

Effects of Welding on Health, IV



American Welding Society



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Effects of Welding on Health IV

*An up-dated (December 1980-June 1982) literature survey
and evaluation of the data recorded since the publication of
the first report, to understand and improve the occupational
health of welding personnel.*

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Preface

This literature review has been prepared for the Safety and Health Committee of the American Welding Society to provide an assessment of current knowledge of the effects of welding on health, as well as to aid in the formulation of research projects in this area, as part of an ongoing program sponsored by the Society. Previous work has included studies of the fumes, gases, radiation, and noise generated during various forms of arc welding (see Bibliography). Conclusions based on this review and recommendations for further research are presented in the introductory portions of the report. Section 1 summarizes recent studies of the occupational exposures. Section 2 contains information related to the human health effects of exposure to byproducts of welding operations. Section 3 discusses studies of the effects of welding emissions on laboratory animals and *in vitro* cell systems. Referenced materials are available from Tracor Jitco, Inc.

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*. Three volumes have been published to date (Refs. 135, 143, and 144); the first covered data published prior to 1978, while the latter two covered the periods 1978 to May, 1979 and June, 1979 to December 1980, respectively. The current report included information that was published between December, 1980 and June, 1982, and 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 impact on the control technologies necessary to protect the welding worker (Section I). Considerable discussion is devoted to ozone which may become a greater problem to welders as improved ventilation and

decreased fume exposures reduce the rate of degeneration of this hazardous gas. Much recent research has focused on chromium and nickel, since exposure to certain chemical forms of these metals may cause serious chronic health problems.

In keeping with previous volumes, the health studies are organized according to the organ system affected. The respiratory tract, the primary route of entry of welding fumes and gases into the body, also is a major target organ of a number of components of these emissions. Acute (e.g., metal fume fever, cadmium poisoning) as well as potential chronic respiratory effects (e.g., emphysema, cancer) of welding emissions are of concern. The latter are far less well understood and whether or not there is an excess risk of cancer from these exposures has not been established. Continued research in the form of epidemiologic studies, investigations with laboratory animals, and *in vitro* genotoxicity studies will help to resolve this question.

Executive Summary

A problem inherent in research concerning the health effects of welding is that there is a great deal of variability in both welding processes and in working conditions which makes it difficult to perform studies on homogeneous populations of sufficient size to permit statistical analysis. These variations may be less critical when examining causes of acute physiological responses to welding exposures (e.g., metal fume fever, burns, photokeratitis). However, the association between chronic exposures to welding emissions and disease conditions whose causes are less well understood, or which occur at a low incidence, remains ambiguous in many cases.

The Respiratory Tract

Of the five metals (Cr, Ni, As, Be, and Cd) that have been shown by epidemiologic studies to be related to an increased cancer incidence in workers in certain industries, chromium and nickel are present in significant quantities in fumes released during welding certain metals (e.g., stainless steel and nickel alloys). However, only some chemical compounds containing these metals are carcinogenic, and it is not known if these compounds are present in welding fumes. The available epidemiologic evidence is insufficient to determine whether or not welders are at an increased risk of developing lung cancer from exposure to chromium and nickel in welding fumes.

Most of the reports of the effects of welding on health which appeared during the period of this review dealt with effects of welding on the respiratory tract. Metal deposits have frequently been found in welders' lungs by chest X-rays and at autopsy. The use of

magnetopneumography enables rough estimates to be made of the quantities of metals retained in the lungs. However, the association between this retention of metals and impaired lung function is not clear. For this reason, it is important to develop more accurate methods for the determination of lung function. Of the six studies using pulmonary function tests of welders which appeared during this report period, three indicated impaired lung function among welders, and three reported no differences between welders and controls.

Four epidemiologic studies of the lung cancer incidence among welders have appeared in the recent literature. Two of these indicated an elevated lung cancer risk. One of these two studies focused on welders of stainless steel, but the size of the study cohort was too small for the results to be considered conclusive. The second was a death record study of welders selected from the rosters of a trade union in Seattle, Washington. A significant increase (SMR*=174) in the lung cancer rate was found when deaths that occurred more than 20 years from the initial date of exposure were considered. A study of welders exposed to nickel-rich welding fumes did not indicate an elevated lung cancer risk; however, the investigator emphasized the need for a follow-up study of this cohort to allow more time for the appearance of tumors. There is a great need for further well-planned epidemiologic studies of welders. Because of the high cost of these studies and the limited resources available to the welding community, Stern suggested

*Standardized mortality ratio

that such studies focus on exposure to welding processes in which it is suspected that genotoxic or carcinogenic materials, such as nickel and chromium compounds, are released (Ref. 122).

Other Organ Systems

Reports of recent health studies that examined the effects of welding on organ systems other than the respiratory tract are highlighted below.

- With the exception of cutaneous burns and erythema of the neck which were more common in welders, no significant differences between the frequency of skin and eye disorders were found between welders and nonwelders from the same fabrication facility. Good safety and health measures were practiced in this plant.

- An excess of inflammation of the oral mucous membranes, including periodontal disease, was observed in two separate studies of welders.

- No differences were observed in the morphology, number, and motility of sperm produced by welders and by workers in other occupational groups.

Biological Monitoring of Exposure to Welding Emissions

The development of methods for the accurate determination of personal exposures are needed to establish and measure the effectiveness of control

technologies. In conjunction with devices that collect personal air samples for determining the welder's actual exposure, biological monitoring affords a means for estimating the actual dose of contaminants taken up by the body. Such tests are useful for the support of population and epidemiologic studies and for the evaluation of the effectiveness of industrial hygiene measures introduced to reduce worker exposure. Finally, biological monitoring during routine medical examinations may play an important part in alerting the occupational physician to individuals who may be exposed to unacceptable levels of welding emissions.

The importance of this area of research is witnessed by the number of studies that have been published on this subject. Studies using magnetopneumography have demonstrated that the amount of materials retained in the lung correlates with the number of years spent welding, the extent of siderosis, and the relative quantity of fumes generated by the welding process. In other work, the relationship between urine concentrations and breathing zone levels was linear for fluorine, suggesting that this element may be useful for monitoring the exposure of welders who use basic-coated electrodes. Although urine chromium levels tended to increase during the work week, this metal nevertheless may be useful for estimating exposures to fumes generated by welding of stainless steel. Urine nickel levels tend to fluctuate widely and are apparently not a useful measure of nickel exposures.

Technical Summary

The Exposure

Fumes

The major objectives of research on fume emissions are to evaluate health hazards, to develop welding methods which produce less toxic fumes, and to enable estimation of air exchange rates required to bring fume concentrations to acceptable levels. Total fume emissions are greatest with shielded metal arc welding and flux cored arc welding and vary with the electrode used and welding parameters.

To determine the airflow requirements of ventilation systems, Alekseeva *et al.* examined the emissions released during gas tungsten arc welding of manganese-copper alloys (Ref. 4), copper alloys containing nickel or zinc (Ref. 3), and eight different welding wires containing from 2 to 70% nickel (Ref. 5). Pokhodnya *et al.* (Ref. 102) found that the rate of manganese vaporization from rutile or basic electrodes increased with the alkalinity of the slag. Oleinchenko *et al.* (Ref. 98) determined that fluoride emissions from electrode coatings increased with the moisture of the coating during automatic aluminum welding.

A large portion of the solid phase of welding aerosols consists of respirable particles. Particles may exist as single entities or as chains or agglomerates (Refs. 12, 23, 51, 70 and 81). When present, chromates appear to be condensed on the surface of metal oxide particles (Refs. 70 and 81).

Two major interlaboratory studies are currently examining methods for the determination of soluble and insoluble hexavalent chromium in welding emissions (Refs. 11 and 51). Variations in the methods

of sample collection, storage, and extraction procedures may affect the analytical results (Refs. 11, 49, and 128).

Gases

The sources of toxic gases, e.g., nitrogen oxides, ozone, and carbon monoxide, during welding are discussed. Johansson (Ref. 71) reported that the addition of helium or hydrogen to shield gases reduced the ozone levels released during GMAW or GTAW of stainless steel, and Smars (Ref. 117) reported that the addition of nitric oxide, but not helium, significantly reduced ozone levels during GTAW of aluminum. However, Farwer (Ref. 39) argued that because of its toxicity and stability, the NO₂ generated from nitric oxide in shield gases may be a greater hazard than the ozone whose formation it prevents. The presence of magnesium, but not silicon, in aluminum alloys significantly reduces the production of ozone during GMAW of aluminum (Ref. 117).

Production Coatings

Primers or paints on metal surfaces may contribute significant quantities of formaldehyde, carbon monoxide, hydrogen cyanide, and other organic vapors to welding emissions (Ref. 21). These vary primarily with the characteristics of the binders used in the coatings.

Electromagnetic Radiation

Since ultraviolet radiation in the vicinity of 270 to 280 nm is most likely to be absorbed by and damage

the genetic material (DNA), Bartley *et al.* (Ref. 14) investigated the intensity of radiation with these wavelengths generated by GTAW and GMAW of aluminum. They found that, unlike its effect on ozone levels, magnesium in aluminum alloys effects an increase in ultraviolet radiation between 270 and 280 nm.

Pabley and Keeney (Ref. 99) showed that reflective gold polycarbonate filter plates in welders helmets more effectively reduced exposure to infrared radiation than did green glass filter plates. Sliney *et al.* (Ref. 116) developed design criteria for a semitransparent curtain which would enable safe bystander viewing of the welding area and increase visibility within the welding booth.

Noise

Hermanns (Ref. 65) compared the noise levels produced by different welding processes and found that, while most produced at least occasional noise above 85 dB, plasma cutting was the noisiest.

Effects of Welding on Human Health

Respiratory System

Using magnetopneumography, the quantity of particles retained in the lungs of welders in the asbestos (Ref. 31) and shipyard (Ref. 42) industries was found to be significantly higher than that in workers not employed in welding. Of workers using a variety of common welding methods, stainless steel welders employed in SMAW had the highest quantities and those using GTAW had the lowest quantities of retained metals in the lung (Refs. 73 and 80). Welders performing SMAW of mild steel had intermediate levels of retained metals.

Two cases of pulmonary fibrosis were reported in aluminum arc welders (Refs. 62 and 134). Cigarette smoke and other exposures may also have contributed to the disease. Gobatto *et al.* (Ref. 45) examined lung tissue from 17 autopsied welders. Fibrosis was present in more than half, and siderosis was present in all of the lungs examined. Areas of inflammation or fibrosis consistently had associated iron deposits which led the investigators to speculate that the metal or associated toxins, or both, were involved in the disease process. Zober (Ref. 147) reviewed and analyzed reports of 47 cases of pulmonary fibrosis in welders published between 1955 and 1979. He concluded that, at most, only 20 cases could have been related to the welding experience.

Hayden *et al.* (Ref. 60) found that welders in the engineering industry had slightly more absences due to upper respiratory tract infections than did controls, but absenteeism resulting from other diseases did not

differ from control groups. McMillan and Molyneux (Refs. 83 and 84) found no differences in the absentee patterns from respiratory tract diseases in nonsmoking welders and controls. However, they did note that smoking welders tended to have slightly more absences from lower respiratory tract disease than did the non-welding controls who smoked tobacco products.

The results of lung function tests of welders are inconsistent. No significant differences between the results of pulmonary function tests of welders and controls were found by Schneider and Rebohle among a population of shipyard workers (Ref. 111) or by Hayden *et al.* (Ref. 60) among workers in the engineering industry. Zober examined 40 welders and 40 age matched controls and, with the exception of siderosis detected by chest X-rays, no abnormalities in pulmonary function were identified that could be related to welding (Ref. 145). However, Akbarkhanzadeh (Ref. 2) found that welders in the shipyard industry had impaired lung function, and Cavatorta (Ref. 25) reported changes in respiratory function which were related to the duration of the welding experience. Ohmori *et al.* (Ref. 97) found a slight decrease in peak flow rate and maximum expiratory flow rate at 75% vital capacity which was related to ozone exposures during GMAW. According to Stern (Ref. 122), some of these inconsistencies may result from population dynamics, whereby workers with pulmonary difficulties may change occupations, and to bystander effects whereby some welders may be exposed to toxic substances from nonwelding sources at the place of employment.

Lung Cancer

Polednak (Ref. 103) compared the causes of mortality among welders of nickel alloys with a separate cohort of workers who welded mild steel, stainless steel, and aluminum. The number of deaths from all causes as well as diseases of the respiratory tract, including cancer, were the same in both groups and did not differ significantly from the general U.S. population. Because the period of time following the initial welding exposures may have been too short to rule out an increased respiratory cancer risk in welders exposed to nickel-containing fume, Polednak (Ref. 103) and Gibson (Ref. 44) stressed that follow-up studies should be performed with this important cohort as the number of years from the initial exposure to welding fumes increases.

Beaumont and Weiss (Ref. 16) examined the number of deaths from lung cancer among 3247 welders selected from the rosters of a trade union in Seattle, Washington. A significant increase (SMR = 174) in the lung cancer rate was found when deaths that occurred more than 20 years from the initial date of exposure were considered. Sjogren (Ref. 115) noted an increased risk of lung cancer (3 deaths observed

versus 0.68 expected) among a population of 234 stainless steel welders in Northern Sweden. The results of a death certificate study by Ahonen (Ref. 1) indicated that the risk of lung cancer was the same for welders and for workers in other occupations.

Ear and Hearing

A survey of the effectiveness of earmuffs and earplugs indicated that welders and platers who use earplugs may suffer less hearing damage than those using earmuffs (Ref. 38). The investigators speculated that their results may reflect the greater ease with which earmuffs can be removed and replaced by the wearer.

Eye and Vision

A Bureau of Labor Statistics Survey showed that welding and cutting injuries represented 0.5% of the Workmen's Compensation cases in the United States in 1978. Of these injuries 67% involved the eye, 1/3 of which were welder's flash. Emmett *et al.* (Ref. 36) found no difference between visual acuity or frequency of ocular abnormalities between welders, nonwelders exposed to welding fumes, and workers who were not exposed to welding fumes. All workers were employed for a comparable time period at the same facility.

A case of a pterygium (ultraviolet-induced growth on the outer surface of the eye) was reported in a 56 year-old former welder (Ref. 68). It is unlikely that this resulted from work-related exposure to ultraviolet radiation (Refs. 96 and 126).

Skin

Scars from skin burns were found on 45%, and ultraviolet-induced dermatitis in 8% of welders during a survey of Soviet shipyard workers (Ref. 131). The results of a survey performed in a Danish hospital indicated that welders suffered from burns more frequently than workers in other occupations (Ref. 112). A study in a U.S. facility revealed more cutaneous scars resulting from thermal and mechanical injuries in welders and machinists than in other workers (Ref. 36).

In the latter study, facial erythema, actinic elastosis, and premalignant and malignant skin lesions were found with the same frequencies in welders and nonwelders. Erythema of the neck was more frequent in welders. The investigators noted that this was a relatively young population and the absence of excess premalignant and malignant skin lesions may not be conclusive due to the relatively short period of time following initial welding exposures.

Cardiovascular System

An experimental apparatus that simulated the

welding experience was designed and used in a laboratory setting to determine changes in heart rate while carrying out typical welding procedures (Ref. 130). The variation in heart rate was greatest when the "welder" altered his posture to change electrodes. This variation was greater with a stooped (downhand welding) position than with a standing (overhead welding) or a crouched position.

Nervous System

Chandra *et al.* found that urine manganese and serum calcium levels were elevated in welders who worked with manganese-containing electrodes and had positive neurological symptoms (tremors and deep brisk tendon reflexes in the extremities) (Ref. 27). The investigators suggested that serum calcium levels may be of value in diagnosing early stages of manganese poisoning.

Musculoskeletal System

An incidence of about 15 to 20% was found for supraspinatus tendinitis in shipyard workers (Ref. 63). The number of years of welding experience and the rated level of shoulder muscle load could not be correlated with the development of supraspinatus tendinitis, but these factors could not be excluded by the results of this study. Kadefors *et al.* (Ref. 72) measured the myoelectric activity in individual muscles while eight basic welding postures were assumed by human subjects in an experimental setting. All positions caused localized muscle fatigue, but the overhead welding position was potentially the most damaging to shoulder muscles. This study indicated that the assumption of certain positions may reduce the total muscle load in different welding situations. Tumakov and Grigorev (Ref. 132) designed an exercise program aimed at reducing tension in muscles subjected to static stress to be followed by welders suffering from lumbosacral radiculitis.

Urogenital Tract

No differences were observed in the morphology, number, and motility of sperm produced by welders and workers in other occupational groups (Ref. 76). This and an earlier study (Ref. 58), indicate that welding has no effect on fertility.

A study by Alsirk *et al.* (Ref. 6) detected no changes in kidney function in welders of stainless steel.

Teeth and Oral Cavity

An excess of inflammation of the oral mucous membranes, including periodontal disease, was observed by Wulf and Seefeld (Ref. 140) and Melekhin and Agarkov (Ref. 89). To investigate the cause of complaints by underwater electric arc welders of a metallic