HEALTH HAZARDS IN WELDING APPLICATION DUE TO FUMES AND GASES AND ITS CONTROL

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ABSTRACT

Welding and cutting of metals can involve a great number of health hazards due to welding fumes and gases. This paper details the hazards associated with different kinds of fumes and gases arising from vapourisation of consumable electrodes, threshold limit values and the measures to be taken to minimise their harmful effects.

Keywords : *Threshold Limit Value, Time Weighted Average, Short Term Exposure Limit, Particulate fume, Fume extractor, Respiratory Protective Equipment*

INTRODUCTION

Welding technology is now the backbone of construction and fabrication industry. New technologies are being developed to enhance the productivity, quality, safety and reliability in the application. But at the same time, welding application involves a great number of health and safety hazards. Though some measures are taken in the form of safety appliances, very little measure is evidenced especially in the small scale construction and fabrication industry to minimise the health hazards of welders with respect to the release of fumes and gases during different types of welding. It is happening mainly due to ignorance of personnel engaged in welding industry. Spreading of information and awareness among welders and their supervisors can improve the situation significantly.

WELDING FUMES AND GASES

During welding operation a mixture of airborne fine particles and gases are generated. The type of fumes and gases produced depend primarily on the composition of the metals being welded and the welding rod.

Particulate Fumes

Hot vapour is produced from the vapourisation of the consumable electrode, wire or rod when material is transferred across the arc or flame. Fume particles are formed when hot vapours cool and condense into very small particles of less than one micron and stay suspended in the gas. Sometimes they may join together to form large particles upto 100 microns but the respirable fraction of particles ($<3\mu m$) are more harmful. The primary component of fumes are oxides of the metals involved like iron, zinc, chromium, aluminium, nickel, cadmium etc. Fumes

produced during the welding of stainless steel and high alloy steel may produce serious and longlasting problems.

Gases

The following harmful gases may be encountered during welding :

- Gases used for arc-shielding such as argon, helium and carbon dioxide.
- Carbon dioxide and monoxide produced on combustion of fuel gases and by the action of heat in both the flame and the arc.
- Ozone and oxides of nitrogen produced by the action of heat or ultraviolet radiation on the atmosphere surrounding the welding arc.
- Fluorides emitted from coating on low hydrogen rods.
- Organic vapours such as cyanides, formaldehyde, isocyanates, phosgene and phosphine may be released from heated metal coatings, paints and degreasing solvents.

HEALTH HAZARDS FROM FUMES AND GASES

Gases and fumes enter the body of the welder with the air he breathes. The degree of health risk to the welder from above will depend on

- Concentration
- Composition
- Duration of time the welder is exposed
- The welder's susceptibility

The health effects resulting from the inhalation of fumes and gases may either occur immediately as "acute effects" or take long time to appear as "chronic effects".

Acute effects

It is a short term effect generally noticed immediately after exposure and disappear over time - once exposure is stopped.

Irritation of eye, nose and throat : Fine particles of copper oxide, molybdenum, nickel, vanadium and gases/organic vapours like hydrogen fluoride, oxides of nitrogen, formaldehyde, isocyanates, phosgene etc. can cause irritation of eye, nose and throat.

Irritation of the respiratory tract : Fine particles of aluminium, vanadium, cadmium oxide and gases/organic vapours like hydrogen fluoride, formaldehyde, phosgene and phosphine can cause dryness of the throat, tickling, coughing and chest pain.

Metal fume fever : Metal oxides such as copper and zinc, beryllium and manganese can cause an acute flue - like illness called 'metal fume fever'. It usually begins several hours after exposure with pain in the limbs and fever. It may include chest soreness, gastro - intestinal pain, nausea and vomiting. The symptoms usually subside within one to three days of exposure with no residual effect.

Pulmonary oedema : Exposure to ozone and oxides of nitrogen may produce excessive fluid in the lung tissues and even hemorrhage in the lungs.

Asphyxiation : If welding is done in confined area with inadequate ventilation, there may be a risk of asphyxiation due to oxygen deficiency caused by the replacement of air with gases produced by welding.

Chronic effects

If harmful gases and fumes are inhaled over threshold limit values for a longer period of time the following long term effect may be seen which causes considerable damage to health.

Respiratory system : Deposition of iron oxide particles in the lung may cause siderosis - a benign form of lung disease. Long term exposure to beryllium, nickel, vanadium, nitrogen oxide and ozone can cause significant change in lung function including bronchitis, asthma and pneumonia.

Cardiovascular system : Carbon monoxide generated in carbon dioxide - shielded processes, when inhaled combines readily with haemoglobin. It lowers the oxygen carrying capacity of blood.

Nervous system : Lead and manganese fumes are toxic and may cause damage in central nervous system including Parkinson's disease.

Skin : Hexavalent chromium is a frequent cause of dermatitis.

Lead poisoning : Lead fume generated from paints may lead to lead poisoning. The effects may be memory loss, anaemia, damage in digestive system and kidney.

Carcinogenic effects : Now-a-days everybody is concerned regarding the presence of potential cancer causing agents, carcinogens in certain types of welding fumes and gases. Hexavalent chromium, nickel, beryllium and ozone may be carcinogenic. Studies have indicated that welders may experience a 30 to 40 percent increased risk of lung cancer compared to the general population.

EXPOSURE LIMITS

Every human being is able to assimilate small quantities of contaminants without permanent injury because the physiological flushing, excretion and repair processes operate at a higher rate than the deleterious effects of the contaminants of the air when present at a tolerable level, Therefore, the human body living in a hostile industrial environment during the working day develops adaptive mechanism to maintain its vitality.

Threshold Limit Values

Over a long period of time the industrial toxicologists have developed a set of values called Threshold Limit Values (TLVs) which gives the level of exposure to airborne contaminants without any harmful effect. TLVs are of two types:

- *Time Weighted Average (TWA):* It is the permitted concentration of air contaminants for 8 hrs. exposure for an industrial worker.
- *Short Term Exposure Limit (STEL) :* It is the permitted concentration level for short time ($\leq$ 15 minutes) exposure, maximum of 4 times in a 8 hrs working period with at least 1 hr interval between exposures. Also the 8 hrs TLVs - TWA can not be exceeded.

The threshold limit values of different harmful contaminants generally seen during welding are given in Table I. These values are applicable for a healthy adult. But there may be increased risks for a person with a pre-existing health problem or for individuals who suffer from allergies. The values are also changing from time to time based on further research and analysis.

Also it is to be kept in mind that when more than one type of impurity is present as in the case of welding the threshold limit value for the

Table I :Threshold limit values

Contaminants	TWA	STEL
Fe	5 mg/m^3	10 mg/m^3
Pb	0.15 mg/m^3	0.45 mg/m^3
Cr $^{+6}$	0.05 mg/m^3	—
Ni	0.1 mg/m^3	0.3 mg/m^3
Cd	0.05 mg/m^3	—
SO_2	2 ppm	5 ppm
NO_x as NO_2	3 ppm	5 ppm
O3	0.1 ppm	0.3 ppm
Tatal dust	10 mg/m^3	—
Mo	5 mg/m^3	10 mg/m^3
Fluoride	2.5 mg/m^3	—

mixture is to be determined as per formula given hereunder :

$$\frac{C1}{T_1} + \frac{C2}{T_2} + \ldots\ldots\ldots + \frac{Cn}{T_n} < 1$$

..... Eqn. (1)

Where C1, C2, ... Cn are atmospheric concentrations and T1, T2, ...Tn are corresponding TLVs.

WORKPLACE MONITORING AND MEASUREMENT

Before initiating any control measure to reduce the exposure level or assessing the effectiveness of control measures, an organisation should determine the values of airborne harmful contaminants present in the working atmosphere. Static samples may be taken for assessing the risks posed to workers from a particular contaminant. Now-a-days very good portable battery operated personal samplers are available in the market. Samples are to be collected at a maximum flow rate of 2.0 litres/min until a maximum collection volume of 960 litres is reached. It is important that the welder carry out the welding operation in a normal way to get an accurate evaluation of exposure.

For the assessment of dose already received by welder, biological monitoring will be required. It involves measurement of the concentration of a contaminant, its metabolites or other indicators in the tissues or body fluids of an individual.

CONTROL MEASURES

The following steps can be taken to reduce exposure to welding fumes and gases :

- Elimination/substitution and process modification
- Engineering controls
- Administrative controls
- Respiratory protection

Elimination / substitution and process modification

The quantity and composition of welding fumes and gases can be reduced by making proper modification or substitution in the following :

Welding consumables : Consumable manufacturers supply information on fume composition which can be used in selecting welding consumables for a particular job.

Nature of MMA flux coating or core of FCA consumables : Manufacturers of welding electrodes may be able to substitute less hazardous ingredients in their products without altering important metallurgical or welding characteristics.

Shielding gas composition : If present shielding gas composition is found giving contaminants more than TLVs, the gas composition may be changed. For example, fume formation rate can be reduced if a mixture of argon and carbon dioxide is used instead of carbon dioxide alone.

Presence of any material coating : Rust inhibitors, paints, degreasers or other coatings on metals may be removed before cutting or welding operation.

Type of process : Choice of welding process in an industry is done on the basis of required weld quality, economics and equipment availability. Some welding processes like submerged arc and TIG generates significantly less particulate fumes than others. Switch over from one process to another may be considered if appropriate.

Engineering control

A substantial improvement can often be made by improving work practices and ventilation.

Welding position : Welder should adopt a working position which ensures that his head is away from the plume. The welding position and proximity of the welder to the fume plume affect exposure level.

Location and type of workplace : Welding in outdoor or semi outdoor situation prevents build-up of fumes and gases. But in the case of same operation in a small workshop or within an enclosure, the fume will not be readily dispersed and the welder may get higher than average

exposure. In such cases effective ventilation system shall be ensured so that there is no depletion of oxygen inside. If any welding curtain is used, ensure that they are at least 20 centimeters off the floor.

Natural ventilation : In outdoor or semi-outdoor situations, wind provides natural ventilation. However effectiveness will depend on whether it is a windy or a calm day and direction of wind. In indoor condition natural ventilation is usually considered adequate to prevent the accumulation of excessive amounts of fumes when welding is done on mild steel with electrode which do not contain fluorides in the coating, room volume is not less than 330 m^3 per welder and cross ventilation is not blocked.

General ventilation : Draft fans and air extractors are provided for general ventilation in indoor locations. The movement of air is controlled in such a way that clean air streams are drawn past workers and contaminated ones led away from them. As a guide minimum 65 m^3 of air per minute has to be moved for each welder in the room. This is useful to control minor emissions of contaminants of low toxicity.

Dilution ventilation : In this case the concentration of contaminants is diluted with a sufficient volume of clean air to reduce the level of exposure. Portable circulating fans are employed to dilute fumes which might otherwise tend to accumulate in the breathing zone of the welder. This method is effective when welding operation is carried out in open or semi-covered area.

Local exhaust ventilation : General ventilation and dilution ventilation is not sufficient when contaminant emission is more or of high toxicity. Such situation can often be controlled effectively at their source by means of a local exhaust system engaging different types of fume extractors. Selection of suitable local exhaust system will depend on the place where it will be engaged. Some of them are discussed below :

Extracted bench : An exhaust hood is fixed at the top of the bench where welding operation is carried out. Effectiveness of such system will depend on the distance of the hood from the source of the gases and fumes, the air velocity and the placement of the hood.

Extracted booth : Wherever practicable such enclosed booth with fume extraction system may be engaged. It is most effective way to control fumes and gases generated by welding and cutting operations.

Movable fume extractor : This system consists of a movable exhaust hood, flexible duct, a powered fan and a fume or dust collector. During welding operation, the exhaust hood is placed in such a way that welding fumes are not drawn across the worker's face or into the breathing zone. It should also capture the fume without disturbing the gas shield.

On gun extraction system — Fume extractor gun that removes fumes from the point of generation is an alternative to an exhaust hood for gas shielded arc welding processes. Such extraction system can reduce breathing zone concentration significantly. These systems require that the gun and shielding gas flow rates be carefully balanced to maintain weld quality and still provide good exhaust flow.

Care should be taken to ensure that air from a local exhaust ventilation system is not re-circulated into the workroom. As local exhaust ventilation is never 100% efficient, especially when welding awkward structures, general ventilation may also be necessary to control the background level of fume. It is also important that welders are adequately trained to use the equipment and adopt good working practice.

Administrative control

Control of this type generally involves scheduling of the welding and cutting work or the persons engaged in such work. Employee exposure can be controlled by scheduling activities or workers' task in such ways that minimize employee exposure levels. One method may be to schedule the most harmful fume producing welding

operations for a time when least number of employees will be present.

Another method is worker rotation which is done by rotating persons into and out of contaminated areas in the course of a shift, thereby reducing the full shift exposure of any person. For such rotation the following data shall be collected and analysed :

a) Identification of each affected worker.

b) The duration and exposure levels at each job or work station where the worker is located.

c) Any other information that may be useful in assessing the reliability of administrative controls to reduce the exposure.

Respiratory Protective Equipment (RPE)

In certain circumstances, respiratory protection of the individual may be required as a supplement to other preventive actions. This should not be regarded as a substitute for other control measures. All respirators are uncomfortable to a degree. So selection of respirator must be done by the advice of an expert based on fume concentration, presence of toxic gases and oxygen deficiency. Also personnel to be trained in use of an RPE, its maintenance and cleaning. RPEs are of two types :

Air purifying masks : It will protect from low levels of metal fumes, welding gases and organic vapour. Correct filtration cartridge is to be selected. Also the frequency for changing disposable filters is to be known from the mask supplier.

Supplied air respirator : It is best for all round protection from gases, fumes and vapours.

EDUCATION AND TRAINING

Everybody working with welding processes should be informed of the hazards from exposure to the contaminants and the precautions necessary to prevent damage to their health. Welders should be trained in appropriate procedures so that as little contamination as possible is produced and proper use is made of all safeguards against exposure to themselves.

Instructions for generating awareness must be easily understandable and in different languages including local language. Special attention should be given to ensuring that newly recruited employees are subjected to orientation programme before engagement in work.

FIRST AID

If a person is overcome by welding fumes and/or gases, the following precautions should be taken.

- Remove the patient to an uncontaminated atmosphere and loosen tight clothing at the neck and waist.
- Keep the patient warm and at rest.
- If the patient has difficulty in breathing, oxygen may be administered provided that suitable apparatus and a trained operator are available.
- If breathing is weak or has ceased, artificial respiration should be started.
- Seek medical advice at the earliest. It is also important for the doctor to know the contaminants which might have been present in the air of the work place.

First aid instructions including phone nos. of doctors, ambulances etc. shall be displayed at different prominent places in case of emergency.

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