HETA 96-0137-2607
Yankee Atomic Electric Company
Rowe, Massachusetts

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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by David C. Sylvain, M.S., CIH, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Eric J. Esswein, M.S.P.H., CIH, and C. Eugene Moss, HP, CSS. Desktop publishing by Pat Lovell.

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Yankee Atomic Electric Company
Rowe, Massachusetts
October 1996

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SUMMARY

The National Institute for Occupational Safety and Health (NIOSH) conducted a Health Hazard Evaluation (HHE) at the Yankee Nuclear Power Station (Yankee Rowe) located in Rowe, Massachusetts, in response to a management request for evaluation of ozone exposure during plasma arc cutting and welding. The company had conducted air monitoring, but found ozone exposure to be difficult to evaluate. The request indicated that welders had reported chest tightness, dry cough, and throat and bronchial irritation.

Yankee Rowe, which had operated from 1962 until February 1992, was in the process of being decommissioned at the time of this HHE. Welders were isolating and dismantling plant components using a variety of welding and cutting methods. Plasma arc cutting was the preferred technique for dismantling components because it enabled work to be completed quickly; however, Yankee staff discovered that plasma arc cutting produced ozone that was believed to be related to welders' health complaints.

NIOSH investigators conducted personal breathing zone air monitoring for ozone using a Metrosonics personal dosimeter equipped with an ozone sensor. Sampling was conducted during welding and cutting operations inside a mock-up welding enclosure in a non-radiation area. In addition to PBZ monitoring, results obtained using a CEA TG-800KA direct reading ozone meter were compared with similar readings obtained on an identical instrument that was used inside the enclosure by Yankee staff.

Of welding and cutting operations conducted during the site visit, the highest ozone concentrations were generated during plasma arc cutting; followed by MIG welding, and arc welding. During plasma arc cutting, average and peak concentrations exceeded the NIOSH REL and the ACGIH ceiling. Comparison of readings obtained using the two CEA ozone monitors indicated that they differed by 0 - 0.03 ppm. An exact comparison of the performance of the two meters was not possible due to factors such as variability in the position of the probes and welding plume size.

Air monitoring data indicates that exposure to ozone during plasma arc cutting and MIG welding presents a health hazard to welders during decommissioning operations. Ozone concentrations during plasma arc cutting and MIG welding exceeded 0.1 ppm which is the ceiling exposure criteria established by NIOSH and ACGIH. Employee reports of chest tightness, dry cough, and throat and bronchial irritation are consistent with exposure to ozone at these levels.

Keywords: SIC 4911 (electric services), Direct-reading instruments, MIG welding, nuclear power plant decommissioning, ozone, plasma arc cutting, welding.

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INTRODUCTION

On April 8, 1996, the National Institute for Occupational Safety and Health (NIOSH) received a Health Hazard Evaluation (HHE) request from the Health and Safety Supervisor at the Yankee Nuclear Power Station (Yankee Rowe) located in Rowe, Massachusetts. The request expressed concern about ozone exposure during plasma arc cutting and welding. The company had conducted air monitoring, but found ozone exposure to be difficult to evaluate. The request indicated that welders had reported chest tightness, dry cough, and throat and bronchial irritation.

BACKGROUND

Yankee Rowe was the third nuclear power plant constructed in the United States. The plant operated from 1962 until February 1992, when the decision was made to permanently cease operation. At that time, plans were made to decommission the plant and return the site to a "green field condition." During late 1993 through early 1994, steam generators, pressurizer, and reactor internals were removed and shipped to the low-level radioactive waste disposal facility in Barnwell, South Carolina. Other components were sent to Oakridge, Tennessee, for reuse in the nuclear industry. The decommissioning process is expected to be completed in 1997.

During decommissioning, the various plant systems are systematically isolated, dismantled, and processed. Welders isolate components using welding methods which include arc, metal inert gas (MIG), tungsten inert gas (TIG) and plasma arc welding. Components are dismantled using plasma arc cutting equipment. Both operations (welding and cutting) occur within tented enclosures that are erected around the system which is to be dismantled.

On or about October 1995, welders reported chest tightness, dry cough, and upper respiratory irritation. Yankee staff used detector tubes to evaluate ozone concentrations, and found levels to be generally around 1.7 parts per million (ppm), with occasional peaks which exceeded the range of the tubes. Reports of symptoms subsided when respiratory protection was upgraded from powered air-purifying respirators (PAPRs) to supplied-air respirators. The company continued to monitor for ozone using a direct-reading ozone meter, and found that ozone concentrations exceeded the maximum concentration that could be measured by the meter (1.99 ppm) for indeterminate periods. The accuracy of the measurements was uncertain, and there was concern that halogen gases and electromagnetic fields might be affecting the measurements. In addition, the meter did not provide an estimate of time-weighted average (TWA) or peak ozone concentrations.

METHODS

On June 4, 1996, NIOSH investigators conducted air monitoring for ozone using a CEA TG-800KA direct reading ozone meter, and a Metrosonics personal dosimeter equipped with an ozone sensor. Each of these instruments was calibrated prior to the site visit. Sampling was conducted during welding and cutting operations inside a simulated welding enclosure (mock-up) which had been constructed in a non-radiation area. Yankee staff typically use mock-ups to evaluate the effectiveness of decommissioning operations that are planned for use in radiation areas. Mock-ups are used to qualify welders, and to ensure that satisfactory welds can be achieved using specific equipment and methods. In this case, the mock-up was also used to evaluate ozone exposure during selected welding and cutting operations. Employees participating in the mock up exercise, and NIOSH representatives who monitored ozone concentrations inside the enclosure, wore supplied-air full-facepiece respirators during the simulation.

The mock-up consisted of an 8′ x 10′ x 7 ½′ poly enclosure configured with heat-resistant welding cloth on the lower half of the inside perimeter wall. Local exhaust ventilation was provided by a plain (unflanged) flexible duct connected to an Air-Pak model AP-2000 portable HEPA unit (2000 cfm rating). The end of the duct was suspended over the bench where the workpiece was placed. While cutting and welding, the worker moved the point of operation along the workpiece, while the duct remained stationary above the workbench. Make-up air for the enclosure entered through two low-efficiency filters mounted approximately two feet above floor-level near a corner of the enclosure. Air also entered the enclosure through the double-sided poly flaps serving as the entry and exit to the enclosure.

Personal air monitoring was conducted using a Metrosonics dosimeter equipped with an ozone sensor. The sensor was clipped to the welder's right lapel, i.e., in his personal breathing zone (PBZ). The datalogging capability of the Metrosonics dosimeter was utilized to store sampling data and to generate sampling reports. Reports include an overall statistics report and a plot of ozone concentration over time. The statistics report provided minimum, maximum, and average ozone concentrations during each round of sampling.

A NIOSH investigator remained in the enclosure during the multiple rounds of sampling that were conducted during various cutting/welding operations. The investigator used the CEA monitor to evaluate ozone concentrations near the worker's breathing zone and at various points throughout the enclosure. Since the CEA monitor was not equipped with a datalogger or strip-chart recorder, data obtained using the CEA had to be hand-recorded as it appeared on a digital display.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially 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: (1) NIOSH Recommended Exposure Limits (RELs)[1], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs™)[2] and (3) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs)[3]. In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

A time-weighted average (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 which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term. A STEL is a 15-minute TWA concentration which should not be exceeded. Ceiling values denote limits that should not be exceeded even instantaneously.

Ozone

Ozone (O_3) is a colorless gas consisting of three atoms of oxygen rather than two, as in normal atmospheric oxygen. Ozone is unstable and highly reactive, and consequently high concentrations are usually found only in the immediate vicinity of where it was formed.[4] Ozone is less stable at high relative humidities. Natural sources may produce ambient air levels of 0.04 to 0.05 ppm, caused predominately by the down draft of stratospheric ozone. Ambient ozone is also produced by a photochemical interaction of hydrocarbons, nitrogen oxides, and light. Concentrations of ozone in indoor environments have been reported to range between 0.04 and 0.40 ppm.[5] Common indoor sources of ozone include photocopy machines, laser printers, and electrostatic air cleaners. Ozone is often produced by equipment utilizing high electrical charges.[5]

During welding operations, atmospheric oxygen is converted to ozone in the ultraviolet field produced by the welding arc.[6,7] Of the various welding processes that are commonly used, researchers have reported that MIG and TIG welding produce the highest ozone concentrations, especially when aluminum is used as a base metal.[7,8,9] Ozone concentrations produced during MIG and TIG processes were reported to increase with increasing current density.[7,10,11] The shielding gas used during MIG and TIG welding has been found to have an effect on ozone generation. Reports indicate that use of argon results in higher ozone concentrations than does the use of helium or carbon dioxide.[11,12]

The primary health effects of ozone involve irritation of the mucous membranes and the lungs. Symptoms include nose and throat irritation, cough, difficulty breathing, and chest pain.[13] Animals exposed to high concentrations of ozone over long durations displayed inflammatory responses and development of scar tissue in the lungs.[4] The long-term effects of lower ozone exposures in humans are not as clearly defined, but some studies have found changes in lung function and vital capacity.[14] Ozone is also reported to cause increased susceptibility or exacerbation of respiratory disease of bacterial or viral origin.[15,16]

The World Health Organization's (WHO) Working Group Consensus of Concern about Indoor Air Pollutants reports that ozone concentrations of "limited or no concern" are in the range of <0.05 ppm. Concentrations of "concern," which may result in symptoms, are in the range of 0.08 ppm and greater. These indicated ranges are for short-term exposures.[17] The Food and Drug Administration prohibits devices that generate concentrations of ozone of more than 0.05 ppm in enclosed areas occupied by the ill or infirm.[18]

The NIOSH REL and ACGIH TLV for ozone is a ceiling limit of 0.1 ppm. The OSHA PEL is 0.1 ppm as an eight-hour TWA.

RESULTS

Personal air sampling results are presented in Table 1. Of the operations observed during the site visit, the highest ozone concentrations were generated during plasma arc cutting; followed by MIG welding, and arc welding. During plasma arc cutting, average and peak concentrations exceeded the NIOSH REL and the ACGIH ceiling.

During 70 amp plasma arc cutting of half-inch stainless steel in the absence of mechanical ventilation, personal dosimetry indicated that ozone concentrations exceeded five ppm for a six-minute period (sample 77005). This result is not consistent with other sampling conducted on this date, and may have resulted from an unidentified positive interference. Nitrogen dioxide (NO_2) is a likely positive interferant which is produced in the welding environment.

MIG welding on half-inch carbon steel produced maximum ozone concentrations $\geq$0.1 ppm during six minutes of the 17-minute sampling period (sample 77006). Average ozone levels equaled or exceeded 0.1 ppm for a total of four minutes.

Ozone concentrations did not exceed the NIOSH REL, or the other limits, during arc welding on carbon steel (angle iron). Three different electrodes were used: 7018, 308, and 309. The average concentrations recorded by the datalogger was 0.04 ppm, with a peak concentration of 0.09 ppm at the end of the sampling period when the 309 electrode was being used (sample 77007).

DISCUSSION

During this HHE, investigators monitored ozone concentrations during the welding and cutting of selected base metals. Parameters (base metals, local exhaust ventilation, and electrodes) were chosen which were likely to exist during actual welding operations in radiation areas. However, changes in the welding environment were made during, rather than between, sampling periods. This resulted in obscuring differences between ozone concentrations generated under the various conditions. Nevertheless, ozone measurements which were documented during specific welding operations provide information which can be used to anticipate exposures during future decommissioning activities.

Monitoring conducted by Yankee staff using the company's CEA monitor appeared to correspond with readings obtained using the NIOSH CEA. At those times when readings on both meters were compared, they differed by 0 - 0.03 ppm. An exact comparison of the performance of the two meters was not possible due to factors such as variability in the position of the probes and welding plume size. Due to the lack of a datalogger or other means of recording readings, data obtained using CEA meters are less comprehensive than data obtained using the Metrosonics dosimeter. In addition, the CEA sensors could not be held in the same position during all sampling runs, therefore samples could not be obtained consistently within the breathing zone. This may account, in part, for the observation that the CEA meters produced lower readings than did personal dosimetry. Also, it was noted that the CEA ozone meters produced spurious readings if the probes were jarred or moved rapidly. By lightly tapping the probe of the NIOSH meter, a reading of 0.2 ppm was produced outdoors in the absence of any apparent source of ozone.

During sample period 77005, the dosimeter indicated ozone concentrations in excess of 5 ppm, whereas the NIOSH CEA monitor indicated ozone concentrations of 0.48-0.68 ppm. A difference of this magnitude is not consistent with other measurements made on this date, and may result from an unidentified positive interference. Nevertheless, the possibility of very high ozone concentrations cannot be discounted with absolute certainty. It would be appropriate to reevaluate ozone concentrations under these conditions to discount (or confirm) this result. It is important to note that five ppm is the immediately dangerous to life and health (IDLH) concentration, and a self-contained emergency escape air supply must be included as an integral part of the supplied air respirator system when IDLH levels are attained or exceeded.

When ozone was evaluated in the ventilation discharge airstream during plasma arc cutting on aluminum, ozone concentrations in the airstream increased to the level that was measured by the CEA monitor within the enclosure. This observation highlights the importance of ensuring that ventilation units exhaust outside of the building; or, if external ducting is not allowed, units should be exhausted to unoccupied areas of the facility.

The effectiveness of local exhaust ventilation depends upon the capture velocity at the point of contaminant generation. Air velocity at a point one duct diameter from an unflanged duct opening will be approximately seven percent of the face velocity.[19] Therefore, to achieve a capture velocity of 100 - 150 feet per minute (fpm) at this point, a face velocity of $\geq$1450 - 2150 fpm would be needed. The capture velocity can be increased by approximately 25 percent by adding a flange to the duct opening.[19] Use of a flange would result in a capture velocity of approximately ten percent of the face velocity at a point one duct diameter from the opening, i.e., approximately 100 - 150 fpm at a face velocity of 1000 - 1500 fpm.[19] In addition, the capture velocity could be increased by placing the duct on the work surface (bench), and drawing air along the work surface. This would decrease the airflow area by approximately 50 percent, and would result in an increased capture velocity. Improvements in ventilation efficiency would help reduce NO_2 and other contaminants found in the welding plume; however, it is not clear whether greater efficiency would substantially reduce exposure to ozone that may be generated in the ultraviolet field beyond the immediate area of the duct opening.

In addition to toxic contaminants such as metal fumes or nitrogen oxides, intense ultraviolet and visible radiation produced by many welding processes presents a potential health hazard. Overexposure to ultraviolet radiation can result in keratoconjunctivitis (inflammation of the cornea and conjunctiva) and erythema (reddening) of the skin. Chronic exposure to broad spectrum ultraviolet radiation can result in an increased risk of skin cancer.

CONCLUSIONS

Air monitoring data indicate that exposure to ozone during plasma arc cutting and MIG welding presents a health hazard to welders during decommissioning operations. Ozone concentrations during plasma arc cutting and MIG welding exceeded the 0.1 ppm ceiling value which has been established as the NIOSH REL and ACGIH TLV. Welders' reports of chest tightness, dry cough, and throat and bronchial irritation are consistent with exposure to ozone at concentrations identified during this survey.

Monitoring conducted using the company's direct-reading monitor appeared to correspond to readings obtained by NIOSH investigators using an identical instrument. It is likely that both of these instruments underestimated the welder's exposure due, in part, to difficulty in maintaining the sampling probe in the breathing zone.

RECOMMENDATIONS

1. The continued use of local exhaust ventilation and personal protective equipment in the form of supplied air respirators are needed to protect employees from ozone exposure during welding and cutting performed within enclosures. This level of protection is necessary during plasma arc and MIG operations, and is recommended for use during arc welding within enclosures.

2. Whenever possible, the opening for ventilation make-up air should be located so that fresh air is drawn from behind the employee. This arrangement will help to prevent air contaminants in the welding plume from moving towards or through the worker's breathing zone. Where feasible, an employee can minimize air contaminants from reaching the breathing zone by standing so that the work is downwind of the breathing zone.

3. Where possible, a flanged local exhaust ventilation hood should be used to help ensure effective collection of air contaminants during hot work. Ventilation smoke tubes can be used to evaluate the capture distance achieved by a local exhaust system. Further information on flanging and the design of local exhaust ventilation systems can be found in the American Conference of Governmental Industrial Hygienists (ACGIH) publication, Industrial Ventilation, A Manual of Recommended Practice, 22nd edition.

4. Local exhaust ventilation units should be exhausted outside of the building. If external ducting is prohibited, local exhaust ventilation units should discharge contaminated air in unoccupied areas of the facility. Since ozone is an oxidizer, charcoal and other oxidizable sorbents should not be installed in ventilation units to remove ozone from discharge air.

5. Nitrogen dioxide levels can become quite high during hot work, especially during plasma arc cutting or welding. As with ozone, nitrogen dioxide is irritating to the eyes and respiratory system. It is recommended that monitoring for nitrogen dioxide be conducted during hot work.

6. In addition to air contaminants, many welding processes produce physical hazards such as intense ultraviolet and visible radiation. It is recommended that exposed workers wear protective clothing, use ultraviolet blocking lotion, and continue to utilize the appropriate shade of eye protection. (Shade 5 appeared to be satisfactory for plasma arc cutting).

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Table 1. Personal Air Sampling, June 4, 1996.

Sample ID	Operation	Equipment	Base Metal	Sample[1] Period	Time[1] (minutes)	Ozone (ppm)		Ventilation	Comments
						Maximum	Average		
77002	plasma arc cutting	Powermax 800 Hypertherm (50 amp)	ss, cs	1137-1218	40	0.54	0.17	on	≈12 minutes arc time
77003	plasma arc cutting	Powermax 800 Hypertherm (50 amp)	½" Al	1246-1306	20	1.75	0.56	on/off	≈4½ minutes arc time. Ventilation off for final ≈3 minutes of cutting.
77004	plasma arc cutting	Hypertherm Max 70 (70 amp)	½" Al	1448-1505	18	1.45	0.45	on/off	9+ minutes arc time. Ventilation off for final ≈2½ minutes of cutting.
77005	plasma arc cutting	Hypertherm Max 70 (70 amp)	½" ss	1514-1525	10	>5.01	3.98	off	This result is not consistent with other sampling conducted on this date.
77006	MIG welding	MIG: 70% argon, 25% CO_2	cs	1533-1550	17	0.29	0.07	on	
77007	shielded metal arc welding	electrodes 7018, 308, 309	cs	1624-1635	11	0.09	0.04	on	

ss stainless steel
cs carbon steel
Al aluminum
1. Datalogger report times have been rounded to the nearest minute.