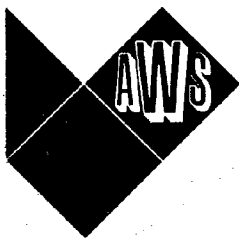


Welding Fume Control:

A Demonstration Project



AMERICAN WELDING SOCIETY

Welding Fume Control: A Demonstration Project

Evaluation of the Effectiveness and Applicability of Selected
Ventilation Controls and an Air Purifying Helmet for Welding
Applications.

Research performed by the Rexnord Corporation at its
Environmental Research Center under contract with the American
Welding Society and supported by industry contributions.

Prepared for:
Safety and Health Committee
AMERICAN WELDING SOCIETY
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Evaluation of the Effectiveness and Applicability of Selected Ventilation Controls and an Air Purifying Helmet for Welding Applications

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Abstract

This report presents the results of a welding fume control demonstration project performed for the American Welding Society. The study evaluated the effectiveness and applicability of three different types of commercially available exhaust methods for control of welding fume at the source during shielded metal arc welding. The three methods evaluated, all of them mobile methods, included high volume exhaust, high velocity, low volume (HVLV), and the handheld shield.

Of particular interest in the study was determination of whether use of these control measures would result in reduction of worker exposures to toxic metals such as nickel and hexavalent chromium to the low limits being considered by OSHA. Besides the exhaust control measures, the protection offered by an air purifying helmet was also studied.

The tests were conducted under controlled conditions in a simulated industrial setting using stainless steel base metal and electrodes. The results showed that each of the exhaust control measures studied, if used properly, was capable of substantially reducing breathing zone and general area concentrations of welding generated contaminants in both open and confined spaces. However, even with consistent usage and proper positioning, not all of the limits being considered by OSHA for hexavalent chromium were met. Not even the air purifying helmet met all the limits being considered. The limit being considered for nickel was met in many cases.

The study of applicability identified the attributes and deficiencies of the various methods. It must be remembered in interpreting the results of these evaluations, however, that the test conditions were established to represent common industrial welding operations, not worst case conditions. A useful followup for this study would be to establish, on the basis of field evaluations, limiting constraints for the use of each of these methods and selection and design criteria using a system approach. It would also be useful to extend these controlled experiments to the gas shielded arc welding process.

Acknowledgement

Our gratitude is extended to the Harnischfeger Corporation - Milwaukee for providing floor space at their Corporate Manufacturing Training Center to house the experiments, and supplying welding personnel for performing the welding during the tests. A special thanks is also due to the Arcos Corporation for supplying the electrodes and Crucible Inc., who supplied the stainless steel base metal used in the tests.

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Welding Fume Control: A Demonstration Project

SECTION 1 INTRODUCTION

PAST RESEARCH

Both industry and governmental agencies have been active in research efforts to determine worker exposure to contaminants generated by welding and to develop appropriate ventilation controls. Early research was directed primarily at quantifying the welder's exposure under different conditions, e.g., in open versus confined space, using different types of welding, with or without localized and general ventilation (Refs. 1, 2, 3, 4, and 5).

Recent studies by the American Welding Society (AWS) and the National Institute for Occupational Safety and Health (NIOSH) have been aimed at methods for assessing the welder's exposure and design criteria for local and general ventilation systems. *The Welding Environment*, published by the AWS, provided the following useful information (Ref. 6):

- (1) The type and amount of particulate and gaseous contaminants resulting from commonly used electrodes.
- (2) The manner in which fume composition from selected electrodes is affected by different manufacturing techniques.
- (3) The development of a standard method for sampling airborne particulate in the welding environment. This information was later published as a separate document (Ref. 7).

In a second AWS publication, entitled *Fumes and Gases in the Welding Environment*, data were presented to enable ventilation engineers to design effective systems for capturing welding fume (Ref. 8). These

data were generated under closely controlled, open space conditions within a laboratory. The publication addressed both general and local exhaust ventilation methods, and their effects on each other. Both theoretical and experimental results were used to characterize the effect of induced air velocity and exhaust volume on fume concentration within the welder's breathing zone. Several local exhaust configurations were tested, including portable flanged intakes of different diameters, a slotted exhaust inlet and an overhead canopy hood. Each of these configurations were custom built to the researcher's specifications. Fume and crossdraft simulators were used in the experiments.

A NIOSH published document entitled *Engineering Control of Welding Fumes* developed design criteria for local ventilation systems (Ref. 9). During this investigation, the effectiveness with which selected ventilation methods protected the welder from exposure to the fume was measured. These methods included a slotted backdraft hood similar to that presented in the Ventilation Manual of the American Conference of Governmental Industrial Hygienists (ACGIH) (Ref. 10), as well as a free standing, flanged, rectangular hood. Several types of welding processes were tested, including shielded metal arc welding (SMAW) and gas metal arc welding (GMAW). This research was similar to the AWS research in that the exhaust control methods were custom built and the tests were performed in open spaces in a laboratory setting.

STUDY OBJECTIVE

Recently, NIOSH has issued criteria for revised standards for occupational exposure to nickel and hexavalent chromium (Cr VI). NIOSH is recommending a reduction in the current permissible exposure limit (PEL) from 1,000 to 15 $\mu\text{g}/\text{m}^3$ for nickel and from 50

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$\mu\text{g}/\text{m}^3$ for total Cr VI to $1 \mu\text{g}/\text{m}^3$ for certain water insoluble Cr VI compounds, and $25 \mu\text{g}/\text{m}^3$ for water soluble Cr VI (Ref. 12). The Occupational Safety and Health Administration (OSHA) is considering several options for the Cr VI PEL which include (Ref. 14):

- (1) $10 \mu\text{g}/\text{m}^3$ with a $25 \mu\text{g}/\text{m}^3$ ceiling.
- (2) $1 \mu\text{g}/\text{m}^3$ with a $10 \mu\text{g}/\text{m}^3$ ceiling.
- (3) The lowest technologically feasible TWA with no ceiling or with an appropriate ceiling (such as 10, 25, or $50 \mu\text{g}/\text{m}^3$).

The question arises as to the technical feasibility of reducing nickel and chromium levels within the high alloy welding environment to these low standards using today's state-of-the-art ventilation control methods. It was the primary intent of this study to evaluate the effectiveness and applicability of three different types of commercially available local ventilation controls in reducing worker exposure to welding generated contaminants. In addition, a personal protective device (air purifying helmet), was also studied.

Tests were limited to shielded metal arc welding (SMAW) on stainless steel. Both open and confined space conditions were tested in a controlled environment within a welding research center. To establish a baseline for evaluation of the devices, tests were also conducted without the use of ventilation controls.

This demonstration study is intended to serve as a basis for further ventilation studies under a much wider range of production conditions.

DEVICES EVALUATED

The devices tested are listed in Table 1-1; specifications are presented in Table 1-2. Photographs of each of the devices are presented in Figs. 1-1 through 1-5.

EVALUATION OF VENTILATION CONTROL

The primary emphasis in the study was directed at assessing the effectiveness of the control measures. Besides effectiveness, other important aspects relating to the applicability of these control measures were also evaluated including: usability, reliability, effect on the process and worker acceptance. Specific design related considerations were not included in this evaluation, e.g., system size and weight, complexity, and power consumption; nor were costs considered. These latter factors, although important in the selection of a device for a specific application, should be addressed using a systems design approach.

*The OSHA standard is $100 \mu\text{g}/\text{m}^3$ for chromate (CrO_3) which on a weight basis equate to approximately $50 \mu\text{g}/\text{m}^3$ for CR VI alone.

Ventilation Effectiveness

A ventilation control has a twofold role of preventing the contaminants from directly entering the breathing zone of the welder as well as protecting other personnel in the area. Effectiveness in protecting the breathing zone from welding generated contaminants was evaluated in this study using personal filter samples taken underneath the welding helmet. General area samples were taken to assess buildup in the workplace. It should be emphasized here that effectiveness, as defined above, is different than capture hood efficiency. Capture hood efficiency is defined as the ratio of the amount of generated contaminant that is removed by the capture method to the total amount that is generated by the welding process. Effectiveness, on the other hand, is evaluated in terms of the control's ability to reduce breathing zone concentrations.

Usability

In industry, welding is performed in both production and maintenance applications on a wide variety of workpieces. The physical interferences which limit the applicability of a particular ventilation control measure may result from the size and limited mobility of the control measure itself or they may be due to the size and configuration of the workpiece or the room, compartment or vessel in which it is housed. All of the welding control methods evaluated in this study can be classified as mobile methods, i.e., they are capable of being repositioned as necessary to accommodate varying requirements of a job.

Another important aspect of usability relates to the ability of a control measure to maintain itself in the various positions required by the work. Even if physical interferences or lack of mobility do not limit access to the proper position needed for effective control, in a given situation the control measure may not be able to maintain the required position for effective capture itself. A control measure without the means for being properly positioned will not be used properly, if at all. The usability of these three control methods was assessed by subjecting them to tests requiring that they be used in various positions both in open areas and in confined spaces.

Reliability

There were two different factors explored in assessing the reliability of the control measures. The first aspect concerns the amount of worker interaction that is necessary for effective performance. The most desirable situation would be for the control method to be fully automatic with respect to the welding process and not require *any* worker involvement and very little maintenance. No such measure, however, was found for the shielded metal arc process (SMAW). Each control measure evaluated required some degree of worker involvement; the extent of that involvement

Table 1-1
Devices tested

Type	Description	Abbreviation	Figure no.
High volume	Two types evaluated:	Hi-Vol	1-1
	(1) Flexible hose with suction hood; hood repositioning mechanism consisting of adjustable support arms extending from movable platforms (for open spaces).		1-2
High velocity, low volume	Portable, "vacuum-cleaner" style pick-up with five different attachments.	HVLV	1-3
Handheld shield exhauster	A handheld pickup for use on the "HVLV" system, which has the viewing glass and face shield incorporated into the exhauster.	Hand shield	1-4
Air purifying helmet	A helmet consisting of a face shield, viewing glass, hard-hat and battery powered blower/filter.	APH	1-5

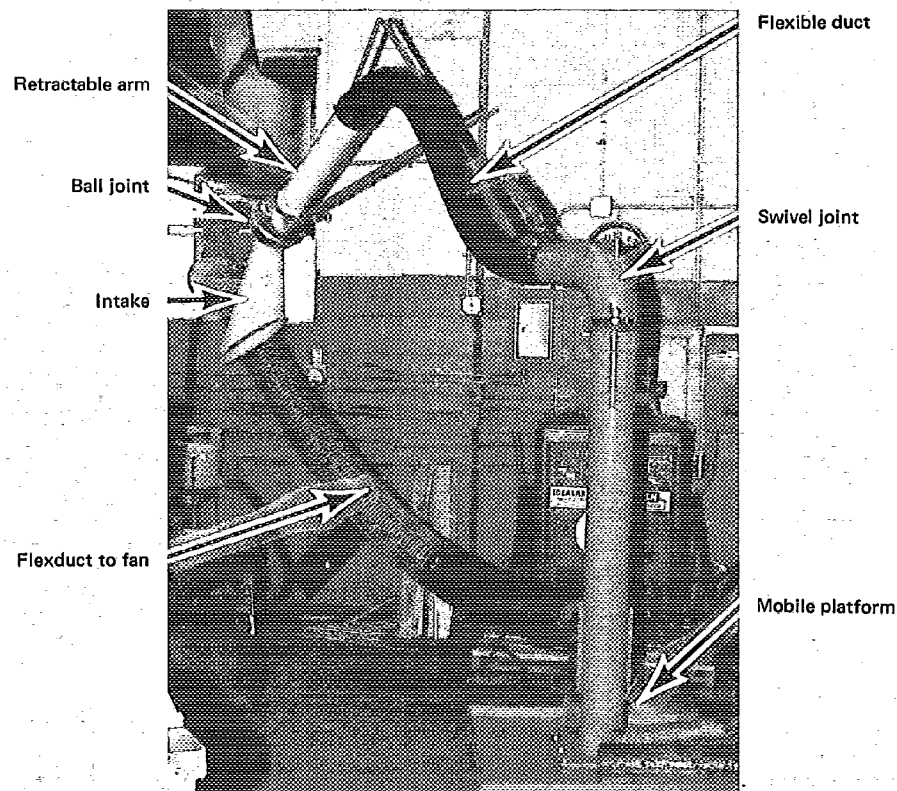


Fig. 1.1—High volume-open space exhauster

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Table 1-2
Specifications for devices tested

High volume:

Airflow rate:	1000 cfm (0.47 m ³ /sec)
Duct diameter:	Open space — 5 in. (12.2 cm) Confined space — 8 in. (20.3 cm)
Intake size:	Open space — oval 10 x 15 in. (25.4 x 38.1 cm) Confined space — 8 in. (20.3 cm) square
Intake material:	Open space — fiberglass Confined space — galvanized sheet metal.
Reach:	Open space — 15 ft (4.6 m) Confined space — as long as flex duct.

High velocity, low volume:

Airflow rate:	Rated at 130 ft ³ /min (0.06 m ³ /sec) (rating conditions not specified). Using the blower and hoses supplied with the unit, and using 25 ft (7.6 m) on the inlet and 10 ft (3.1 m) on the outlet of the blower, the measured exhaust rate was 80 ft ³ /min (0.03 m ³ /sec).
Hose diameter:	1.75 in. (4.45 cm)
Blower type:	High pressure — 2 stage
Recommended arc to intake distance:	3/4 to 2 in. (1.9-5.1 cm)

Handheld shield:

The handheld shield was used with the portable HVLV blower system.

Air purifying helmet:

Airflow rate:	8 cfm (13.6 m ³ /Hr)
Noise:	70 dbA at wearer's ear
Filters:	HEPA (99.97% efficiency on DOP with 0.3 micron particle size).
Face protection:	Complies with ANSI Z87.1-1968.
Welding shield:	4-1/2 x 5-1/4 in. (11.4 x 13.4 cm) glass
Battery pack:	Ni Cad rechargeable, 8 hr continuous use per charge.
Weight:	Helmet and hose - 2.0 lbs (0.9 kg) Airflow module (with batteries and filters) - 3.9 lbs (1.8 kg)

and the susceptibility for the method to be improperly, and thus ineffectively, applied by the welder during the course of its use was thus evaluated.

The second aspect of reliability relates to the ability of a control to sustain its performance for a long period of time in severe industrial applications. Susceptibility to failure could arise, for example, because of a control method's potential for plugging, resulting in reduced air flow, and incomplete fume capture, or to physical damage to the hood, support systems, or ducting.

During this study, the worker interaction aspect of reliability was evaluated by giving a welder specific instructions on how to use the control properly and then assessing his performance as he attempted to carry out these instructions. The second aspect of reliability, however, was more difficult to assess because the controlled conditions and short duration of the tests did not allow ample opportunity for the kinds of failures to occur that might eventually occur in industrial applications. Thus, failure modes were evaluated by assessing possible causes of failure and noting any required maintenance procedures.

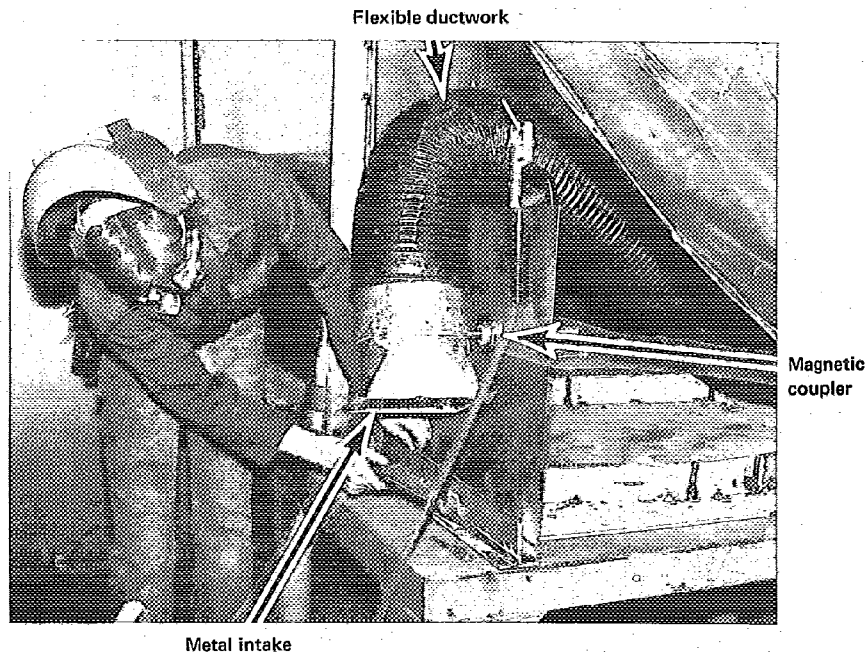


Fig. 1.2—High volume-confined space exhauster
(Posed picture; during tests welder wore safety glasses and gloves)

Effect on the Process

A ventilation control could affect the welding process by:

- (1) Affecting the ability of the welder to produce a weld of acceptable quality.
- (2) Slowing the welder down, thus reducing the production rate.
- (3) Adding unusual constraints that the welding procedure cannot tolerate.

As was indicated earlier, the ventilation control measures available for shielded metal arc welding do not function automatically. Rather, they require manual input from the welder, primarily to reposition the intakes to effectively capture the fume. The possibility exists that the welder could position the control either too far from or too close to the point of welding. If the distance is too great, ineffective capture results. If too close a distance is used, the possibility exists that the shielding atmosphere around the weld could be disrupted to the extent that welding quality would be affected. It is doubtful that adverse effects on weld quality resulted from the control methods used in this study. The welder reported that the controls caused no apparent changes in the welding process or the ultimate appearance of the weld. Had such changes been suspected, further tests would have been required to assess the extent of the disturbance.

The effect of a particular ventilation control on productivity was easier to assess. By having the worker perform a fixed protocol of welding operations, with and without the use of the control measure, permitted an assessment of potential reductions in productivity.

The possible addition of unusual constraints was also evaluated by maintaining close surveillance of the worker as he welded.

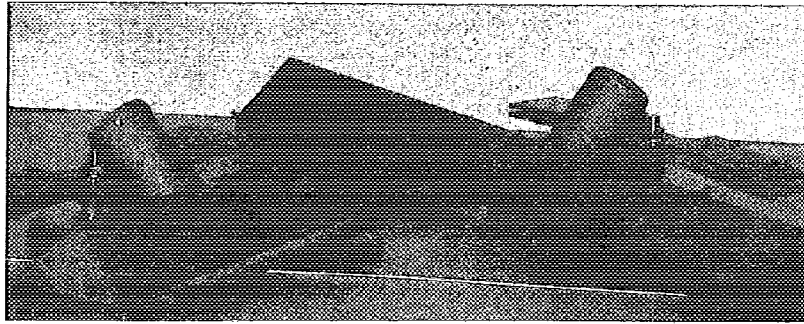
Worker Acceptance

Whether or not a particular control measure is accepted by the welder is dependent on many factors, both objective and subjective in nature. Three objective factors that represent physical requirements of every job, are critical to worker acceptance. These include:

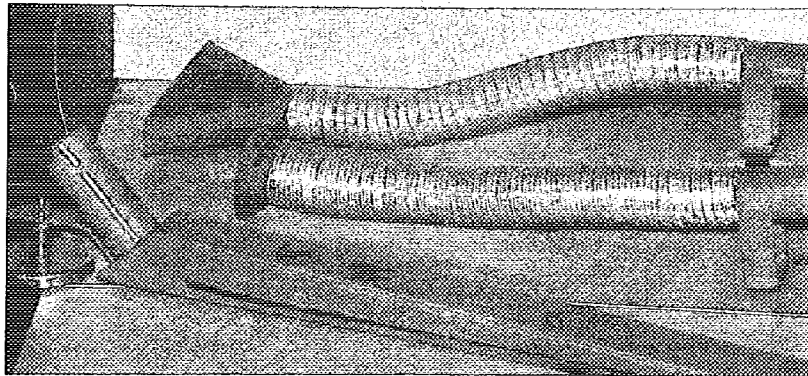
- (1) The amount of effort required to operate a control.
- (2) Any geometrical limitations that would prevent the worker from gaining safe access to and performing the work.
- (3) Anything that would obstruct the workers vision.

Other factors, more subjective in nature, center around the worker's basic attitude toward additional tasks associated with operating safety and health measures.

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Long and short stick nozzles



Side stick (foreground) and funnel nozzles

Fig. 1.3—High velocity low volume (HVLV) nozzles

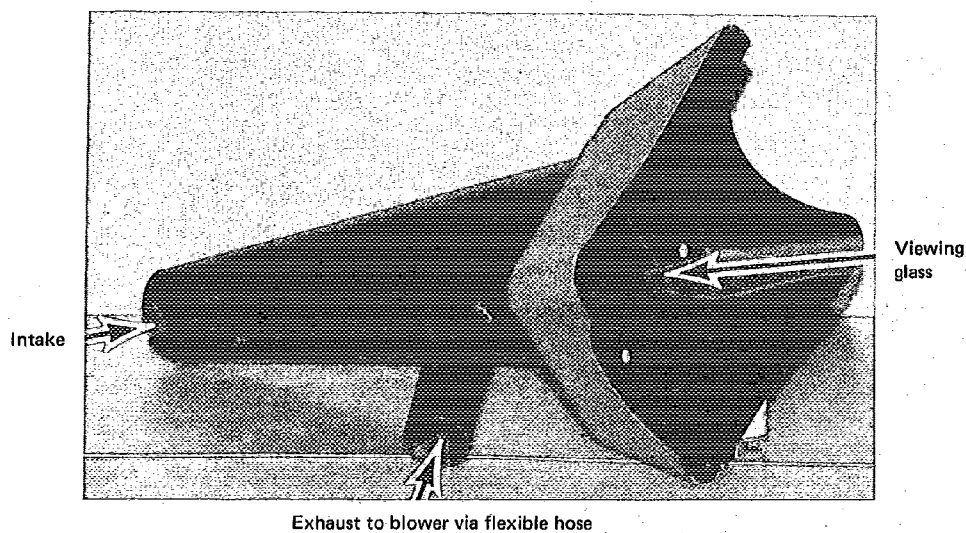


Fig. 1.4—Hand-held shield exhauster for use in an HVLV system

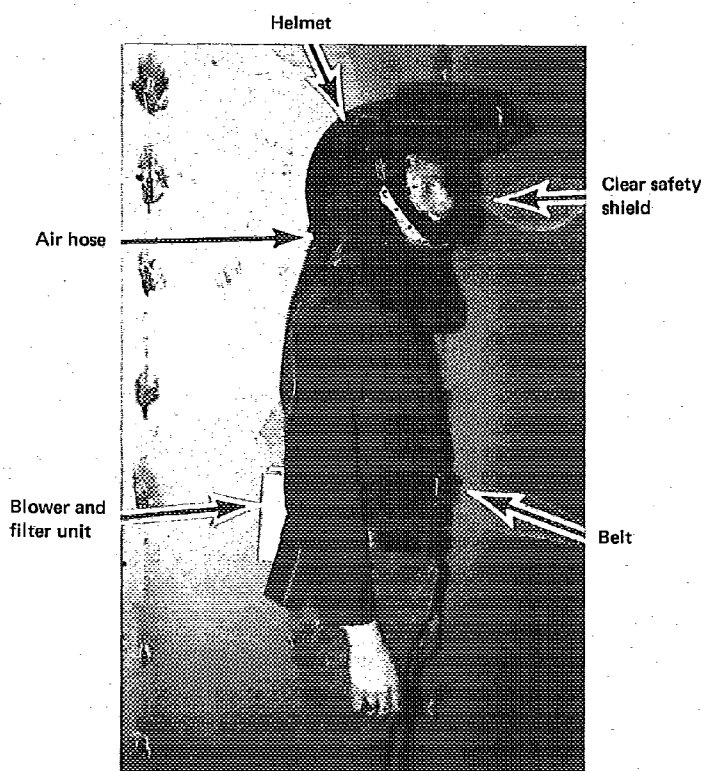


Fig. 1.5—Air purifying helmet - welding shield in raised position

In this study, worker acceptance was evaluated as follows. At the beginning of the testing, the welder was informed that he would be using several different techniques to control fume. He was invited to freely comment as the tests progressed giving his opinions about the controls and any problems he encountered in using them, especially in the three areas listed above. The observations of the study representative who witnessed the tests are also reported.

EVALUATION OF THE AIR PURIFYING HELMET

The air purifying helmet was evaluated in the same basic way as the ventilation controls, with one notable exception. The air purifying helmet is not an exhaust control method, i.e., it does not effect reductions in worker exposures by removing contaminants from the workplace. Instead, it isolates the breathing zone of the worker from the conditions of the workplace. Thus, when evaluating effectiveness and reliability, it is the effectiveness and reliability with which the isolation is accomplished that is the subject for evaluation.

TESTING FACILITY

Building

The testing was conducted at Harnischfeger Corporation's Manufacturing Training Center Complex, located in Milwaukee, Wisconsin. The building used was a separate, small facility, which was not in use at the time. No other fume or metal dust producing processes were being operated in the building.

A schematic diagram of the building is shown in Fig. 1-6. The building measures 24 feet (7.3 m) W x 51 feet (15.5 m) L x 14.5 feet (4.4 m) H, with a volume of approximately 17,750 ft³ (503 m³). One-third of the building was used for conducting the study. Welding took place on a metal table, measuring approximately 3 x 4 ft (0.9 x 1.2 m). The building was heated by two gas-fired heaters, but to avoid disruptive crossdrafts in the work area, only the heater on the far side of the building away, from the test area, was operated during the study.

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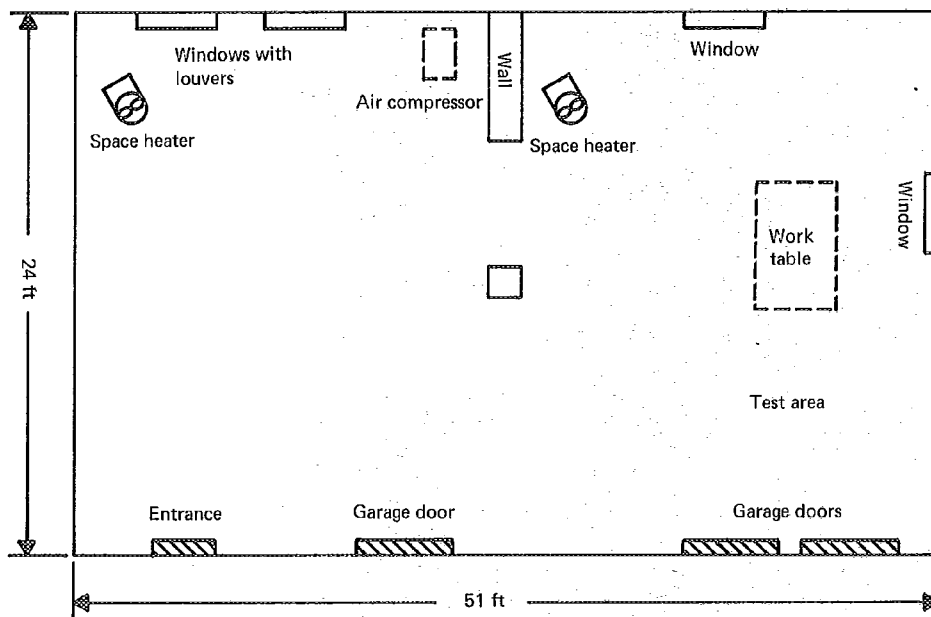


Fig. 1.6—Schematic plan view diagram of building where tests were conducted

General Ventilation and Fan Systems

Without some general ventilation, the amount of welding fume within the building would have significantly increased with time, which would, in turn, have made it more difficult to assess the effectiveness of control measures. To prevent this buildup, some general ventilation was necessary, however, care was taken to prevent disruptive crossdrafts. The general ventilation was regulated so that it could be reproduced for each test within acceptable tolerances. It consisted of a continuous exhaust of 1600 ft³/min (0.75 m³/sec) from a baffled area at roof level far enough above the work bench to prevent the creation of updrafts which could alter the conditions to which the local exhaust control methods would be subjected (Fig. 1-7). The general ventilation rate was 5.4 air changes per hour. Because it was not feasible to penetrate the roof and use a roof ventilator, a ducting section was used (back of baffled area) to exhaust air through the wall of the building. The wall exhaustor is shown from outdoors in Fig. 1-8. Just below it in the figure, the blower system is shown which was used to exhaust the high volume control devices. This blower was oversized for the application so that it could be easily modulated as necessary using a flow control damper and orifice flowmeter. The exhaustor for the two low volume methods is shown in Fig. 1-9.

SECTION 2 CONCLUSIONS

(1) Each of the ventilation controls tested substantially reduced breathing zone and general area concentrations of welding generated contaminants in both open and confined spaces.

(2) The reductions in worker exposure measured in this study represent what can be achieved when control measures are used consistently and positioned properly.

(3) Both the high volume and high velocity low volume (HVLV) ventilation controls reduced breathing zone and general area concentrations of total particulate, iron, chromium, nickel, hexavalent chromium, manganese, and fluorides in both open and confined spaces to below existing OSHA PEL's. The handheld shield exhaustor was able to meet existing OSHA PEL's in open space conditions, but the existing limit for hexavalent chromium was exceeded in confined space tests.

(4) The high volume ventilation methods reduced breathing zone concentrations of nickel in all cases to below the 15 µg/m³ limit being considered by OSHA and hexavalent chromium concentrations to levels

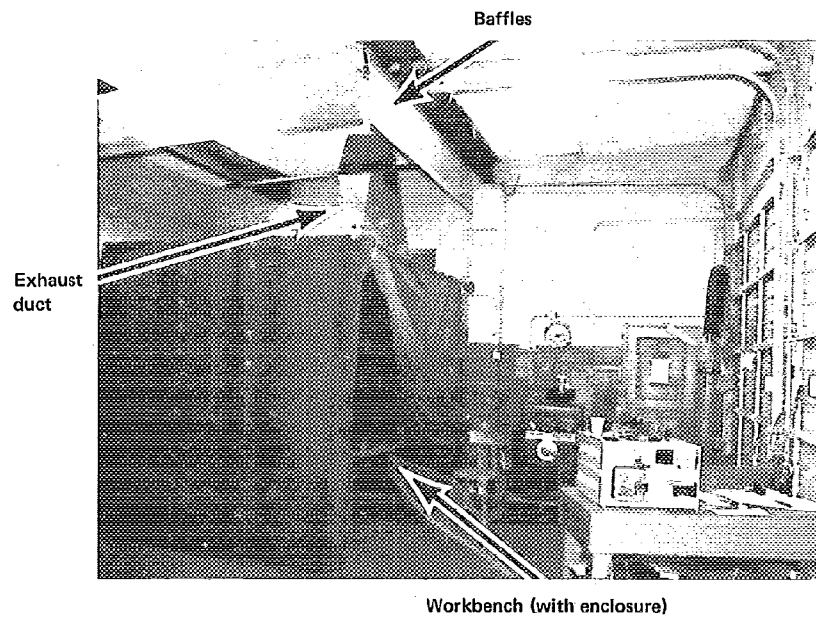


Fig. 1.7—General ventilation system

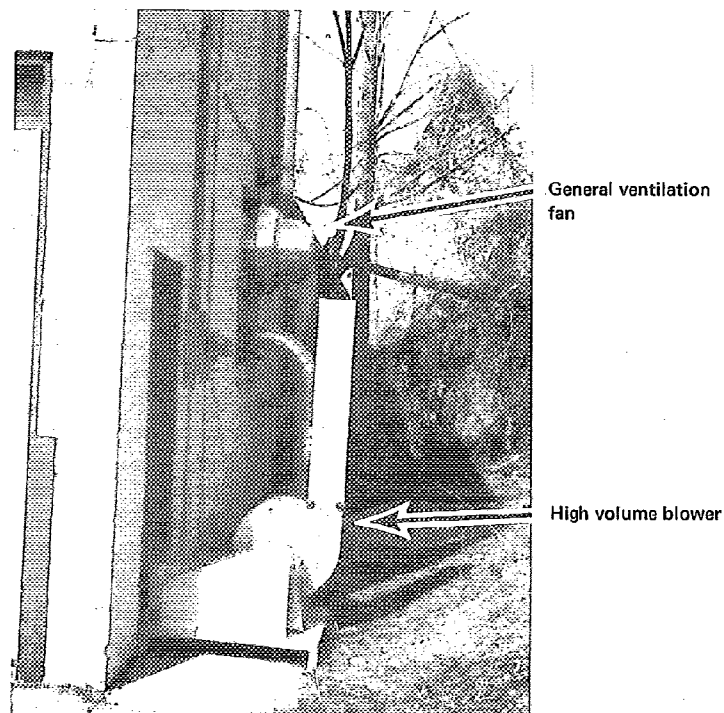


Fig. 1.8—General ventilation and high volume blowers

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Fig. 1.9—Blower for external exhaust of high velocity low volume and handheld shield control measures

below $10 \mu\text{g}/\text{m}^3$, one of the limits being considered by OSHA. HVLV also met both of these levels in open space conditions, but on the average exceeded them in confined spaces. The handheld shield produced average breathing zone results that exceeded these new limits being considered in both open and confined space.

(5) Exposures in confined spaces were typically greater than exposures in open spaces, but not always as much greater as one would expect. This was due to the fact that the exhaust methods used to directly capture the fume also contributed to the general ventilation rate in the vicinity of the worker. This effect was especially pronounced in the case of the high volume exhauster.

(6) The air purifying helmet produced breathing zone exposures far below the existing OSHA PEL's. Nickel exposures were less than the $15 \mu\text{g}/\text{m}^3$ limit being considered, and hexavalent chromium exposures were less than $10 \mu\text{g}/\text{m}^3$, which is one of the limits being considered by OSHA.

(7) Applicability was evaluated in terms of usability, reliability, effect on the process and worker acceptance. Some of the attributes and deficiencies of the devices tested which were concluded from this evaluation are:

High Volume Exhauster

Attributes — The higher amount of exhaust used permitted some flexibility in positioning the hood.

The device was easy to use when welding in open spaces.

Deficiencies — Different devices were needed for open and confined spaces.

Some difficulty was encountered in properly positioning the exhaust in confined spaces.

The large suction opening and ductwork were susceptible to pluggage by shop rags.

High Velocity, Low Volume (HVLV)

Attributes — The relatively small size and light weight of the exhaust hose and nozzles made this method easily usable in both open and confined spaces.

A good selection of available nozzles permitted close capture in all of the positions tested.

Deficiencies — Different nozzles were needed for different tasks, requiring the worker to change nozzles during the work.

Handheld Shield

Attributes — This device was usable in both open and confined spaces with no apparent limitations.

During horizontal welding, the extractor was favorably located above the weld to receive the rising fume.

Deficiencies — Continuous awareness was necessary to assure that the extractor did not drift too far from the arc.

The device eliminated the use of one hand, which limitation the worker did not like.

Peripheral vision was obstructed by the necessity to view through a long tube.

Air Purifying Helmet

Attributes — No interferences were encountered when using this personal protective device in either open or confined spaces.

Deficiencies — When used without local exhaust capture, the performance of routine maintenance (changing filters, charging batteries) appears essential to prevent overexposure to the worker.

(8) Productivity was not affected by the use of the air purifying helmet. However, for the welding protocol used in this study, the ventilation control methods reduced productivity by about 14-17% on the average

as compared to tests where no control was used. All three ventilation controls had essentially the same impact on productivity.

(9) Selection of any of these controls measures for a specific application will require evaluation of more factors than were considered in this study, among them: cost, energy consumption, constraints of the workplace, number of welders to be controlled, and applicable air pollution codes.

(10) Linear correlations among total particulate concentrations and the various fume constituents were high under the conditions of the study, i.e., as total particulate concentrations increased, the various metal concentrations increased accordingly.

(11) Most of the hexavalent chromium generated by the shielded metal arc welding (SMAW) used in this study was of the water soluble variety. No water-insoluble hexavalent chromium was (suspected carcinogen) found in any of the samples analyzed.

(12) The data base was too small to make statistically valid comparisons between air samples taken under the welding helmet and those taken on the lapel.

SECTION 3 RECOMMENDATIONS

(1) A set of tests, similar to those conducted in this study, should be performed to determine the effectiveness and applicability of gun mounted exhausters that are commercially available for use with gas metal arc and flux cored arc welding (GMAW and FCAW). These tests should be conducted on a variety of materials, including stainless steel and aluminum. Although not necessary in the present study, measurements should be made for gaseous contaminants as well as particulate when the guns are used.

(2) A study should be undertaken, including field assessments, to identify the limiting constraints for use of a wide variety of exposure control methods and to establish selectively and design criteria on a systems basis. A systems approach could take into account such factors as number of welders, type of welding and workpiece, plant ventilation systems, energy use, capital and operating costs, climate, and potential for recirculation.

(3) Tests need to be performed to establish a statistically valid data base, comparing in-helmet and lapel sampling methods being used to determine worker exposure to welding generated particulate. These tests should be conducted in such a manner that the effect of important external variables, including fume generation rate, general air quality, welding position, helmet shape and the presence of crossdrafts on each of these measurement methods can be assessed.

SECTION 4 DISCUSSION

USEFULNESS OF CONTROLLED TEST RESULTS

The consistency of the results and the high correlation among the contaminants measured in this study attest to the merits of studying worker exposures and capture method effectiveness under controlled conditions. The team who performed this study had previously performed two other studies in industry related to welding and torch cutting fume control technology in foundries (Refs. 15 and 16). In both studies, capture methods were assessed during actual production operations. In the second of these studies, attempts were made to establish correlations among the various contaminants measured, but no such correlations were found. It is hypothesized that the primary reason for lack of correlation was that welding was performed side-by-side with other processes such as abrasive grinding, which also produced particulate containing material other than the base metal, such as sand. Cross-contamination among processes does not permit the isolation that is so necessary for establishing correlations.

A real feature of the type of evaluations performed in this study is that, besides being well-controlled, they still employ the basic essentials of a full-scale industrial welding operation. The worker was a trained welder and the workbench and workpiece and degree of confinement simulated one type of common industrial operation.

NEED FOR ADDITIONAL INDUSTRIAL ASSESSMENT

Tests in actual manufacturing operations do have their place along with controlled experimentation in establishing the effectiveness and applicability of control measures and they should be done in the present case. Field tests in a variety of industrial situations can be used to identify the limiting constraints of a particular control device and to establish selectivity and design criteria on a systems basis. A systems approach to evaluating control situations would include consideration of such factors as:

- (1) The number of welders and their proximity to each other.
- (2) The type of welding performed and the nature of the workpiece.
- (3) The ventilation systems in use in the manufacturing space.
- (4) The availability and cost of energy.
- (5) The climate.
- (6) Costs of controls and ductwork.
- (7) Air pollution codes to be met.
- (8) Potential for recirculation of cleaned exhaust air.

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Another difference between controlled experimentation and evaluation of existing industrial operations is that, in the latter case, it is very difficult to differentiate between deficiencies in a particular control method which may be attributed to inherent defects in the method itself as opposed to defects in applying the method. The objective of the study performed here was to install selected types of control measures and to supervise their use to assure that they were being applied properly. Important system parameters were monitored, the worker was trained in the proper use of the systems, and the operation was strictly supervised. As such, these tests probably represent a baseline defining what can be accomplished under ideal conditions. A myriad of factors could act to detract from that baseline. Chief among these factors is the improper or incomplete use of the method by the worker. There is a discipline that must be maintained by the worker which is not easy (sometimes the worker and his management don't accept the need to faithfully apply these control measures to protect the worker's health). A second leading factor contributing to ineffectiveness is lack of maintenance; third in line is probably the distribution from crossdrafts, especially from mancooler fans. It would be possible to run tests to establish the impact of each of these defects but their impacts can be widely variable, and they are for the most part preventable.

EVALUATION OF CONTROL MEASURES FOR OTHER PROCESSES

The same basic study methodology could be applied to study other forms of welding and cutting technology. A logical next step to this study, for example, could be to use an identical protocol to study gun mounted exhausters used on GMAW and FCAW equipment on stainless steel, and perhaps also aluminum.

MEASURING WELDERS' EXPOSURES

Currently, there is controversy about how the welder's exposure to air contaminants should be measured. Two basic approaches are to use: inside and outside helmet sampling. Differences in sampling inside versus outside the helmet primarily relate to the barrier which the helmet represents between the air contaminant source and the breathing zone. The inside-the-helmet method withdraws a sample on the same side of the barrier as the breathing zone; the outside-the-helmet withdraws a sample on the same side of the barrier as the contaminant source.

Limited numbers of samples comparing inside versus outside the helmet exposures were gathered in this study (Appendix D) as well as other studies (Ref. 15). The variability measured in each of these studies emphasizes the need to perform a study which will statistically define the relationships between these two sampling locations and assess the effects of important factors such as fume generation rate, general air qual-

ity, welding position, helmet shape, and presence of crossdrafts. This study could provide a basis for a better interpretation of measurements made to assess exposure during welding.

SECTION 5 TESTING PROCEDURES AND MEASUREMENT METHODS

WELDING PROCEDURES

A welding protocol was established and implemented that required welds to be made in specific positions and locations, following a set pattern and sequence. The simulated work pieces consisted of Tee shaped bars and a large circular ring that was placed on top of a workbench as shown in Fig. 5-1. The vertical barriers in the figure were installed for two reasons:

(1) To present a barrier, simulating an obstruction, around which the ventilation controls had to be moved to perform the various welding tasks involved in the sequence. This was done to evaluate the mobility of the ventilation control devices.

(2) To simulate the air baffling effect that the workpiece or other industrial obstruction may have to the direct flow of air toward the exhaust point.

The sequence of welding tasks is indicated on the plan view schematic in Fig. 5-2. Each new test always started with Step 1. All of the welds were continuous and all but Step 10 were fillet welds; Step 10 was a bead run across a flat plate. Most of the welds were horizontal, with the exception of three vertical down welds (Steps 4, 6, and 8). The sequence of tests required that the welder move frequently from one side of the vertical barriers to the other.

The Tee shaped bars measured 4 in. (10 cm) wide and high by 36 in. (91.4 cm) long. Steps 5 and 9 were performed on the same fillet piece; only the position of the piece on the table was changed. The circular weld was approximately 9.5 ft (2.9 m) in circumference. Fillet welds were placed both on the inside and outside of the circle (Steps 3 and 7).

Test Materials

All tests were conducted using 5/32 in. (3.9 mm) diameter, E308-16 electrodes and 3/8 in. (0.95 cm) type 304 plate. The compositions of the electrodes and base metal are given in Table 5-1. Welding was performed using DC (+) polarity with the machine set at approximately 130 amperes.

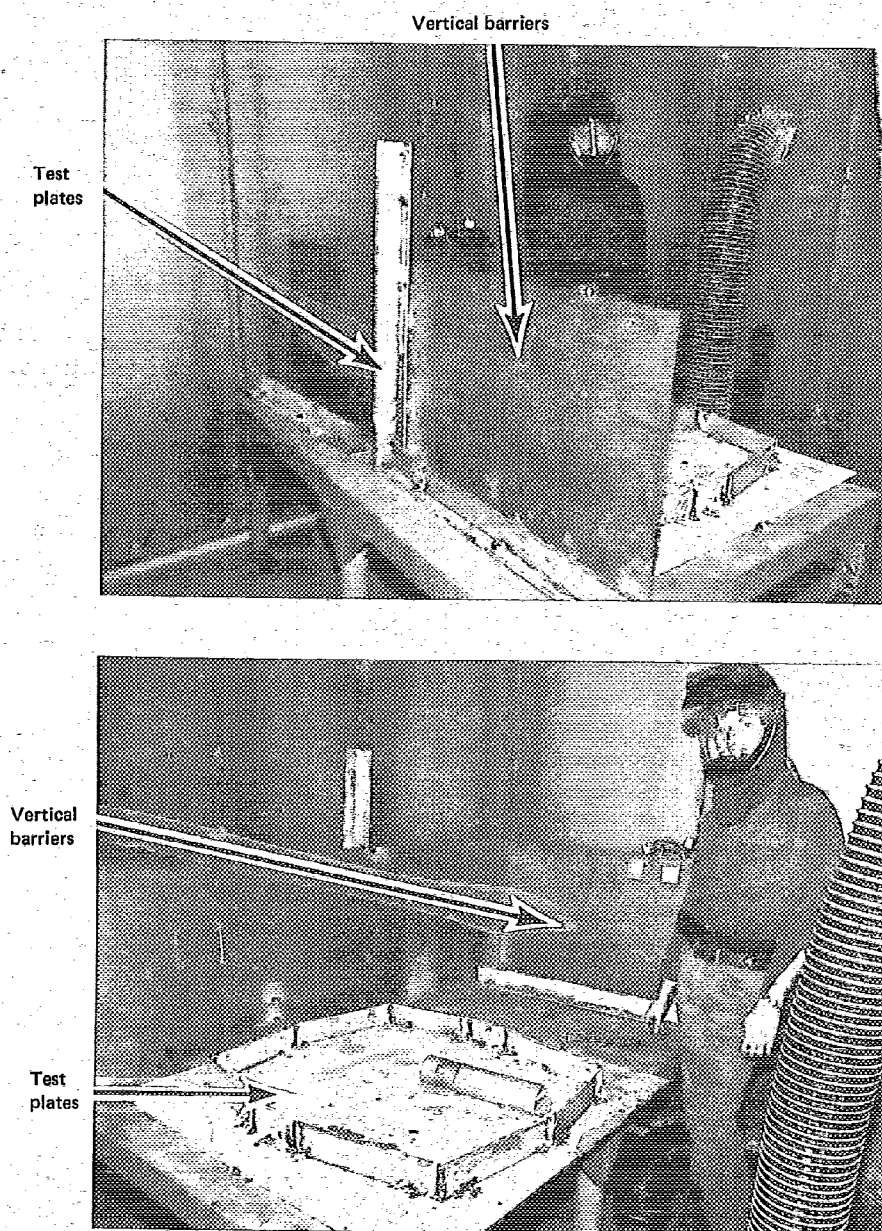


Fig. 5.1—Welding table, with test plates and vertical barriers