

Effects of Welding on Health, VIII



American Welding Society



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Effects of Welding on Health VIII

Research performed by Southwest Research Institute, San Antonio, Texas, under contract with the American Welding Society and supported by industry contributions.

This is an updated (January 1988–December 1989) literature survey and evaluation of the data recorded since the publication of the first report (1979). This series of reports is intended to aid in the understanding of the health effects of welding.

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Abstract

This literature review, with 193 citations, was prepared under contract to the American Welding Society for its Safety and Health Committee. The review deals with studies of the fumes, gases, radiation, and noise generated during various arc welding processes. Section 1 summarizes recent studies of occupational exposure to fume, while Section 2 contains information related to the human health effects of exposure to electromagnetic radiation. Section 3 discusses studies of the effects of welding emissions from production coatings, and Section 4 describes hygiene and work practices. The remaining sections are devoted to reports on health studies on affected organ systems.

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Foreword

(This Foreword is not a part of *Effects of Welding on Health VIII*, but is included for informational purposes only.)

This literature review was prepared for the Safety and Health Committee of the American Welding Society to provide an assessment of current information concerning the effects of welding on health, as well as to aid in the formulation and design of research projects in this area, as part of an on going program sponsored by the Committee. Previous work consists of the reports *Effects of Welding on Health I* through *VII* each covering approximately 18 months to two years. Conclusions based on this review and recommendations for further research are presented in the introductory portions of the report. Referenced materials are available from:

Institute of Scientific Information, Inc.
3501 Market St.
Philadelphia, PA 19104
Tel. (800) 336-4474, Ext. 1591

Comparative Listing — Welding Processes

Explanatory Note: Terms used in the technical literature sometimes do not correspond to those recommended by AWS in its publication ANSI/AWS 3.0, *Standard Welding Terms and Definitions*.

Accordingly, the following list may aid the reader in identifying the process in use.

EWI — VIII		Preferred AWS Term
Gas or Flame Cutting	(OC)	Oxygen Cutting or (OFC) Oxyfuel Gas Cutting
Gas Welding	(OFW)	Oxyfuel Gas Welding or (OAW) Oxyacetylene Welding
MAG	(GMAW)	— (with specified shielding gas)
MIG, GMA	(GMAW)	Gas Metal Arc Welding
MMA, SMA	(SMAW)	Shielded Metal Arc Welding
TIG	(GTAW)	Gas Tungsten Arc Welding
Wire		Electrode

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Introduction

The health of workers in the welding environment is a major concern of the American Welding Society. To stay abreast of this subject, the health literature is periodically reviewed and published in the report *Effects of Welding on Health*. Seven volumes have been published to date; the first covered data published before 1978, while the latter six covered time periods between 1978 and December 1987. The current report includes information published between January 1988 and December 1989. It should be read in conjunction with the previous volumes for a comprehensive treatment of the literature on the *Effects of Welding on Health*.

Included in this volume are studies of the characteristics of welding emissions that may have an impact on control technologies necessary to protect the welder (Section 1). In keeping with previous volumes, the health studies are organized according to the affected organ system. The effects of electromagnetic radiation, covered in Section 2, are not yet completely understood and more research is needed. The respiratory tract, the primary route of exposure to welding emissions, is also a major target organ of many components of these emissions as noted in Section 5. Acute effects (e.g., metal fume fever in Section 7), as well as potential chronic respiratory effects (e.g., cancer in Section 6) of welding emissions are of concern. However, the risk of cancer from these exposures has not been clearly established, and more research in the form of epidemiologic studies, investigations with laboratory animals, and in vitro genotoxicity studies will help to resolve this question.

Executive Summary

Welding and related technologies require active risk management to mitigate the well known, and not so well known, effects of exposure to chemical and physical agents. This survey of the literature related to the effects of welding and health covers the calendar years 1988 and 1989.

Several of the epidemiologic studies identified a synergistic interaction between cigarette smoking in populations exposed to welding fumes and lung cancer. Workplace smoking policies may eventually become an especially important part of occupational hygiene programs in industries using welding.

Electric and magnetic fields are identified as a new physical agent exposure which may eventually need to be controlled. It is entirely possible that regulation relating to electric and magnetic field exposures may arise from concerns of residential exposure and eventually impact the welding industry.

Ironically, a technology which may reduce human exposure to welding emissions, the use of robots, may

increase the possibility of other threats to health and welfare such as crushing injuries.

Tenuous connections with parental occupations in groups of activities which include welding or soldering have been identified in studies of childhood cancer. This general area of research may well have more specific investigations of welding in the future, because of the potential for exposure to metals.

Regulatory changes occurred world-wide in 1988–89. The general tone of the regulations is toward reduction of exposure to hazardous materials to the minimum attainable levels. Effective management of risk will require implementation of management systems to facilitate and monitor worker compliance.

Advances in biological monitoring, especially for metals, and systems for the physical analysis of welding emissions make it reasonable to predict that, within the next few years, it will be possible to monitor exposure and assess the effectiveness of engineering controls.

Technical Summary

The Exposure

Fumes

Fumes from welding processes are usually complex mixtures, the composition of which is usually different from the composition of the electrode or consumables. Fume components are generated by volatilization, reaction, or oxidation of the materials involved in the process including the consumables, the base metal and its coatings and other materials present in the atmosphere at the welding site (Ref. 166).

The potential hazards associated with exposure to the components of welding fumes are recognized, and work practices for the minimization of exposure are included in materials on welding safety (Ref. 165) and a consensus standard on welding and cutting safety, ANSI/ASC Z49.1-88 (Ref. 1). Ventilation equipment for welding fume control is also the subject of a consensus standard, ANSI/AWS F3.1-89.

One approach to reducing the potential health hazards from welding fumes is modification of the consumables. A carcinogen, hexavalent chromium, Cr(VI), is normally present in fumes when welding stainless steel, but a low-fume electrode described by Griffiths and Stevenson (Ref. 58) is reported to give an almost 10-fold reduction in Cr(VI) concentration in the fume.

Fume composition is a function of many factors which interact in a complex manner. For example, a sample of hardfacing and surfacing wires had nearly a 5-fold difference in fume particulates, but the testing was performed at only one load point per wire (Ref. 64) which gives an incomplete picture.

Despite the information available on safety and ventilation and the research on processes and supplies, actual workplace fume concentrations may exceed acceptable levels (Ref. 45).

Gases

The gases which may be generated during welding processes include ozone, carbon dioxide, fluorides, car-

bon monoxide and oxides of nitrogen (Ref. 165). One approach to the reduction of ozone and nitrogen dioxide emissions from GTAW may be to add a low concentration of nitric oxide to the shielding gas (Ref. 10).

Carbon monoxide concentrations measured with personal samplers and the difference in carboxyhemoglobin levels between cigarette smokers and nonsmokers is a function of the work environment. For outside work, smokers had a 2- to 3-fold higher concentration of carboxyhemoglobin. For inside work, the absolute levels were higher, and the smokers and nonsmokers had similar blood carboxyhemoglobin levels (Ref. 169)

Electromagnetic Energy

Many wavelengths of electromagnetic radiation are involved in welding processes. The hazards of ultraviolet light are addressed by guides for lens shade selection such as the consensus standard ANSI/AWS F2.2-89 (Ref. 14). Lasers have important differences from conventional processes, and there may be diffuse reflection hazards near the target (Ref. 140).

Extremely Low-Frequency Electromagnetic Energy (ELF)

Concern about the potential health effects of very low levels of nonionizing radiation, usually in the context of the A.C. power system, has implications for users of electric arc welding processes. Although the area is controversial and the connection to adverse health outcomes is inconclusive (Ref. 176), it is clear from exposure studies (Ref. 161) that electric arc welding can cause relatively high levels of exposure.

Production Coatings/Paints

Characterization of the organics released in fumes can differentiate the profiles associated with different types of production coatings (Ref. 48) which may lead to lower risk production coatings.

Lead-based paints are used as a coating on structural steel and may be a significant source of lead exposure even in outdoor welding or cutting operations (Ref. 138).

Hygiene and Work Practices

Robotic welding systems have the potential to reduce human exposure to potentially toxic materials, but they also bring the need for new safety considerations involving aspects ranging from mechanical interlocks and software issues (Ref. 132).

Fatal accidents related to welding and cutting ranged from 10 to 39 per year between 1975 and 1985. Over half of the fatalities in general industry were related to fires or explosions, or both. The compilation by Cloe (Ref. 36) includes 217 case files involving 262 fatalities which provide a narrative description of the incident as well as useful summary tables, some of which are reproduced in the corresponding section of this document.

Effects of Welding on Human Health

Respiratory Tract

Alveolar Macrophages. Tissue culture studies of the effects of fumes from different welding processes on bovine macrophages and soluble Cr were reported by Hooftman, Arkesteyn, and Rosa (Ref. 67). In this study, most of the cytotoxicity of the fumes sampled could be explained by their soluble chromium content. Fume particles obtained from MIG-MS were similar to those for inert glass beads and particles from MMA-SS were the most toxic in this assay.

Anti-oxidant Systems. Study of aluminum welders by Pierre et al. (Ref. 133) showed changes in serum ceruloplasmin levels through the work week in "confined space" welders. The authors suggest that ceruloplasmin is being consumed as part of the extracellular long antioxidant system and that this process influences serum levels.

Retained Particles. Magnetopneumography by AC susceptibility bridge methods (Ref. 159) can provide information about total lung magnetic particulates. An alternative method is SQUID (superconducting quantum interference device) measurements of the magnetic signal from particles magnetized by an external magnetic field (Ref. 157). These small studies demonstrate the possibility of these measurements.

Pulmonary Function and Bronchitis. An interaction between welding and smoking on pulmonary pathology

was reported in several studies (Refs. 30, 59, 77, and 78). The general finding is that welders have a higher rate of pulmonary pathology than nonwelders and that welders who smoke have higher rates than welders who did not smoke.

Cancer. Welders were the subjects in seven cancer epidemiology studies and appear as a class of workers in several occupational survey studies. Cigarette smoking and exposure to asbestos are confounding variables which can obscure the relationship to welding processes per se. Evidence is accumulating that the relationships between welding process and cancer are complex. Tola (Ref. 168) studied mild steel welders who had not been exposed to Cr(VI) fumes in a large study (1689 welders). Welders had a small but not statistically significant elevated risk for lung cancer. Merlo et al. (Ref. 102) who reported that oxyacetylene welders have an excess risk of respiratory tract cancer, but arc welders did not. They propose that this difference is accounted for by differences in the type and level of exposure to fumes and polycyclic aromatic hydrocarbon exposure because of work inside oil tankers. These studies provided evidence that specific characteristics of the welding environment may be associated with cancer.

Welding has been identified in classes with many other occupations as a parental job factor in childhood cancers: Wilm's tumor (Ref. 29), brain cancer (Ref. 185), and liver cancer (Ref. 28). These studies use very general occupational categories and are not specific to welders; however, they do suggest variables for studies of the children of welders.

Metal Fume Fever

While zinc fume fever is usually transient (Ref. 85), inhalation of cadmium fumes can produce severe illness (Ref. 123).

Effects on Hearing

Some combinations of welding technology and process parameter values can produce sufficient noise such that an exposure of 1 hour reaches the maximum permissible noise exposure criterion (Ref. 54).

Effects on the Eye and Vision

Despite safety recommendations and guidelines, retinal injuries occur in developed countries (Ref. 25). In a study of workmen's compensation claims in Canada, 72% of welder's eye injury claims resulted from foreign body injuries (Ref. 137).

Effects on the Nervous System

Although most welding-related nervous system effects involve incidental chemical exposure such as hydrogen sulfide (Ref. 170) or aliphatic hydrocarbons (Ref. 66), Rudell et al. (Ref. 144), studied welders who reported dizziness after welding with a battery of oculomotor tests and found that a small sample of welders had lower scores than controls which decreased further after only 30 minutes of welding.

Effects on the Musculoskeletal System

Work position (Ref. 164) may be a contributory factor in development of musculoskeletal complaints, and it is possible that ergonomic studies (Ref. 146) and workplace interventions (Ref. 183) will reduce musculoskeletal complaints.

Effects on the Reproductive System

A questionnaire and semen analysis study by (Ref. 109) did not detect a strong relationship between welding and "poor sperm quality" and the summary of a Danish review article (Ref. 18) suggests because of methodological problems with studies showing a relationship between sperm quality and welding, further research is required

Effects on the Urogenital Tract

Although both welders and platers had elevated levels of urinary Cr (Ref. 174), this study examined a variety of biochemical markers of kidney function and found little evidence of pathology from Cr(VI) exposure.

Effects on the Immune System

An immune system screening of welders with immunoglobulin measurements and intradermal challenges (Ref. 19) led the authors to conclude that a significantly higher proportion of welders had signs of deficiency of cell-mediated immunity.

Biological Monitoring

A two-compartment model is suggested by Sjogren et al. (Ref. 152) to account for urine aluminum levels. One compartment, perhaps the lungs and skeleton, has a long half life and is related to years of exposure. The other component has a short half-life and is related to current air Al concentration.

Welding processes which involve Cr are associated with uptake and increased urinary excretion (Ref. 108) but the urinary Cr does not reflect the oxidation state of the exposure source because Cr(VI) is reduced to Cr(III) in blood (Ref. 105).

Toxicologic Investigations In-Vivo and In-Vitro

In vitro studies of fume samples in tissue culture cytotoxicity assays with kidney or embryo primary cells (Ref. 160), macrophages (Ref. 67), or sister chromatid exchanges in ovary cells all suggest that the soluble Cr(VI) is the major contributor to the cytotoxicity observed.

In vitro studies on cultured cells of the effects of vanadium (Ref. 74) showed changes with hyperbaric pressure.

Conclusions

Many of the potential effects of welding on health are related to specific chemical or physical agents involved in the welding process. These welding factors range from components of welding fume to electromagnetic radiation. In general, management of these risks can be accomplished by appropriate industrial hygiene practices, once the risk factor is identified and exposure is controlled.

Some risks to welders are work-related secondary factors that do not result from the welding process itself but are a part of the occupational setting. Examples of these types of risks are asbestos exposure during shipyard welding and industrial accidents involving falls. Industrial hygiene and safety practices target the reduction of these secondary risks.

Personal risks are those which occur within an individual's lifestyle without regard to occupational setting. Examples of personal risks include cigarette smoking, "Type A" personality characteristics, and driving while intoxicated.

Welding-process, occupational, and personal risk factors occur in combination in individual workers and complicate the process of risk assessment. Welding is a complex chemical and physical process which makes the process of risk assessment (and consequently, risk management) especially difficult. The complex nature of the potential exposures and the combination of welding, occupational and personal risk factors makes attribution of risk to a specific aspect of the exposure a difficult task. For example, exposure to asbestos (an occupational risk factor) and cigarette smoking (a personal risk factor) are both associated with increased lung cancer risk. In the context of combined exposures, the question then becomes one of potential additional risk associated with welding processes, not the risk of the welding process itself.

One way to categorize the health aspects of welding-related exposures is to assess their status in the risk assessment process. The risk assessment process has four stages: (1) hazard identification, (2) establishment of dose-effect relationships, (3) exposure assessment, and

(4) risk assessment based on the information from stages 1–3. Most of the information gathered for this review is related to the hazard identification stage of the risk assessment process with some information about different exposure levels involved.

Some aspects of welding have known hazards such as the effects of welding processes on the eye. In addition to the known hazards, there is a large set of unresolved hazards associated with welding. Unresolved hazards have some data to indicate possible hazard but not enough to clearly demonstrate hazard. Cancer, immune system effects, and reproductive effects are all in the unresolved category. There are several reasons why hazards remain unresolved: (1) the relevant aspect of exposure may not be identified correctly and so the effect is diluted by the miscategorized exposures, (2) confounding variables related to occupational and personal risk factors can obscure the relationships under study and preclude the identification of hazards, and (3) the statistical power of the studies conducted may be too low to detect an important health effect or so high as to flag a welding-related trivial biological change as "statistically significant". Potential hazards would be those factors for which there is insufficient information to categorize as either unresolved hazards or as nonhazards. The potential effects of exposure to magnetic fields are in this category.

Unresolved hazards are the most troublesome for risk assessment. It is possible, as outlined below, that no practically attainable study will be able to resolve status of a potential risk factor with respect to welding per se. It may be most effective for risk managers to focus on industrial hygiene and exposure assessment while unique risk factors associated with welding are investigated.

Three reasons why practically attainable studies, especially epidemiology may not resolve unresolved hazards are (1) dilution by miscategorization, (2) confounding variables (other risk factors), and (3) insufficient statistical power. Dilution by miscategorization of exposure is a possibility in any epidemiology study of welding which uses a surrogate measure of exposure. Because the composition of welding fumes is a complex function of the