m^3 Pb	Cu	Mn	Fe_2O_3	ZnO	Ni	Cr	Total Fume
GMAW[a]	ND	ND-0.05	ND-0.4	0.3-2.4	ND-0.03	0.04-0.005	ND-0.01	1.0-2.1
SMAW[b]	ND	ND	ND-0.4	0.06-2.5	ND-0.03	ND-0.008	0.009-0.04	0.30-1.4
PAC[c]	ND	0.02-0.9	ND-2.9	0.07-32.2	ND-0.03	0.1-3.8	ND-3.9	1.6-16.7
FCAW[d]	ND	ND-0.03	ND-0.5	0.3-2.6	ND	ND-0.2	ND-0.5	0.8-2.4
GTAW[e]	ND	ND	ND-0.05	0.08-0.7	ND	ND-0.3	ND	0.5-0.8
SPW[f]	ND	0.02	0.6	1.8	ND	0.3	ND	1.3
8-hr. TWA IHG =	0.05	0.2	1.0	5.0	5.0	1.0	0.5	5.0

IHG = Industrial Hygiene Guideline
TWA = Time Weighted Average
ND = Non-detectable at typical analytical sensitivity of 0.017 mg/m^3
[a]GMAW = Gas Metal Arc Welding
[b]SMAW = Shielded Metal Arc Welding
[c]PAC = Plasma Arc Cutting
[d]FCAW = Flux Core Arc Welding
[e]GTAW = Gas Tungsten Arc Welding
[f]SPW = Synergic Pulse Welding

Pb = Lead
Cu = Copper
Mn = Manganese
Fe_2O_3 = Iron Oxide
ZnO = Zinc Oxide
Ni = Nickel
Cr = Chromium

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TABLE 4. WORK AREA CONCENTRATIONS OF METAL FUMES DURING VARIOUS TYPES OF WELDING, MICHIGAN
(Page A) DIVISION FABRICATION SHOP, 593 BUILDING, JULY - AUGUST 1988 HEH2.1-1-64(11)

SAMPLE NUMBER	DESCRIPTION OF PROCESS	TIME IN MINUTES	RESULTS IN mg/m³				
			SnO	Pb	Cu	Mo	Mn
1.	GMAW[a] on carbon steel 7/18	07	ND	ND	ND	ND	ND
2.	SMAW[b] on stainless steel 7/18	30	ND	ND	ND	ND	ND
3.	PAC[c] on Hastelloy 7/25	15	0.02	ND	0.02	1.6	ND
4.	FCAW[d] on carbon steel 7/25	15	ND	ND	ND	0.03	0.18
5.	FCAW on stainless steel 7/25	10	ND	ND	ND	0.03	0.13
6.	GTAW[e] on stainless steel 7/26	13	ND	ND	ND	ND	0.05
7.	SPW[f] on stainless steel 7/26	20	ND	ND	0.02	ND	0.6
8.	PAC on stainless steel 7/26	12	ND	ND	0.18	0.1	0.56
9.	FCAW on carbon steel inside a vessel 7/26	10	ND	ND	0.03	ND	0.49
10.	SMAW on stainless plate 7/26	17	ND	ND	ND	ND	0.03
11.	SMAW on stainless plate 7/26	11	ND	ND	ND	ND	0.43
12.	GMAW using solid wire inside a vessel 7/26	15	ND	ND	0.05	ND	0.36
13.	Silver soldering on copper tubes 7/27	13	ND	ND	0.03	ND	ND
14.	FCAW on carbon steel 7/28	15	ND	ND	ND	ND	ND
15.	GTAW on stainless steel 8/1	25	ND	ND	ND	ND	ND
16.	PAC on stainless steel 8/2	14	ND	ND	0.33	0.42	0.78

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TABLE 4. (CON'T.) WORK AREA CONCENTRATIONS OF METAL FUMES DURING VARIOUS TYPES OF WELDING,
(Page A) MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING, JULY - AUGUST 1988

HEH2.1-1-64(11)

RESULTS IN mg/m^3

SAMPLE NUMBER	Fe_2O_3	Al_2O_3	TiO_2	ZnO	Ni	Cr	TOTAL FUME
1.	0.25	ND	ND	ND	0.04	ND	8.57
2.	0.06	ND	0.01	ND	0.008	0.009	2.0
3.	0.07	ND	ND	ND	0.10	ND	6.3
4.	1.09	ND	0.04	ND	0.02	ND	4.0
5.	0.28	ND	0.11	ND	0.05	0.11	9.0
6.	0.70	ND	0.04	ND	0.08	0.11	1.92
7.	1.82	ND	0.13	ND	0.31	ND	5.0
8.	12.43	ND	0.04	0.03	2.0	1.13	29.6
9.	2.63	ND	0.33	ND	0.19	0.54	9.52
10.	0.11	ND	0.04	ND	ND	0.04	1.2
11.	2.46	ND	0.11	0.03	ND	0.03	5.44
12.	2.37	ND	0.03	0.03	0.005	0.01	4.0
13.	0.29	ND	ND	0.16	ND	0.03	5.4
14.	0.45	ND	ND	ND	ND	ND	3.0
15.	0.08	ND	0.03	ND	ND	ND	3.0
16.	11.57	ND	0.03	ND	0.14	0.13	-

TABLE 4. (CON'T.) WORK AREA CONCENTRATIONS OF METAL FUMES DURING VARIOUS TYPES OF WELDING,
(Page B) MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING, JULY - AUGUST 1988

HEH2.1-1-64(11)

SAMPLE NUMBER	DESCRIPTION OF PROCESS	TIME IN MINUTES	RESULTS IN mg/m^3 SnO	Pb	Cu	Mo	Mn
17.	PAC on stainless steel 8/2	18	ND	ND	0.75	0.72	2.75
18.	PAC on stainless steel 8/2	18	ND	ND	0.87	0.67	2.9
19.	PAC on stainless steel 8/2	10	ND	ND	0.11	0.04	0.42
20.	Lunchroom 8/4	535	ND	0.0008	0.005	ND	ND
		8-hr. TWA IHG =	2.0	0.05	0.2	5.0	1.0

TABLE 4. (CON'T.) WORK AREA CONCENTRATIONS OF METAL FUMES DURING VARIOUS TYPES OF WELDING
(Page B) MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING, JULY - AUGUST 1988

HEH2.1-1-64(11)

RESULTS IN mg/m^3

SAMPLE NUMBER	FeO_2O_3	AL_2O_3	TiO_2	ZnO	Ni	Cr	TOTAL FUME
17.	25.9	ND	ND	ND	2.9	3.05	66.68
18.	32.1	1.83	ND	ND	3.77	3.9	66.32
19.	5.6	ND	0.04	ND	0.53	0.6	19.52
20.	0.007	ND	ND	0.002	0.0017	0.0008	0.30
8-Hour TWA IHG =	5.0	10.0	10.0	5.0	1.0	0.5	5.0

[a]GMAW = Gas Metal Arc Welding
[b]SMAW = Shielded Metal Arc Welding
[c]PAC = Plasma Arc Cutting
[d]FCAW = Flux Core Arc Welding
[e]GTAW = Gas Tungsten Arc Welding
[f]SPW = Synergic Pulse Welding

IHG = Industrial Hygiene Guideline

ND = Non-detectable at a typical analytical sensitivity of 0.017 mg/m^3

TWA = Time Weighted Average

SnO = Tin Oxide
Pb = Lead
Cu = Copper
Mo = Molybdenum
Mn = Manganese
Fe_2O_3 = Iron Oxide
Al_2O_3 = Aluminum Oxide
TiO_3 = Titanium Dioxide
ZnO = Zinc Oxide
Ni = Nickel
Cr = Chromium

TABLE 5. SUMMARY OF EMPLOYEES' SHORT TERM EXPOSURE TO DUST DURING HAND HELD GRINDING OPERATIONS, MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING, JULY-AUGUST, 1988. (Summarization of data in Table 6)

HEH2.1-1-64(11)

RESULTS IN mg/m^3

Description of Process	Pb	Cu	Mn	Fe	Zn	Ni	Cr	Total Particulate
Grinding on stainless steel 7/26 MN 63355	ND	ND	0.02	0.64	ND	0.08	0.13	6.28
Grinding on stainless steel 7/26 MN 63355	ND	ND	0.02	0.46	0.02	0.06	0.09	12.48
Grinding on carbon steel painted with zinc primer 7/27 MN 53135	0.05	0.1	0.35	29.3	2.46	0.1	0.06	46.64
Grinding on combination of carbon and stainless steel 7/27 MN 63355	ND	0.04	0.19	24.0	ND	0.85	1.8	78.0
Grinding on carbon steel with zinc primer 7/27 MN 53135	ND	ND	0.12	10.6	0.03	0.03	0.02	64.0
Grinding on combination of carbon and stainless steel 7/27 MN 63355	ND	0.03	0.1	17.5	ND	0.79	1.7	128.0
Grinding on stainless steel 8/4 MN 64272	0.03	0.03	0.12	4.23	0.05	0.59	0.55	113.6
8-hour TWA IHG =	0.15	1.0	5.0	10.0	10.0	1.0	0.5	10.0

IHG = Industrial Hygiene Guideline
TWA = Time Weighted Average
ND = Non-detectable at typical analytical sensitivity of 0.017 mg/m^3
MN = Master number

Pb = Lead
Cu = Copper
Mn = Manganese
Fe = Iron
Zn = Zinc
Ni = Nickel
Cr = Chromium

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TABLE 6. EMPLOYEES' EXPOSURE TO DUST DURING HAND HELD GRINDING OPERATIONS, MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING, JULY - AUGUST 1988. HEH2.1-1-64(11)

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SAMPLE NUMBER	DESCRIPTION OF PROCESS	TIME IN MINUTES	RESULTS IN mg/m^3 Sn	Pb	Cu	Mo	Mn	Fe
1.	Grinding on stainless steel 7/26 MN 63355	25	ND	ND	ND	0.01	0.02	0.64
2.	Grinding on stainless steel 7/26 MN 63355	25	ND	ND	ND	ND	0.02	0.46
3.	Grinding on carbon steel painted with zinc primer 7/27 MN 53135	15	0.05	0.05	0.1	0.04	0.35	29.3
4.	Grinding on combination of carbon and stainless steel 7/27 MN 63355	10	ND	ND	0.04	0.09	0.19	24.0
5.	Grinding on carbon steel painted with zinc primer 7/27 MN 53135	25	0.01	ND	ND	0.02	0.12	10.6
6.	Grinding on combination of carbon and stainless steel 7/27 MN 63355	10	ND	ND	0.03	0.09	0.1	17.5
7.	Grinding on stainless steel 8/4 MN 64272	10	0.04	0.03	0.03	0.13	0.12	4.23
	8-hour time weighted average IHG =		10.0	0.15	1.0	10.0	5.0	10.0

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TABLE 6. (CON'T.) EMPLOYEES' EXPOSURE TO DUST DURING HAND HELD GRINDING OPERATIONS, MICHIGAN DIVISION FABRICATION SHOP, JULY - AUGUST 1988. HEH2.1-1-64(11)

RESULTS IN mg/m^3

SAMPLE NUMBER	Al	Ti	Zn	Ni	Cr	CALCULATED TOTAL PARTICULATE 8-HOUR TWA*
1.	0.16	0.02	ND	0.08	0.13	0.79
2.	0.15	0.03	0.02	0.06	0.09	1.56
3.	0.24	0.22	2.46	0.1	0.06	5.83
4.	0.45	0.14	ND	0.85	1.8	9.75
5.	ND	0.01	0.03	0.03	0.02	8.0
6.	0.30	0.11	ND	0.79	1.7	16.0
7.	1.17	ND	0.05	0.59	0.55	14.2
8-hr. TWA* IHG =	10.0	10.0	10.0	10.0	10.0	10.0

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IHG = Industrial Hygiene Guideline

*TWA = Time Weighted Average

ND = Non-detectable at analytical sensitivity of 0.004 mg/m^3

MN = Master Number

Sn = Tin
Cu = Copper
Mn = Manganese
Al = Aluminum
Zn = Zinc
Cr = Chromium

Pb = Lead
Mo = Molybdenum
Fe = Iron
Ti = Titanium
Ni = Nickel

TABLE 7. COMPARISON OF METAL FUME CONCENTRATIONS INSIDE VERSUS OUTSIDE THE WELDING HOOD, MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING JULY - AUGUST 1988.

HEH2.1-1-64(11)

SAMPLE NUMBER	DESCRIPTION OF PROCESS	RESULTS IN mg/m^3 SnO	Pb	Cu	Mo	Mn	Fe_2O_3
1.	GTAW[a] on carbon steel, 8/10, no ventilation						
	a) inside welding hood	ND	0.01	0.01	ND	0.04	0.69
	b) outside welding hood	0.03	0.03	0.02	ND	0.1	3.02
2.	FCAW[b] on stainless steel, 8/10, no ventilation						
	a) inside welding hood	ND	0.02	0.02	ND	0.27	0.61
	b) outside welding hood	ND	ND	ND	ND	0.09	0.33
3.	GMAW[c] on carbon steel using copper coated wire, 8/10, no ventilation						
	a) inside welding hood	ND	0.11	0.16	ND	0.47	4.87
	b) outside welding hood	ND	0.21	0.26	ND	0.73	8.66
4.	Hardfacing on carbon steel, 8/10, no ventilation						
	a) inside welding hood	ND	ND	ND	ND	2.95	4.12
	b) outside welding hood	ND	0.03	ND	ND	3.60	8.93
5.	Synergic Pulse welding on nickel, 8/10, no ventilation						
	a) inside welding hood	ND	ND	ND	ND	ND	0.12
	b) outside welding hood	ND	0.02	ND	ND	0.02	0.12
	8-hr. TWA IHG =	2.0	0.05	0.2	5.0	1.0	5.0

TABLE 7. (CON'T.) COMPARISON OF METAL FUME CONCENTRATIONS INSIDE VERSUS OUTSIDE THE WELDING HOOD, MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING, JULY-AUGUST, 1988.

HEH2.1-1-64(11)

RESULTS IN mg/m^3

SAMPLE NUMBER	Al_2O_3	TiO_2	ZnO	Ni	Cr	TOTAL FUME
1. inside	ND	0.02	0.04	0.04	0.01	6.12
outside	0.2	0.01	0.07	0.08	0.03	7.0
2. inside	ND	0.17	0.02	0.06	0.27	8.67
outside	ND	0.67	ND	0.03	0.07	10.97
3. inside	ND	ND	0.11	ND	ND	12.90
outside	ND	ND	0.17	0.02	ND	14.33
4. inside	ND	0.05	0.07	0.07	0.12	16.5
outside	ND	0.15	0.07	0.15	0.20	20.5
5. inside	ND	ND	ND	0.05	ND	3.59
outside	ND	ND	ND	0.03	ND	7.5
8-hr. TWA IHG =	10.0	10.0	5.0	1.0	0.5	5.0

[a]GTAW = Gas Tungsten Arc Welding
[b]FCAW = Flux Core Arc Welding
[c]GMAW = Gas Metal Arc Welding

IHG = Industrial Hygiene Guideline

ND = Non-detectable at an analytical sensitivity of 0.17 mg/m^3

SnO = Tin Oxide
Pb = Lead
Cu = Copper
Mo = Molybdenum
Mn = Manganese
Fe_2O_3 = Iron Oxide
Al_2O_3 = Aluminum Oxide
TiO_2 = Titanium Dioxide
ZnO = Zinc Oxide
Ni = Nickel
Cr = Chromium

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TABLE 8. SUMMARY: EMPLOYEE EXPOSURE AND SIMULTANEOUS WORK AREA CONCENTRATIONS OF METAL FUMES, MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING JULY-AUGUST, 1988

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RESULTS IN mg/m^3

	Pb	Cu	Mn	Fe_2O_3	ZnO	Ni	Cr
SHIELDED METAL ARC WELDING							
No vent., stainless steel							
Personal	0.02	0.03	1.76	8.4	0.2	0.04	0.03
Area	ND	ND	0.44	2.48	0.032	ND	0.03
GAS METAL ARC WELDING							
With vent., carbon steel, inside a vessel							
Personal	ND	0.04	0.36	2.4	0.24	0.12	0.04
Area	ND	0.04	0.36	2.4	0.03	0.008	0.012
PLASMA ARC CUTTING							
No vent, stainless steel							
Personal	ND	0.4	0.76	11.56	ND	0.76	0.76
Area	ND	0.32	0.8	11.56	ND	ND	ND
GAS TUNGSTEN ARC WELDING							
No vent., carbon steel							
Personal	0.012	0.012	ND	0.68	0.16	0.036	0.016
Area	ND	ND	0.04	0.72	ND	0.052	0.11
FLUX CORE ARC WELDING							
No vent., carbon steel inside a vessel							
Personal	ND	0.04	4.56	14.6	0.20	0.08	0.028
Area	ND	0.032	0.48	2.64	ND	1.92	0.56
8-Hour Time Weighted Average IHG =	0.05	0.2	1.0	5.0	5.0	1.0	0.5

IHG = Industrial Hygiene Guideline

ND = Non-detectable at an analytical sensitivity of 0.017 mg/m^3

Pb = Lead
Cu = Copper
Mn = Manganese
Fe_2O_3 = Iron Oxide
ZnO = Zinc Oxide
Ni = Nickel
Cr = Chromium

Table 9. EMPLOYEES' SHORT TERM SAMPLING RESULTS FOR OZONE DURING VARIOUS TYPES OF WELDING, MICHIGAN DIVISION FABRICATION SHOP, 593 BUILDING, JULY - AUGUST, 1988

HEH2.1-1-64(11)

Description of Process	Time In Minutes	Concentration in mg/m^3
PAC[a] on carbon steel 7/18 No ventilation	15	ND
GMAW[b] on stainless steel 7/25 No ventilation	10	ND
GMAW on carbon steel 7/25 No ventilation	15	ND
PAC on hastelloy 7/25 No ventilation	15	ND
FCAW[c] on stainless steel 7/26 With ventilation	10	ND
PAC on stainless steel 7/28 No ventilation	14	0.075
PAC on stainless steel 8/2 No ventilation	18	0.075
	Short-Term Exposure Limit =	0.6

[a]PAC = Plasma Arc Cutting
[b]GMAW = Gas Metal Arc Welding
[c]FCAW = Flux Core Arc Welding
ND = Non-detectable at a typical analytical sensitivity of $0.01 mg/m^3$

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