HETA 91-392-2291
March 1993
Iron Workers Union, Local 372
Cincinnati, Ohio

NIOSH INVESTIGATORS:
Herbert L. Venable
Eric J. Esswein
Howard S. Brightman

I. SUMMARY

On September 10, 1991, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the Center to Protect Workers' Rights on behalf of the International Association of Bridge, Structural and Ornamental Iron Workers, Iron Workers Local 372, Cincinnati, Ohio. NIOSH was asked to evaluate possible hazards arising from the cutting of epoxy coated steel reinforcing rod (coated rod) used in the construction of concrete structures. Concern was expressed about worker exposure to decomposition products of epoxy resins when coated rod was cut with a gasoline powered cut-off saw or an oxy-acetylene cutting torch. Concern was also expressed about exposure to solvents when painting uncoated steel with an epoxy paint patch kit.

A sampling protocol was developed to screen for the compounds known to be present in the epoxy coating and the "patch" kit, as well as unexpected thermal decomposition products.

Under simulated working conditions, personal breathing zone (PBZ) air samples were taken for total particulates, metals, oxides of nitrogen, aldehydes, 4,4-methylene dianiline, volatile organic compounds, and carbon monoxide during cutting procedures using both a cut-off saw and a cutting torch. Similarly, sampling for methyl isobutyl ketone, xylene, and 2-butoxyethanol was conducted during simulated painting activities using an epoxy paint "patch" kit.

Personal breathing zone air samples collected during cutting operations indicated exposures of up to 19.43 milligrams per cubic meter (mg/M^3) of total particulates (OSHA Permissible Exposure Level [PEL]) 15 mg/M^3, 6.27 mg/M^3 of iron (NIOSH Recommended Exposure Level [REL]) 5 mg/M^3, 0.146 mg/M^3 of copper (REL - 0.1 mg/M^3), 0.034 mg/M^3 of nickel (REL - 0.015 mg/M^3), 0.023 mg/M^3 of titanium (REL - lowest feasible level) and 0.009 mg/M^3 of arsenic (REL - 0.002 mg/M^3). Carbon monoxide levels ranged from 0 to 346 ppm with an 8-hour time-weighted average (TWA) exposure of 16 ppm. The 8-hour TWA for CO did not exceed the PEL of 35 ppm but the ceiling value of 200 ppm was exceeded several times during the 8-hour sampling period. Only trace levels of compounds associated with decomposition products of the epoxy resin coating, including aldehydes or volatile organic compounds were detected.

Samples collected during the use of the epoxy "patch" kit indicated trace levels of methyl isobutyl ketone and xylene but no detectable 2-butoxyethanol.

Data obtained under simulated working conditions indicated no exposures of concern which would be directly attributable to the epoxy resin coating on the rods or decomposition of the resin during cutting operations. Similarly no excessive exposures were identified while simulating the use of the epoxy "patch" kit. Overexposures to total particulates and various metals including iron, nickel, copper, titanium, and arsenic were documented. The sources of these substances were most likely the reinforcing rod and the cutting wheel. The peak carbon monoxide exposures correlated with the use of the cut-off saw which was powered by a gasoline engine. Recommendations to control exposures while cutting both coated and uncoated steel are provided in Section VIII of this report.

KEYWORDS: SIC 1791 (Structural Steel Erection) dust, metals, carbon monoxide, epoxy coating, epoxy resin paint, volatile organic compounds, aldehydes, formaldehyde, xylenes, 2-butoxyethanol

II. INTRODUCTION

On September 10, 1991, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from International Iron Workers Local 372, Cincinnati, Ohio to evaluate possible hazards arising from the cutting of epoxy coated steel reinforcing rod (coated rod) used in the construction of concrete structures. Concern was expressed about worker exposure to combustion products of epoxy resins when coated steel reinforcing rod was cut with a gasoline powered cut-off saw, or with an oxy-acetylene cutting torch. Concern was also expressed about exposure to solvents when painting uncoated steel with a "patch" kit consisting of a two-part epoxy resin paint.

In September 1991 an initial planning meeting was held with representatives from the International Iron Workers Union, the Iron Workers Union Local 372, and the AFL-CIO Workers Right-to-Know Center. It was agreed that on-site visits to two construction sites in the Cincinnati area would be conducted in order to familiarize NIOSH personnel with actual working conditions at the construction sites. The on-site visits were conducted on November 3, 1991. Following these site visits it was determined that potential exposures would be more appropriately addressed by conducting the HHE at a simulated construction worksite, where industrial hygiene sampling could be performed without adversely affecting the construction schedule.

On November 16, 1991, an environmental survey was conducted at a simulated worksite designed to represent the various phases of construction that used coated rod. Exposure monitoring was conducted while a volunteer iron worker performed cutting and painting operations.

III. BACKGROUND

Typically, concrete structures are reinforced with steel reinforcing rods. The rods, varying in size and bent to shape based on structural strength, design, and load bearing parameters, are wired together in place, or wired together and then placed in excavated areas or forms into which concrete is poured. The reinforcing rod is totally encased in concrete unless additional rod is to be connected and the process continued. In this latter case, a portion of the rod protrudes from the concrete to allow these connections. The final pouring of concrete usually completes the encapsulation of the rod.

Coated rod is most often used in concrete structures exposed to the weather. Examples include multi-level parking garages, bridges, and road surfaces. The epoxy coating prolongs the life of the rod by minimizing corrosive chemical action between the steel and encasing concrete. To a lesser extent, the epoxy coating also minimizes corrosive chemical action from external sources such as salt used to de-ice parking lot and roadway surfaces.

For economic reasons and for expediting construction, coated rod is usually supplied by the manufacturer already cut to length. According to the Material Safety Data Sheet (MSDS), the bonded epoxy coating applied by the manufacturer consists of modified epoxy resin, chrome oxide, titanium dioxide, methylene dianiline and an organic acid anhydride.

In some instances the rod must be cut because of changes or errors in design, unexpected obstacles in construction, or mistakes in the placement of reinforcement. Rod is cut with either a gasoline powered cut-off saw fitted with a cutting wheel or with an oxy-acetylene cutting torch. Smoke, and possibly fumes, are given off during the cutting operation regardless of the method. In some instances, the rods are welded together, which also generates smoke and possibly fumes.

The MSDS provided by the manufacturer lists carbon dioxide and oxides of nitrogen as possible decomposition products of the epoxy coating.

In cases where the epoxy coating has been burned or scraped away, an epoxy paint "patch" kit is used to re-coat the exposed metal surface. Essentially, the process consists of hand painting the exposed areas with the epoxy paint. The "patch" kit used in this evaluation was supplied in two parts that were mixed just prior to use. Part "A" of the "patch" compound consisted of liquid epoxy resin, methyl isobutyl ketone, xylene, calcium carbonate and titanium dioxide. Part "B" contained a polyamide curative, methyl isobutyl ketone, 2-butoxyethanol and xylene. The MSDS for the "patch" compound indicated potential skin irritation on direct contact, skin absorption of solvents and respiratory irritation and nervous system impairment by inhalation. A NIOSH approved respirator with organic vapor cartridges was recommended where ventilation was limited, with a positive-pressure supplied air respirator recommended for confined spaces.

IV. METHODS

A simulated enclosed working space was constructed using plywood panels and framing supports. The panels were placed horizontally around the worksite and nailed together. The top was left open. This area was used to simulate "worst case" exposure situations, such as with excavation.

In addition, coated rod was wired together in various configurations similar to those at an actual construction site. These configurations included steel reinforcing rod woven and wired into mats and placed on the ground, as in constructing horizontal concrete surfaces. Other configurations simulated the wiring of steel reinforcing rod into vertical columns, as in the construction of reinforced concrete pillars. Finally, large diameter coated rod was configured into reinforcing structures used in the construction of footers, the lowest structural elements which support most of the structure's weight.

To simulate the use of the "patch" kit, the exposed ends of coated rod were painted with the epoxy paint using a 3-inch wide paintbrush. Painting was done on rods held in both the vertical and horizontal positions.

The sampling protocol was designed to screen for the chemical substances listed on the MSDS, as well as thermal decomposition products. Both compound-specific and broad compound-class screening techniques were employed.

During the cutting operations, air samples were collected over an eight hour period for total particulate, nitrogen dioxide, nitric oxide, 4,4'methlyene- dianiline, formaldehyde, aldehydes, metals and volatile organic compounds (VOCs). Samples collected during painting operations included methyl isobutyl ketone (MIBK), xylene, 2-butoxyethanol and VOCs. Table I lists specific information on sample collection and analyses by compound or compound class.

Prior to cutting and painting operations, the worker was fitted with a powered air purifying respirator (PAPR) equipped with a combination organic vapor and high efficiency particulate air (HEPA) filter cartridge to protect against potential airborne hazards.

V. EVALUATION CRITERIA

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

The primary sources of environmental evaluation criteria for the workplace are the following: 1) NIOSH Criteria Documents and Recommended Exposure Limits (RELs), 2) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs), and 3) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs).[5,2,3] The OSHA PELs may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; in contrast, the NIOSH-RELs are primarily based upon the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing those levels found in this report, it should be noted that employers are legally required to meet those levels specified by an OSHA PEL.

A time-weighted average exposure level (TWA) refers to the average airborne concentration of a substance during a normal eight- to ten-hour workday. Some substances have recommended short-term exposure limits (STELs) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from brief high exposures.

<u>Total Particulate</u> - Particulate Not Otherwise Classified
Total particulates, in the form of so called "nuisance" dusts, are dusts which have no evidence of adverse effects on the lungs and do not produce significant organic disease or toxic effects when exposures are kept under reasonable control. Excessive concentrations of total particulates may cause reduced visibility, excessive deposit in the eyes, ears and nasal passages or cause injury to the skin or mucous membranes by chemical or mechanical action. Because the particulate in this evaluation contained a variety of toxic metals, the nuisance dust criteria would not apply but can be used as a general guideline to indicate degree of exposure. The OSHA PEL for total particulates is 15 mg/M^3.

Iron

The inhalation of iron oxide fume or dust may cause a "benign pneumoconiosis" (siderosis). This is a chest x-ray abnormality that is not associated with symptoms or impaired lung function. It is probable that the inhalation of pure iron oxide does not cause fibrotic pulmonary changes, whereas the inhalation of iron oxide plus certain other substances may cause injury. The NIOSH REL for iron oxide is 5 mg/M^3.

Copper

The fumes and dust from copper may cause irritation of the upper respiratory tract, metallic taste in the mouth, nausea, metal fume fever, and in some instances discoloration of the skin and hair. Copper fumes can cause metal fume fever, a self-limited illness characterized by fever, chills, muscle aches and other symptoms. The NIOSH REL for copper fume is 0.1 mg/M^3.

Nickel

Exposure to nickel can be irritating to the conjunctiva of the eye and the mucous membrane of the upper respiratory tract and can cause dermatitis. Nickel exposure can produce an increased incidence of cancer of the lung and nasal passages. NIOSH considers nickel to be a potential occupational carcinogen with a REL of 0.015 mg/M^3.

Arsenic

Exposure to arsenic can cause skin and mucous membrane irritation. Skin hyperpigmentation, keratoses and dermatitis are common effects of chronic exposure. NIOSH also considers arsenic to be an occupational carcinogen with a REL of 0.002 mg/M^3.

Titanium

Titanium and titanium compounds, for the most part, have been considered virtually inert and not highly toxic to man. Titanium dioxide has recently been considered a potential occupational carcinogen based on inhalation studies on rats. Results indicated increases in bronchioloalveolar adenomas and squamous cell carcinomas. As a result, NIOSH recommends exposure to titanium dioxide be reduced to the lowest feasible level. In this survey, we were unable to establish whether the source of the titanium measured was titanium metal from the rod or titanium dioxide from the epoxy resin. It is therefore prudent to control levels of titanium to the lowest feasible concentration.

Carbon Monoxide

Carbon monoxide combines with hemoglobin to form carboxyhemoglobin which interferes with the oxygen carrying capacity of blood, resulting in a state of tissue hypoxia. The typical signs and symptoms of acute CO poisoning are headache, dizziness, drowsiness, nausea, vomiting, collapse, coma, and death. Initially the victim is pale; later the skin and mucous membranes may be cherry-red in color. Loss of consciousness occurs at about the 50% carboxyhemoglobin level. The amount of carboxyhemoglobin formed is dependent on concentration and duration of CO exposure, ambient temperature, health, and metabolism of the individual. The formation of carboxyhemoglobin is a reversible process. Recovery from acute poisoning usually occurs without sequelae unless tissue hypoxia was severe enough to result in brain cell degeneration. The NIOSH REL for carbon monoxide is 35 ppm as a time weighted average (TWA) with a ceiling level of 200 ppm.

VI. Results

Cut-Off SAW

A total particulate concentration of 19.43 mg/M^3 was measured during cutting operations using the cut-off saw. This level exceeds the OSHA PEL of 15 mg/M^3 for total particulate; however, this PEL is not protective enough since emissions were found to contain toxic metals. Iron was identified as the most abundant metal in the sample, at a concentration of 6.27 mg/M^3. This exceeds the NIOSH REL of 5 mg/M^3 (OSHA PEL - 10 mg/M^3). Copper was detected at a concentration of 0.108 mg/M^3 (REL - 0.1 mg/M^3) and nickel at 0.019 mg/M^3 (REL - 0.015 mg/M^3). The titanium concentration was 0.023 mg/M^3 (REL - Lowest Feasible Level). Arsenic levels were found to be 0.009 mg/M^3 (REL - 0.002 mg/M^3). Other metals detected but below their respective PELs or RELs are listed in Table II.

A trace level of formaldehyde was detected on the sampling tube. The presence of trace levels of formaldehyde was also detected by thermal desorption. Formaldehyde levels were below the limits of detection of the direct reading Interscan monitor or the Draeger detector tubes. NIOSH recommends formaldehyde concentrations be reduced to the lowest feasible level. The OSHA PEL for formaldehyde is 0.75 parts per million (ppm). A trace level of acetaldehyde was detected, but not quantitated, using thermal desorption techniques. Toluene (<1 ppm), xylene (<1 ppm), and C_4 - C_8 alkanes were measured on charcoal tubes. All levels were well below their respective RELs. Samples collected using thermal desorption techniques also had low, but detectable, levels of various aliphatic hydrocarbons in the C_4 - C_9 range as well as toluene, xylenes, and higher molecular weight aromatic compounds such as C_9 - C_{10} benzenes including tri-methyl-, tetramethyl-, and dimethylethylbenzene. Ethoxyethyl acetate was detected on two of the samples. The thermal desorption technique is a qualitative procedure and therefore does not permit quantification of these chemicals.

Carbon monoxide levels were monitored throughout the entire sampling period (approximately eight hours). Exposure levels ranged from 0 to 346 ppm, with a calculated 8-hour TWA of 16 ppm. The 8-hour TWA did not exceed the PEL of 35 ppm. The ceiling value of 200 ppm, however, was exceeded several times during the 8-hour sampling period.

Due to analytical problems, the sampling results for nitrogen dioxide and nitrogen oxides were considered invalid. No 4,4'-methylenedianiline was detected (< 0.002 mg/M^3 based on a 51 liter sample volume).

Cutting Torch

A total particulate level of 10.83 mg/M^3 (PEL - 15 mg/M^3) was measured during cutting operations using the cutting torch. Again, iron was the most abundant metal identified in the sample, at a concentration of 6.04 mg/M^3 (REL - 5 mg/M^3). Copper was detected at a concentration of 0.146 mg/M^3 (REL - 0.1 mg/M^3) and nickel at 0.034 mg/M^3 (REL - 0.015 mg/M^3). Titanium levels were 0.014 mg/M^3

(REL - LFL) and arsenic concentrations were 0.006 mg/M^3 (REL - 0.002 mg/M^3). Other metals detected at levels below their respective PELs or RELs are listed in Table II. No detectable concentrations of aldehyde, including formaldehyde, were detected by any of the sampling techniques used. The only VOCs detected were toluene, xylene and some higher molecular weight aromatic compounds. All were present at very low concentrations (<1 ppm). No 4,4'-methylenedianiline was detected.

Epoxy Painting

Traces of MIBK were detected in samples taken during painting activities using thermal desorption techniques. Since this is a qualitative method, quantification was not available. MIBK was not detected in samples collected using charcoal tubes. The PEL for MIBK is 205 mg/M^3.

Xylenes were detected in low quantities using qualitative thermal desorption. Xylene was detected at a concentration of 2.08 mg/M^3 using charcoal tubes in sampling painting activities. The PEL for xylene is 435 mg/M^3.

2-Butoxyethanol was not detected in painting activities to a minimum detectable concentration of 0.001 mg/M^3 based on a 10 liter sample, nor was it detected using thermal desorption techniques. The REL for 2-butoxyethanol is 24 mg/M^3.

VII. Discussion

The data obtained under simulated working conditions indicates no exposures of concern which would be directly attributable to the epoxy resin coating on the rods or decomposition of the resin during cutting operations. Similarly, no excessive exposures were identified while simulating the use of the epoxy "patch" kit. It must be noted that the data reported are based on the sampling of one worker performing work activities in a simulated work site. Differences in working conditions between the simulated construction site and an actual construction site may produce different effects and results. It should also be noted that sampling could not be performed for every possible contaminant present and exposures could be occurring which were not documented. The data, however, suggest another very important fact. Overexposures to total particulates and various metals including iron, nickel, copper, titanium and arsenic were documented. The sources of these substances were most likely the reinforcing rod and the cutting wheel when using the cut off saw. The peak carbon monoxide exposures correlated with the use of the gas powered cut off saw.

This study suggests that significant exposures to a variety of substances are occurring during cutting operations, whether the rod is coated or uncoated. Therefore, a general need exists for ventilation and/or personal protective equipment during cutting operations. Measures to reduce these exposures would also be effective in reducing potential exposures resulting from cutting coated rods.

VIII. Recommendations

The following recommendations should be followed when reinforcing rod is cut using either a gas powered cut-off saw or a cutting torch, regardless of whether the rod is coated or uncoated.

1. An on-site evaluation should be performed to verify the exposures which were documented under simulated conditions.

2. Avoid cutting reinforcing rod (coated or uncoated) in enclosed spaces.

3. If rod cutting is required in an enclosed space, attempts should be made to provide local exhaust ventilation.

4. If rod cutting is performed in an unventilated area, workers should wear a half-face air purifying respirator fitted with a combination organic vapor and HEPA filter cartridge. Supplied air respirators may be necessary if measurements indicate overexposures to carbon monoxide under actual worksite conditions.

5. The manufacturer's recommendations for respirator protection should be followed when using the "patch" kits. The manufacturer recommends the use of an organic vapor cartridge respirator where ventilation is limited and a positive supply air respirator in confined spaces. Contaminants remaining from the cutting operations may reinforce the need for respiratory protection.

6. Butyl rubber gloves, impervious to the solvent present in the "patch" kits, should be worn when painting.

7. A noise dosimetry study should be conducted to measure noise exposures.

IX. REFERENCES

1. National Institute for Occupational Safety and Health. NIOSH Manual of Analytical Methods, 3rd Edition. Cincinnati, OHIO, (DHHS (NIOSH) publication No. 84-100), 1984.

2. Code of Federal Regulations [1989]. Air Contaminants - Permissible Exposure Limits. 29 CFR 1910.1000 (amended). U.S. Government Printing Office, Federal Register.

3. ACGIH [1992]. Threshold limit values and biological indices for 1992-1993. Cincinnati, Ohio: American Conference of Governmental Hygienists.

4. National Institute for Occupational Safety and Health. NIOSH Pocket Guide to Chemical Hazards, 2nd Printing, Cincinnati, Ohio. DHHS (NIOSH) publication no. 85-114, 1985.

5. CDC [1988]. NIOSH recommendations for occupational safety and health standards 1988. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. MMWR 37 (supp. S-7).

X. AUTHORSHIP AND ACKNOWLEDGEMENTS

Originating Office:	Hazard Evaluations and Technical Assistance Branch Division of Surveillance, Hazard Evaluations and Field Studies
Report prepared by:	Herbert L. Venable Industrial Hygienist Hazard Section, DSHEFS Eric J. Esswein Industrial Hygienist Industrial Hygiene Section, DSHEFS
Field Assistance:	Howard S. Brightman Industrial Hygienist Industry Wide Studies Branch, Eric J. Esswein Industrial Hygienist Industrial Hygiene Section, DSHEFS
Analytical Assistance:	Ardith A. Grote Chemist Measurements Development Section Measurements Research Support Branch Division of Physical Sciences and Engineering Data Chem Laboratories Salt Lake City, UT
Report Typed By:	Kate L. Marlow Office Automation Clerk Industrial Hygiene Section, DSHEFS

XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report may be freely reproduced and are not copyrighted. Single copies of this report will be available for a period of 90 days from the date of this report from the NIOSH Publications Office, 4676 Columbia Parkway, Cincinnati, OH 45226. To expedite your request, include a self-addressed mailing label along with your written request. After this time, copies may be purchased from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA

22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

Copies of this report have been sent to:

1. International Iron Workers Union, Local 377, Cincinnati, Ohio
2. International Iron Workers Union, Washington, D.C.
3. OSHA, Region V

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

TABLE I

Sampling and Analysis Techniques
Iron Workers Local Union 372
HETA 91-392
November 16, 1991

Substance	Collection Media	Flow Rate	Analytical Method
Total Particulate	Pre-weighed Polyvinyl chloride filters	1.5ℓ/min.	NIOSH Method 0500
Metals	Polyvinyl chloride filters	1.5ℓ/min.	NIOSH Method 7300
Oxides of Nitrogen	Palmes Tubes	Passive Diffusion	NIOSH Method 6700
Aldehydes	Orbo 42 Sampling Tubes	50cc/min.	NIOSH Method 2539
4,4'Methylenedianiline	Acid Treated Glass Fiber Filter	3ℓ/min.	NIOSH Method 5029
Volatile Organic Compounds	Charcoal Tubes Carbotrap Thermal Tubes	200cc/min 50cc/min.	NIOSH Method 1501 Thermal Desorption
Carbon Monoxide	Draeger Model 190 Data Logger Monitor		

TABLE II
Metals Data

Iron Workers Local Union 372
HETA 91-392
November 16, 1991

SAMPLE DESCRIPTION:*							
Element	Cut-off Saw (Mg/M^3) Sample	MDC[1]	Cutting Torch (Mg/M^3) Sample	MDC[1]	NIOSH REL (Mg/M^3	OSHA PEL (Mg/M^3)	ACGIH TLV (Mg/M^3)
Aluminum	0.205	0.006				15.00	10.0
Arsenic	0.009	0.006			0.002C	0.01	0.2
Barium	0.002	0.001			L	0.5	0.5
Chromium	0.009	0.001	0.023	0.005	0.5	1.0	0.5
Copper	0.108	0.001	0.146	0.005	0.5	0.1	1.0 (dust)
Iron	6.268	0.001	6.042	0.010	0.1	10.0	5.0
Lead	0.011	0.003	0.031	0.010	5.0	0.05	0.15
Magnesium	0.011	0.003			<0.1	10.0	10.0 (fume)
Manganese	0.051	0.001	0.038	0.005		5.OC	5.0 (dust)
					1.0		
Molybdenum	0.006	0.001	0.007	0.005	3.OSTL	10.(insol)	
Nickel	0.024	0.001	0.034	0.005	10.0	1.0	1.0
Thallium	0.031	0.009			0.015	0.1Sk	0.1Sk
Titanium[1]	0.023	0.001	0.014	0.031	0.1	10.0	10.0
Zinc	0.009	0.003	0.031	0.010	***	10.0	10.0 (dust)
Zirconium	0.005	0.001			5.0	5.9	5.0
					5.0	10.0STL	10.0STL
					10.9STL		

* = Sample volume was 351 and 96 liters of air for the cut-off saw and oxy-acetylene cutting torch respectively.
MDC = minimum detectable concentration
*** = Lowest feasible concentration
1 = exposure data reported for the metal oxide.

CL=ceiling, STL=short term exposure limit, Sk=skin, LOQ=limit of quantification; no values given for REL indicates none stated at this time. All other values presented are expressed as 8-hour time-weighted averages (TWAs).