Health Protection in Welding

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Introduction

Health hazards in welding processes include exposure to electric shocks and burns, radiant energy and gases, fumes and dusts. I shall confine myself today to a consideration of the hazards from gases, fumes and dusts and to the measures necessary for protecting the health of welders.

Since the time electric arc welding was put to commercial use sometime in 1910, a few reports appeared in the literature regarding diseases commonly referred to by terms such as "welder's wheeze" "welder's bronchitis" and "welder's siderosis", indicating their occupational origin (1,2). But perhaps the earliest studies to focus attention on the respiratory hazards from electric arc welding were those by Drinker *et al* (3). Subsequent to that, many studies have been conducted on different aspects of the subject. Thus, Doig and Mclaughlin (4) drew attention to the lung changes which would be revealed on X-ray examination. The presence of nitrogen oxides during arc welding and their physiological effects were studied by Harrold *et al* (5) and others (6,7). The occurrence of "metal fume fever" amongst welders has been investigated extensively (8,9).

Dusts, Fumes and Gases—Some General Considerations

It may perhaps be desirable at this stage to describe briefly some of the general properties of dusts, fumes and gases and their physiological significance.

Dusts and Fumes :— These are solid particles dispersed in air. While dusts are formed as a result of mechanical processes, such as grinding, fumes result from chemical action, or from processes, such as condensation and sublimation. Dusts generally contain particles ranging from 0.5 to 20 microns in diameter (1 micron$=10^{-3}$ mm.), whereas the fume particles have sizes ranging from 0.1 to 1 micron. The particles being extremely small do not settle down according to the usual laws of gravity. It is estimated that particles below 0.1 micron tend to float in the air indefinitely unless some other force is brought to bear; particles between 0.1 to 1.0 micron in diameter settle down at rates varying from 0.1 cm. to 12 cm. per hour. Two or more fume particles tend to coalesce and the flocs thus formed settle down more rapidly than would otherwise have been possible. In view of the slow settling down of the fumes no working location in which an operation giving rise to toxic fumes has been carried out could be considered safe even an hour later. This applies equally to situations in which fine dusts from highly toxic substances are given off.

Dust and fumes enter the human system mainly through the respiratory tract i.e. by inhalation. It has been found that particles of the size range 0.5 to 10 microns are of the most physiological significance (10,11) as nature has provided some defence against the entry of the bigger particles : some of the bigger particles are arrested by the fine hairs in the nostrils; some other are caught in the mucous secretions of the nose and the upper respiratory passages and then expelled; and others are arrested by the wave-like action of the cilia which line the nasal and the bronchial passages. The particles which are not expelled are absorbed in the system to produce diseases depending on the chemical nature of the dusts or fumes inhaled, or may be deposited in the lungs, causing "fibrosis" of the lungs. Toxic gases present in the atmosphere can produce on inhalation effects depending upon their nature. Some gases are irritant and affect the respiratory tract and sometimes the lungs also.

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Some other gases produce asphyxiation, either by bringing down the partial pressure of oxygen owing to their presence in high concentrations, or by chemically combining with either haemoglobin or with catalysts in the living tissues, even when present in very low concentrations, e.g. carbon monoxide and hydrogen cyanide. Many other gases on absorption in the system induce anaesthesia and affect the different organs or behave like true poisons.

Based on numerous studies, the threshold limit values (TLV) of safety have been laid down by the American Conference of Governmental Industrial Hygienists (12) for different dusts, fumes and gases for an eight hours' daily exposure, e.g., the TLV of iron fumes is 15 mg./cubic metre of air.

Principal Chemical Hazards in Welding

In arc welding, the main hazard arises from the formation of nitrogen dioxide admixed with small amounts of nitric oxide and nitrous oxide often referred to as "nitrous fumes", through oxygen and nitrogen in air combining under the influence of the arc. Arc welding may also give rise to small amounts of ozone. Though there have been some reports of ozone being present in high concentrations in the welding of aluminium and stainless steel by inert-gas shielded arc process, giving rise to symptoms, such as dryness and roughness of the throat and constriction of the chest (13), this gas is not generally considered to be produced in quantities of industrial hygienic significance. In gas welding, the toxic gases that may be generated in the atmosphere are carbon monoxide, carbon dioxide and nitrous fumes.

The nature of dusts and fumes produced during welding will depend on the nature of the metal being welded and, in arc welding, on the nature of electrodes used. On plain, clean iron parts with a bare iron electrode the fumes will consist entirely of iron oxide. Welding on steel will produce fumes consisting of iron oxide and traces of oxides of silicon, manganese, chromium, nickel and other metals, depending on the composition of the steel and also of the rod. Welding on non-ferrous metals and alloys will produce fumes containing oxides of the metals in question, e.g., copper, aluminium, zinc, tin and cadmium. Welding with coated rods or electrodes will give rise to fumes containing also the breakdown products from the coating which will include chlorides, fluorides and silica. Welding on galvanised plates will produce fumes consisting of zinc oxide and iron oxide. If the surface to be welded is plated, the fumes will contain oxides of the plating metal. If the surface is a painted one, the fumes will contain partly burned particles along with paint pigments.

Nitrogen Dioxide :—Nitrogen dioxide on inhalation, irritates the upper respiratory tract to some extent but causes greater damage to the lungs by causing inflammation. The gas is considered to be extremely insidious as it gives little warning; without serious discomfort one may breathe an atmosphere containing a high concentration of nitrogen dioxide that is sufficient to cause death some hours later (14).

Numerous deaths have been reported from the inhalation of nitrogen oxide produced during both arc welding and gas welding operations in confined spaces (7, 15). However, the consensus of opinion amongst workers in the field is that nitrogen oxide presents a serious hazard to welders only when the operations are carried out in confined, unventilated spaces, e.g., tanks. In this connection, reference may be made to some of our own observations relating to the concentrations of nitrogen dioxide to which electric arc welders were exposed in a ferrous foundry. It was found that the concentrations ranged from 2 to 3 parts per million, the figures being well within the threshold limit value of 5 parts per million for nitrogen dioxide.

Carbon Monoxide :—As is well-known, this is an extremely dangerous chemical asphyxiant which combines with the blood cells so that they cannot take up oxygen required to support life in the tissues. In high concentrations, the gas leads to death. The threshold limit value for carbon monoxide is 100 parts per million.

Carbon monoxide may be formed in small amounts during gas welding but under normal conditions it is not produced in sufficient concentrations to be a potential hazard. But when gas welding is carried out in confined spaces, unsafe concentrations may be present in the atmosphere.

It may also be stated that gas welding in confined spaces may lead under certain circumstances to the depletion of oxygen and suffocation of the operator.

Iron Oxide Fumes :—Inhalation of fumes of iron oxide leads to the condition of the lungs, termed as "welder's siderosis" or "iron oxide lungs" owing to the deposition of iron particles in the lungs. In the circumstances X-ray examination of the lungs indicates a mottled appearance. Contrary to earlier opinion on the subject, recent evidence has indicated that siderosis is unaccompanied by symptoms, abnormal physical signs and diminished capacity for work (4). Notwithstanding this, it would only be prudent to keep the exposure of welders to iron oxide fumes well within the threshold limit value of 15 mg./cubic metre of air.

Zinc Oxide :—Inhalation of zinc fumes produces the disease known as "metal fume fever". The symptoms are dryness in the throat, tightness in the chest, nausea and vomiting accompanied by sudden temperature rise ; after profuse sweating, the temperature returns to normal. The illness is of a transitory nature but causes acute discomfort to the individual. The threshold limit value for zinc oxide fumes has been laid down as 5 mg./cubic metre of air. Welding on galvanized plates, as indicated earlier, can give rise to considerable quantities of zinc oxide fumes.

Lead :—Lead poisoning is by far the most important of the metallic poisonings from the stand-point of frequency. Burning and cutting of lead and lead-coated metals are the chief sources of poisoning in welding work. The symptoms of lead poisoning are numerous, the disease manifesting itself in a great variety of ways. The most common subjective symptoms are colic, constipation, weakness of the extensor muscles of the hand and feet, muscular pains, nausea and vomiting, loss of appetite, peculiar taste in the mouth and nervousness ; the most prominent physical signs are pallor and jaundice, tremor, reflex changes and changes in the blood picture. The TLV for lead is 0.2 mg/cubic metre of air.

In welding operations with metals containing lead, it is necessary to take all measures for protecting the health of welders.

Engineering Control Measures

Suitable control measures will be necessary wherever there is potential risk from dusts, fumes, and gases. The methods adopted in the case of the welding operations are general ventilation, exhaust ventilation and use of personal protective equipment. Mention may be made here that "substitution" one of the principal control measures has only limited application here, though the introduction of 'short arc and dip arc welding' may be considered as a substituted process reducing the health hazard to the welders.

General Ventilation :—For production operations in congested, poorly-ventilated places, the easiest way to improve the situation is by means of general room ventilation. The dilutions with air per welder so as to ensure that no objectionable accumulation of fumes occurs have been worked out by Tebbens and Drinker (16) for different sizes of electrodes ; for a 5/32″ rod, the recommended air movement is 500 cu.ft. per minute and for a 3/8″ rod it is 3000 cu.ft. per minute.

Local Exhaust Ventilation :—If the welding operation is carried out in curtained or partitioned booths, satisfactory ventilation could be obtained by dropping into each booth an adjustable exhaust line extending from an overhead exhaust duct to the welding table. Such a provision is necessary in the case of galvanized metal, even when the operation is conducted in well-ventilated workrooms.

Where welding is carried out in confined spaces, such as tanks, ship compartments, and enclosed process equipment, a suitable method of ventilating would be by a small suction outlet connected to a portable blower by means of a flexible metal hose.

Personal Protective Equipment :—If any welding operation is carried out in a confined place where it is not found possible to arrange local exhaust ventilation, then the only way to protect the concerned worker is by supplying him with uncontaminated air by means of an airline respirator or with a self-contained breathing apparatus, if the work is only of a limited duration.

Medical Control

Apart from taking appropriate engineering control measures, it is also necessary to carry out periodical medical examination of workers to detect early signs and symptoms of poisoning. This would enable a person who is particularly susceptible to a chemical hazard to be shifted to another occupation, where risk to his health is less. Such examinations are essential when electrodes of new compositions are introduced.

Conclusion

An endeavour has been made in this paper to present the more important respiratory hazards that are likely to be encountered in welding operations and the measures that could be taken to secure the health protection of welders. It is hoped that enlightened managements would take all precautionary measures to safeguard workers' health, as this would mean less labour turnover, better morale, better employer-employee relations and higher productivity.

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EDITOR