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Reduction of Airborne Contaminants From Welding Exhaust at Surface Mines

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REDUCTION OF AIRBORNE CONTAMINANTS FROM WELDING EXHAUST AT SURFACE MINES

by

G. K. Derby [1]

ABSTRACT

The Bureau of Mines studied the problems caused by airborne contaminants from welding exhaust in surface mining operations and investigated equipment designed to reduce existing hazards. Four commercially available welding-fume exhaust units were tested to determine their effectiveness. Results indicated that the four units had the capability of controlling airborne particulate concentrations and bringing them to within allowable exposure limits.

INTRODUCTION

Some mining and processing operations produce airborne contaminants at concentrations that are considered unsafe by the Mine Safety and Health Administration (MSHA), U.S. Department of Labor. A recent Bureau of Mines report on inhalation contaminants[2] stated that three sources of excessive air contamination were found in surface metal and nonmetal facilities: (1) welding fumes, (2) fumes from metal cutting, and (3) solvent vapors from degreasing operations.

Welding personnel and others who are required to work near field repair operations have complained that the welding emissions are highly irritant and at times nausea-inducing. But coal mine operators and MSHA regional field office personnel have reported problems in complying with MSHA regulations because of the lack of availability of suitable, effective equipment to overcome problems encountered during field repairs.

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[1]Engineering technician, Spokane Research Center, Bureau of Mines, Spokane, Wash.

[2]LFE Corp. Handbook for Surveys of Inhalation Contaminants in Above-Ground Metal and Nonmetal Mining and Processing Work Areas. Bumines Open File Rept. 9(1)-80, 1977, 87 pp.; available for consultation at Bureau of Mines facilities in Denver, Colo., Twin Cities, Minn., Bruceton and Pittsburgh, Pa., and Spokane, Wash.; U.S. Department of Energy facilities in Carbondale, Ill., and Morgantown, W. Va.; National Mine Health and Safety Academy, Beckley, W. Va.; and National Library of Natural Resources, U.S. Department of the Interior, Washington, D.C.; and from National Technical Information Service, Springfield, Va., PB 80-143969. Contract J0255001.

In response to these concerns, and as part of its program to develop safer work practices and reduce industrial hazards in surface mining, the Bureau of Mines established a research project with these objectives: (1) to identify welding fume problems and problem areas in surface mining, (2) to determine whether particulate-emission control devices were commercially available, and, if so, to test a selection of them to demonstrate their ability to reduce hazards to acceptable threshold limit values, (3) to relay the information obtained to industry, and (4) to determine whether research was needed to develop emission control devices to fit the particular needs of the surface mining industry. A solution to the problem of welding exhaust would also apply to fumes from metal cutting, which are very similar.

In the research reported here, the Bureau's Spokane Research Center assessed the health hazards caused by welding and metal cutting and investigated four devices that control the concentrations of particulates released to the air.

BACKGROUND STUDY

A background study was completed to assess the specific problems caused by welding emissions, the seriousness of these problems, and what means, if any, were available to eliminate them.

Contaminants and Health Hazards

Welding (and oxyacetylene metal cutting) may produce any one or a combination of at least 20 different types of particulate contaminants that can cause harmful effects and even death (table 1). The hazardous particulate substances not only endanger the persons performing the welding or cutting, but may also affect others in the vicinity of the sources of contamination.

TABLE 1. - Possible particulate contaminants from welding fumes

Particulate	Effect	TLV-TwA,[1] mg/m^3
Aluminum oxide	Aluminosis	10
Beryllium dust	Berylliosis; lesion of the skin, liver, kidneys, spleen, and lymph nodes.	.002
Cadmium dust	Pulmonary edema	.05
Carbon black	Anthracosis	3.5
Chromium	Bronchospasm, bronchitis, edema, hypersecretion, asthma.	.5
Copper fumes	Nausea, vomiting, metal fume fever, ulceration of the cornea.	.2
Fluorides	Change in bone structure, respiratory and other problems.	2.5
Iron oxide	Siderosis	5
Lead	Cramps, nausea	.15
Manganese	Total disablement	1.0
Mercury	Kidney damage, vomiting, diarrhea, gingivitis.	.05
Molybdenum	Bronchial and alveolar irritation, liver and kidney problems.	5
Nickel metal	Cancer	1.0
Nickel sulfide	.....do	1.0
Silicates:		
Iron	Pneumoconiosis, respiratory, insufficiency.	10
Sodium	.....do	10
Tin oxide	Stannosis	2
Titanium dioxide	Fibrosis	10
Vanadium pentoxide	Conjunctivitis, pharyngitis, bronchopneumonia, chronic bronchitis.	.5
Zinc oxide	Zinc chills	5
Asbestos:[2]		
Amosite	Asbestosis, cancer	.5
Crocidolite	.....do	.2
All other	.....do	2

[1]American Conference of Government Industrial Hygienists. Threshold Limit Values for Chemical Substances in Workroom Air. ACGIH, Cincinnati, Ohio, 1980, 93 pp. TLV-TWA (threshold limit values/time-weighted averages) are the concentration levels of airborne contaminants to which nearly all workers can be exposed for a normal 7- or 8-hour workday, or 40-hour workweek, without adverse effect. These values should be used as guides in the control of health hazards, not as fine lines between safe and dangerous concentrations.

[2]TVL-TWA for asbestos is given in number of fibers greater than 5 µm in length per cubic centimeter of air.

Source: Widder Corp. Welding Bulletin WCN 11. 1977, 4 pp.; now included in The Problems With Welding Fumes and How To Solve Them, by A. H. Krieg; Widder Corp., Naugatuck, Conn., 1979, 30 pp.

Airborne contamination problems may be increased further by other factors such as prior solvent degreasing or welding coated surfaces. Wet solvents may let off chlorinated vapors that can, in turn, be broken down by ultraviolet radiation in gas-shielded arc welding to produce phosgene gas, which is highly toxic. Surfaces coated with paint containing chrome, zinc, or lead under the high heat of welding will also produce toxic fumes. Dangerous reactions can also take place during the welding of plated surfaces that contain cadmium, chrome, or zinc. Filler metals, fluxes, lubricants, and pickling solutions may also produce injurious gases and particulates when subjected to welding heat.

The possibilities for harm are enormous, and it is impossible to protect the worker from each of them individually. The only solution is proper protection from the welding emissions themselves. Adequate ventilation or purification of the airborne exhaust is therefore a necessity. The particulate contaminants can be neutralized or vented to a location where the harmful effects they produce are minimized or eliminated. The highly toxic and hazardous gases also emitted during welding will be the subject of a future Bureau of Mines study.

Problem Areas in Surface Mines

An investigation was conducted to determine which areas of the surface facilities were experiencing the greatest difficulties. It was found that no great problems are experienced when welding tasks are performed within designated maintenance work areas. Adequate exhaust systems are procurable, and most permanent maintenance facilities with fixed areas for performing welding tasks have proper equipment installed that is capable of overcoming welding emission problems. However, difficulties arise when welding tasks are performed outside established work areas, especially where work is done in the field within confined spaces, such as inside large equipment or inside dragline and shovel buckets.

Some mines have exhaust systems for work performed in the field. The units are generally assembled or fabricated from commercially available material and attached to the welding truck. Large-diameter flex tubing (up to 12-in-diam) is commonly used for air evacuation from the point of welding to an eduction blower mounted on the welding truck. However, this tubing is unwieldly and difficult to maneuver in confined equipment interiors. Maintenance personnel are sometimes unwilling to use these exhaust units because of the difficulty in setting them up. The workers would prefer a small, compact unit, which could be handled by one or two people at or near the point of welding, eliminating the need for extensive ducting. Dilution and dispersion of fumes would be acceptable, but purification or filtration of the fumes to protect other personnel in the area would be preferable.

Problems Outside the Mining Industry

These problems are not confined to the mining industry. Safe evacuation of contaminant emissions when welding is performed in confined spaces away from established fabrication areas has been a recognized problem in many branches of industry here and in other countries. Research has been conducted and equipment developed to deal with the problem, especially in the English mining and Swedish shipbuilding industries. A very thorough study[3] of the problem was completed in 1974, at the Uddevalla Shipyard in Sweden. The study detailed the difficulties the shipbuilders were having with contaminant emissions from welding and the development and testing of equipment to reduce or eliminate the problems.

Exhaust Systems

A market study uncovered numerous exhaust systems using various methods to evacuate or purify industrial contaminants. Small portable units acceptable for this project were readily available. Four units that used different methods of contaminant evacuation or treatment were tested:

1. Widdervac[4] Model 821, Widdervac Corp., Naugatuck, Conn. (fig. 1). Welding emissions are drawn in through the nozzle and evacuated via a 2-in-diam flexible hose to the exhaust unit, which houses a spark arrester, replaceable filter, vacuum pump, and motor. The filtered air is exhausted into the atmosphere. The unit is powered by 115 volts ac. It is a derivative of the unit developed under the Uddevalla Shipyard study.

2. Coppus Portafilter, Coppus Engineering Corp., Worcester, Mass. (fig. 2). Welding emissions are evacuated via a 4-in-diam flexible hose (nozzle optional) to the exhaust unit, which houses a replaceable filter and a centrifugal-type blower-exhauster pump. Filtered air can be discharged at the unit or through a second flexible hose to clear the area. The unit tested was powered by a 115-volt ac, 1/2-hp motor.

3. Coppus Jectair Model 3, Coppus Engineering Corp., Worcester, Mass. (fig. 3). Compressed air is admitted through a single side chamber leading to the nozzle chamber. The compressed air creates a venturi action, which induces a large volume of surrounding air to enter through the inlet. The air is then discharged through the horn-shaped diffuser, which can be coupled to a 7-in-diam flexible hose that conveys the contaminated air to an area away from the point of welding. At this point, the welding emission should be diluted (by the injected compressed air and the neutral atmosphere sucked in with the welding fume) to a safe level.

4. Racal Airstream welding helmet, Airstream, Rockville, Md. (fig. 4). This unit is designed for the protection of the individual worker. It consists of protective helmet and faceshield, air pump, replaceable filters, and battery pack. Air is drawn through a combination filtration-battery pack worn with a harness on the welder's back. The filtered air passes through 1-1/2-in-diam flex tubing to a rear inlet on the helmet. The helmet is fitted with an intergasketed faceshield that guides the filtered air over the breathing zone of the user. This unit has received MSHA certification.

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[3]Ahlstrand, H., and P. Lidehall. Evaluation of Spot Evacuation System for Weld Smoke at Uddevalla Shipyard. Uddevalla, Sweden, April 1974, 56 pp.

[4]Reference to specific equipment, trade names, or manufacturers does not imply endorsement by the Bureau of Mines.

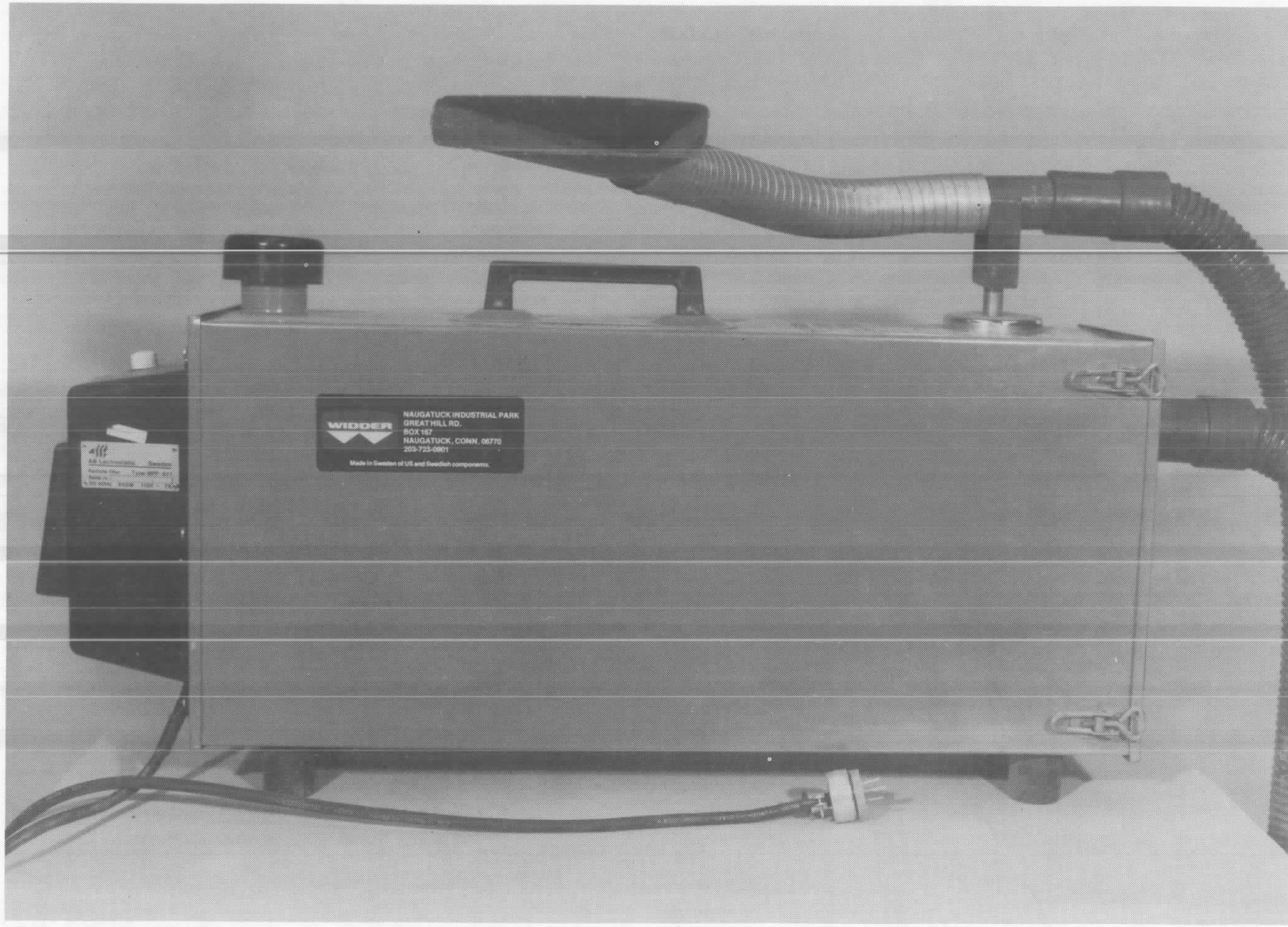

FIGURE 1. - Widdervac welding-exhaust unit with 4-inch nozzle. Overall dimensions: 8 by 18 by 33 inches; weight: 30 pounds.

FIGURE 2. - Coppus Portafilter with flexible tubing and nozzle removed. Overall dimensions: 20 by 17 by 40 inches; weight: 77 pounds.

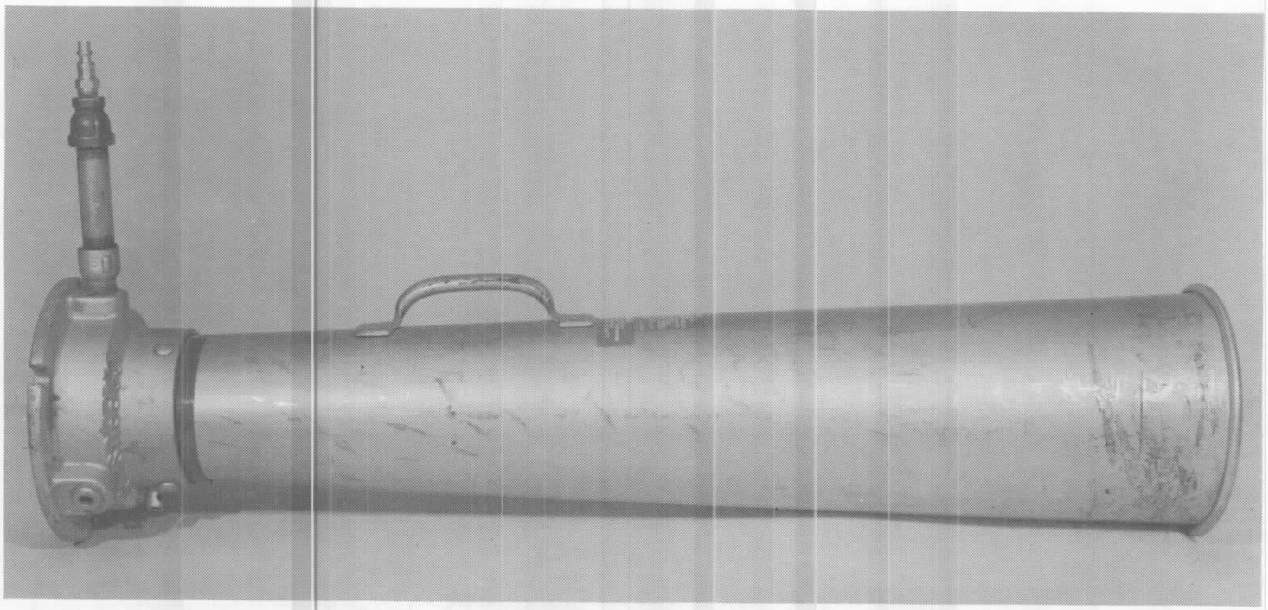

FIGURE 3. - Coppus Jectair with flexible tubing removed. Overall dimensions: 7 inches in diameter, 31-1/2 inches long; weight: 9 pounds.

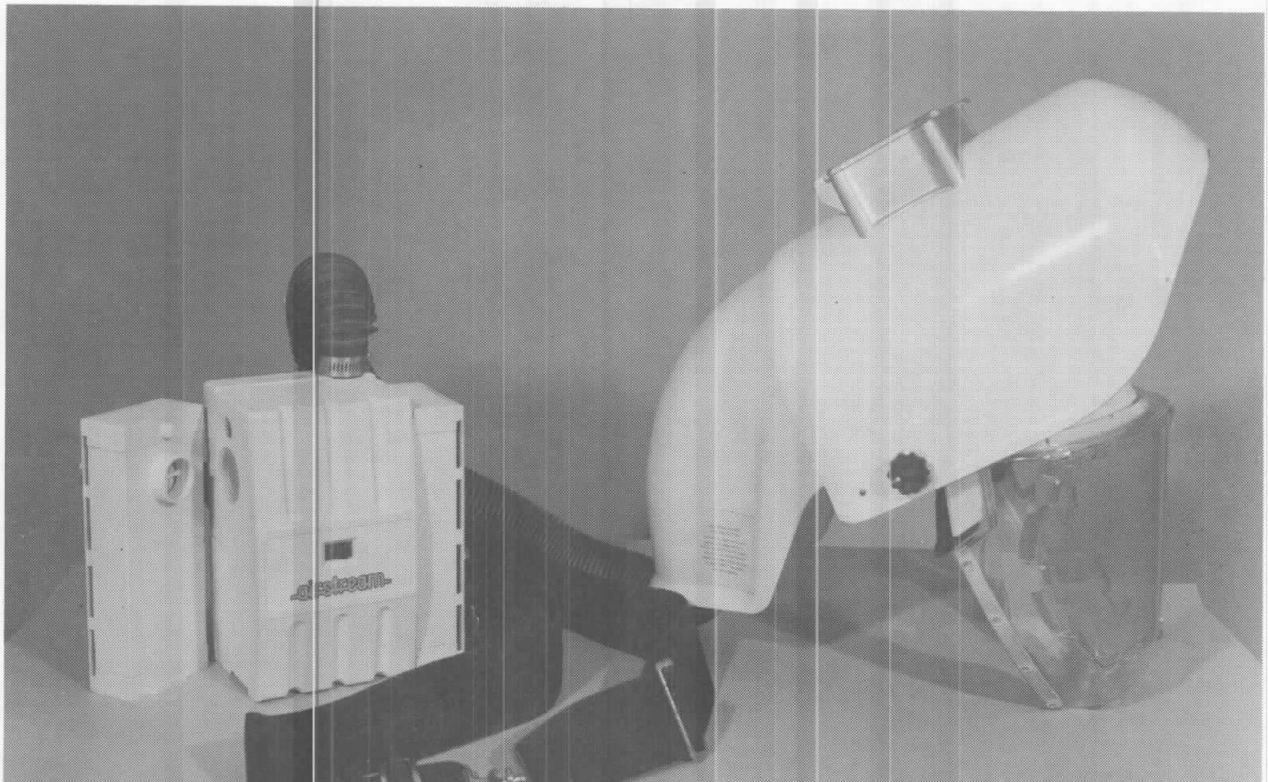

FIGURE 4. - Racal Airstream welding helmet. Weight of filter and helmet: 9 pounds.

The number of units tested was controlled by the funding and time limits of the project. These particular units represent a range of equipment using different methods to overcome welding contaminant problems. The choice of these four units does not imply that they are the preferred or the only acceptable ones. Many other types are currently available, which have certain characteristics that will appeal to individual potential users. Final selection of a unit will depend on the user's particular needs.

TESTING PROCEDURES

Welding emission samples were taken in a test cell made from commercially available welding screen. It measured 4 by 4 by 6 feet, with air circulation coming in from the bottom and exiting from the top. Transparent screening was used so that the welder was not visually isolated. Emissions were monitored and analyzed for five common types[5] of welding rods used in surface mining maintenance operations. The range of rods selected produced a variety of contaminant substances.

Contaminant sampling was restricted to particulate matter. During test runs of the Widdervac and Coppus units, a self-contained personal sampling unit was used, with the air-intake cassette worn on the user's collar. For test runs of the Racal helmet, the air-intake cassette was positioned inside the faceplate in the airstream passing through the user's breathing zone.

Test base samples were taken with the sampler cassette placed in the area of a welder's normal breathing zone,[6] approximately 12 inches above and slightly off center in relation to the point of welding. For protection, the Racal helmet was worn so that filtered air would be provided to the welder, with minimun disruption of welding emission collection. Normal fixed exhaust equipment was used to clear contaminants from the outer work area.

Individual test runs were for 2 hours, with an airflow rate of 1.8 l/min, using the air-intake cassette field monitor with a 0.8-µm pore-size membrane filter. Five test runs (one for the sample case and one for each unit tested) were completed for each type of welding rod used. Sample analysis for particulate levels and certain types of metal contaminant exposure was performed by an independent laboratory.

Sample analysis was performed by Northwest Health Services of Richland, Wash. A total of 35 cassette filters was evaluated; content determinations were made to establish levels of total particulate, iron, and manganese for 25 samples, and total particulate, titanium, nickel, and chromium levels for the remaining 10. The total particulate concentrations were determined gravimetrically, and the metal content was determined using atomic absorption or flame-emission spectroscopy. Analysis results indicated that all four units tested had the capability of reducing the welder's hazard exposure to particulates to within acceptable concentration limits.

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[5]For one type, the rods of three manufacturers were used, making a total of seven different rods tested.

[6]The normal breathing zone is the volume of air within about a 36-inch radius of the worker's mouth.

TEST RESULTS

Table 2 reflects the total particulate count for the sample cases and for each system, tested for comparison purposes with each type of welding rod. The TLV-TWA for total welding fume particulates, other than those individually classified (table 1) is 5 mg/m^3.[7] All values listed in tables 2 and 3 as "less-than numbers" (<) indicate that the results are below the limit of detection for that particular analysis. Drastic reduction in total particulate level is evident from the sample case runs to those in which welding emission controls were used. Because of the predominate use of the ASME-E7018 rod for general welding and repair work, the rods of three manufacturers were tested. No appreciable difference in the particulate levels produced by the three rods was noted, so results were averaged for simplification.

TABLE 2. - Total particulate levels, milligrams per cubic meter of air

Welding rod used[1]	E7018[2]	E6010	E6011	E6013	E8018-B2
Sample case	30.5	86.3	67.3	21.3	39.0
Widdervac	1.44	1.78	1.93	1.38	1.15
Coppus Portafilter	1.34	.33	1.06	.90	.56
Coppus Jectair	2.74	<.2	.88	.49	.33
Racal Airstream	.27	.22	<.2	.05	<.2

[1]Rod number is designation used by the American Society of Mechanical Engineers (ASME).
[2]Rods from 3 manufacturers were tested and the results averaged.

TABLE 3. - Concentrations of contaminants, milligrams per cubic meter of air

Welding rod used[1]	Manganese			Iron		
	E7018[2]	E6010	E6011	E7018[2]	E6010	E6011
Sample case	1.2	3.09	2.31	5.12	43.0	30.5
Widdervac	.54	.78	.039	.42	.88	.45
Coppus Portafilter	.046	.006	.016	.45	.16	.3
Coppus Jectair	.092	.008	.033	.59	.34	.34
Racal Airstream	<.005	<.005	<.005	<.023	<.006	<.025
	Titanium		Nickel		Chromium	
	E6013	E8018-B2	E6013	E8018-B2	E6013	E8018-B2
Sample case	0.85	0.31	<0.01	0.02	0.04	<0.03
Widdervac	.02	<.2	<.01	<.02	<.01	<.02
Coppus Portafilter	.08	<.2	<.01	<.02	<.01	<.02
Coppus Jectair	<.02	<.2	<.01	<.02	<.01	<.02
Racal Airstream	.02	<.2	<.01	<.02	<.01	<.02

[1]Rod number is ASME designation.
[2]Rods from 3 manufacturers were tested and the results averaged.

[7]Work cited in footnote 1 of table 1.

Table 3 reflects filter analysis for detection and level of specific metals known to be emitted during combustion of certain welding rods. Confirmation of unhealthy levels of contamination was not directly a part of this research, but these results clearly show that the manganese and iron levels in the sample cases were well above the threshold values given in table 1, at concentrations likely to cause serious health problems. Note that the reductions from the sample case runs, in manganese and iron levels, are relatively proportional to the lowering of total particulate count for the different emission control systems.

CONCLUSIONS

Welding produces air contaminants that present health hazards if not effectively diffused or eliminated. This is particularly a problem when welding is done in confined spaces and exhaust equipment is unavailable or unused.

Although the surface mining industry has definite welding-fume problems, they are not peculiar to mining. Private industry has developed technology to overcome the problem of controlling particulate emissions. Four small, portable devices were tested and shown to reduce particulate concentrations to acceptable levels. (These devices were not graded or ranked, and many others are also commercially available.)

It is recommended that a program be established to inform all segments of the mining industry of the equipment and methods currently available to control welding-fume particulates.

Because adequate equipment already exists, it is not recommended that the Bureau of Mines or other Government agencies proceed with development research in this area. Further research should be conducted to ascertain the hazards presented by gaseous welding emissions and the tools needed to minimize these hazards.

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