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Hazards and Its Effects of Arc Welding to Welders and People Belonging to the Welding Zone

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Abstract:
Environmental problems are one of the main problems due to the rapid development of engineering technologies. Specially welding is a job with the major impact on environment and human health. Arc welding is a family of fusion welding processes that utilizes heat of an electric arc for the purpose of welding. In every arc welding method, safety should be the paramount consideration. It requires the most protection of the face, body and welding area during welding to reduce the welding hazards to welders and non-welders. The intensity of the arc produces strong ultraviolet and infrared radiation, fumes and dusts. Any person exposed during the welding process can be affected. This project is adapted from different publications to provide an overview of welding hazards, health effects and safety measures. The review describes information currently available from different published research works. It involves the group of people that can be affected by arc welding hazards including arc welders; the crafts constitute the subset of welding group, passerby, bystanders and residents near the welding shop. It has been revealed from different studies that the profession is very hazardous and most of the stakeholders involved possess limited knowledge of welding hazards and hence to avoid these hazards, it is advised to abide to all safety measures. The goal of this project is creating awareness about welding effects on the health and environment.

Key words: Arc Welding Processes, Welding Hazards, Health Effects, Safety Measures.

1. INTRODUCTION

1.1 WELDING PROCESS

Welding is a process of joining two metal parts together by applying intense heat between them, which causes the parts to intermix after melting. Welding processes are widely used for the manufacture of shipyards, civil engineering structures, mining industry, transportation means, petrochemical industry, and metallurgy. Workplace is an important part of human environment. The health and efficiency of workers in any organization get influenced in large extent by conditions in their work environment. It is an established fact that no occupation exists without risk of hazard. Arc welders and other people surrounding the welders have potential exposure to a number of hazards. Arc welding is a safe process when sufficient measures are taken to protect the welder from potential hazards and when proper operating practices are followed. According to World Health Organization (WHO), there are about 250 million cases of work-related injuries per year worldwide. One of the jobs that contribute to these occupational injuries is the welding process, especially in developing countries. Welding is common indispensable procedure in engineering works and is associated with varied health hazards apart from injuries. Welding operations lead to production of gases and small solid particles, together known as welding smoke. Most of this is produced during arc welding. Major hazards welders can encounter if these dangers are overlooked include fumes and gases, arc rays and sparks, and electric shock. The thermal effects can cause agglomeration of the particles into particle chains and clusters that can be deposited in the human respiratory tract. Most of the fume particles are less than 1micron in diameter when produced, but they tend to grow in size with time due to agglomeration. Arc welding produces the full spectrum of ultraviolet radiation (UVR). It is possible that welders are at greater risk of developing skin cancer than the general population. Furthermore, thermal burns from hot metal can occur when welding and contribute to increased risk of developing actinic skin and ocular damage. Electric shock from welding and cutting equipment can result in death or severe burns. Additionally, serious injury can occur if the welder falls as a result of the shock.

1.2 ARC WELDING PROCESS

Arc welding is a method of permanently joining two or more metal parts. It consists of combination of different welding processes wherein coalescence is produced by heating with an electric arc, (mostly without the application of pressure) and with or without the use of filler metals depending upon the base plate thickness. A homogeneous joint is achieved by melting and fusing the adjacent portions of the separate parts. The final welded joint has unit strength approximately equal to that of the base material. The arc temperature is maintained approximately 4400°C. A flux material is used to prevent oxidation, which decomposes under the heat of welding and releases a gas that shields the arc and the hot metal. The second basic method employs an inert or nearly inert gas to form a protective envelope around the arc and the weld. Helium, argon, and carbon dioxide are the most commonly used gases.

2. PROBLEM IDENTIFICATION

According to scientific progress and industrialization, engineering sciences and processes have significant progress in all the areas. There are important problems because of this progress in addition to the advantages such as life simplicity, life quality improvement and many other advantages.

Environmental problems are one of the main problems due to the rapid development of engineering technologies. Therefore, nowadays environment should enter on different the field of engineering, and it should control, guide and develop these processes according to the specific principles and effects of these processes on environment and health. According to the nature and used equipment, welding is a job with the major impact on environment and human health. Released fume in welding, is a combination of various and fine particles such as carbon monoxide, silicates and so on. Welding fume analysis showed this fume is rich in toxic and hazardous compounds. On the other hand, medical investigations proved, welders are in serious danger of acute and chronic respiratory diseases. The problems are not limited to the respiratory diseases only. In this regard, it can be noted some problems such as suffocation, skin diseases, visual disturbances, many long-term negative effects and environmental problems due to the welding fume. It is very painful that many welders don't know anything about these problems, and the suffered from irrecoverable effects because this lack of awareness.

3. TYPES OF ARC WELDING PROCESS

3.1 ARC WELDING

Arc welding is a process that is used to join metal to metal by using electricity to create enough heat to melt metal, and the melted metals when cool result in a binding of the metals. It is a type of welding that uses a welding power supply to create an electric arc between an electrode and the base material to melt the metals at the welding point. They can use either direct (DC) or alternating (AC) current, and consumable or non-consumable electrodes. The welding region is usually protected by some type of shielding gas, vapor, or slag. Arc welding processes may be manual, semi-automatic, or fully automated. First developed in the late part of the 19th century, arc welding became commercially important in shipbuilding during the Second World War. Today it remains an important process for the fabrication of steel structures and vehicles.

Types of arc welding:

- ✓ Carbon arc welding
- ✓ Shielded arc welding
- ✓ Submerged arc welding
- ✓ Metal inert gas welding
- ✓ Tungsten inert gas arc welding
- ✓ Electro slag welding
- ✓ Plasma arc welding
- ✓ Resistance welding
- ✓ Spot welding
- ✓ Flash welding

3.1.1 Carbon Arc Welding

The carbon arc welding is just similar to metal arc welding. The difference of the both welding electrode are different . In this welding process, the electrode is having carbon material (Carbon rod) and it consist of negative pole and work piece as positive pole. The arc is produced to heat the metal to melt temperature. In this heat temperature in negative electrode as 2800^0C and positive electrode as 3800^0C.The carbon electrode using as negative pole because of low temperature generated on the tip than work piece, and carbon electrode not fuse and mix up with the work piece. If happens, the weld will be rich in carbon, and consequently more brittle and consumed excessively

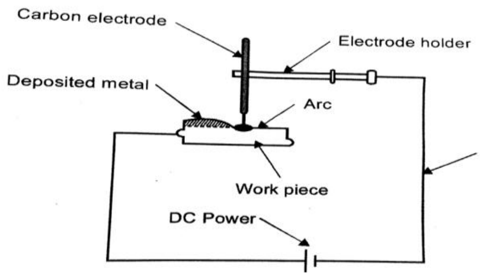

Figure 3.1 Carbon Arc Welding

In this reason DC current used in carbon arc welding AC current not used in the welding because of fixed polarity can be maintained. The weld is best for joint of two metal melted without of addition of filler metal. If need the filler metal in welding process, the welding rod as in oxyacetylene weld. Sometime, portion gas used in welding process because of protection of molten metal from atmospheric oxygen.

3.1.2 Shielded Arc Welding

Shielded metal arc welding (SMAW) is a fusion welding process that uses a consumable, flux-coated electrode to create an arc between the electrode and the work piece. Molten metal travels from the electrode via the electrical arc and is deposited into the work piece. The flux coating is also melted and it surfaces on top of the molten weld pool in the form of slag. Shielded metal arc welding is one of the oldest arc welding processes and is one of the simplest and affordable welding processes that can be used to make quality weldments. This is due to the simplicity of the equipment needed for shielded metal arc welding. All the process requires is a constant current power source, an electrode, an electrode holder, a ground clamp and a work piece.

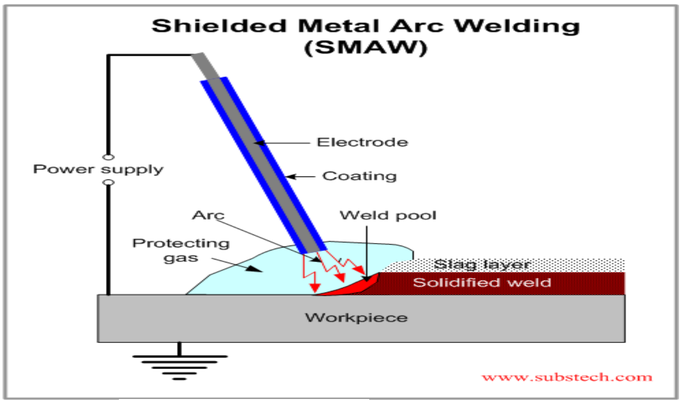

Figure 3.2Shielded Arc Welding

3.1.3 Submerged Arc Welding

The diagram below indicates, in schematic form, the main principles of submerged arc welding. The filler material is an uncoated, continuous wire electrode, applied to the joint together with a flow of fine-grained flux, which is supplied from a flux hopper via a tube. The electrical resistance of the electrode should be as low as possible to facilitate welding at a high current, and so the welding current is supplied to the electrode through contacts very close to the arc and immediately above it. The arc burns in a cavity which, apart from the arc itself, is filled with gas and metal vapour. The size of the cavity in front of the arc is delineated by unmelted basic material and behind it by the molten weld. The top of the cavity is formed by molten flux. The diagram also shows the solidified weld and the solidified flux, which covers the weld in a thin layer and which must subsequently be removed. Not all of the flux supplied is used up: the excess flux can be sucked up and used again.

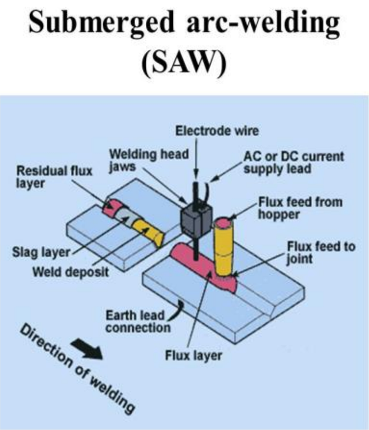

Figure 3.3 Submerged Arc Welding

3.1.4 Metal Inert Gas Welding

The work piece to be welded and the consumable electrode (in the form of wire) are connected to the Power Supply (D.C or A.C). Whenever the consumable electrode is brought near the work piece (with a small air gap), an arc is produced. This arc melts the electrode. The melted electrode fills uniformly over the required regions of the work piece. An inert gas supply is provided around the electrode (hence the name 'Metal Inert Gas Welding') during the welding process. It forms a gas shield around the arc and the weld this is intended to protect the weld from the external atmosphere. The type of electrode used and the shielding gas used primary depends on the material to be welded. In many cases the shielding gas used is a mixture of many gases. f many work pieces are to be welded continuously an electrode spool (in the form of coil) is used. Consumable electrode is continuously supplied from this spool by a suitable feeding mechanism. Commonly, servo mechanisms are used for feeding long electrodes. In MIG Welding, consumable electrode itself acts as filler metal. So, no separate filler rod or filler wire is needed.

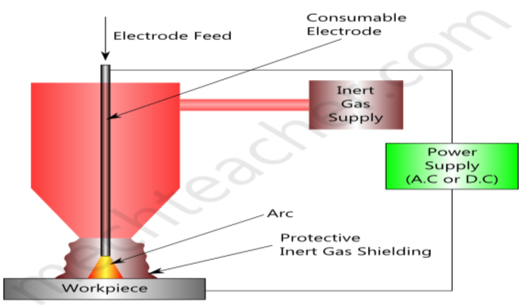

Figure 3.4 Metal Inert Gas Welding

3.1.5 Tungsten Inert Gas Arc Welding

The work piece to be welded is placed on the worktable. The non-consumable tungsten electrode and the work piece are connected to the power supply (A.C or D.C).As the electrode is brought near the work piece (leaving a small air gap), an arc is produced. This arc is used for melting and welding the work piece. Tungsten has high melting point (3422 °C). Hence, tungsten electrode does not melt during the welding process. In tungsten inert gas welding, filler rod may or may not be used. The usage of filler rod depends on the nature of the work piece to be welded. If filler rod is used, it is continuously melted by the arc and fed into the weld pool. Inert gas supply is constantly provided around the electrode during the welding process. The inert gas forms a gas shielding around the weld. It protects the weld from the external atmosphere.

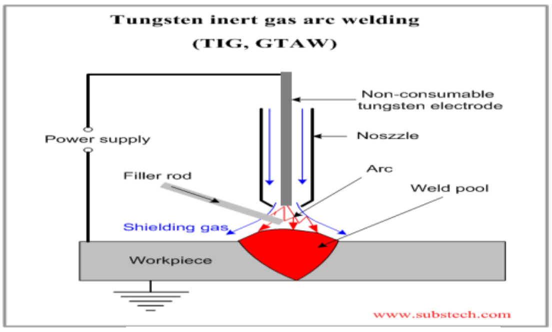

Figure 3.5 Tungsten Inert Gas Arc Welding

3.1.6 Electro slag Welding

Electro slag welding (ESW) is a highly productive, single pass welding process for thick (greater than 25 mm up to about 300 mm) materials in a vertical or close to vertical position. (ESW) is similar to electro gas welding, but the main difference is the arc starts in a different location. An electric arc is initially struck by wire that is fed into the desired weld location and then flux is added. Additional flux is added until the molten slag, reaching the tip of the electrode, extinguishes the arc. The wire is then continually fed through a consumable guide tube (can oscillate if desired) into the surfaces of the metal work pieces and the filler metal are then melted using the electrical resistance of the molten slag to cause coalescence.

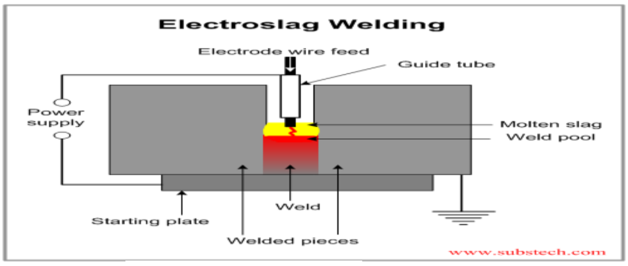

Figure 3.6 Electro slag Welding

The wire and tube then move up along the work piece while a copper retaining shoe that was put into place before starting (can be water-cooled if desired) is used to keep the weld between the plates that are being welded. Electro slag welding is used mainly to join low carbon steel plates and/or sections that are very thick. It can also be used on structural steel if certain precautions are observed. This process uses a direct current (DC) voltage usually ranging from about 600 A and 40-50 V, higher currents are needed for thicker materials. Because the arc is extinguished, this is not an arc process.

3.1.7 Plasma Arc Welding

Plasma arc welding (PAW) is an arc welding process similar to gas tungsten arc welding (GTAW). The electric arc is formed between an electrode (which is usually but not always made of sintered tungsten) and the work piece. The key difference from GTAW is that in PAW, by positioning the electrode within the body of the torch, the plasma arc can be separated from the shielding gas envelope. The plasma is then forced through a fine-bore copper nozzle which constricts the arc and the plasma exits the orifice at high velocities (approaching the speed of sound) and a temperature approaching 28,000 °C (50,000 °F) or higher. Just as oxy-fuel torches can be used for either welding or cutting, so too can plasma torches, which can achieve plasma arc welding or plasma cutting. Arc plasma is the temporary state of a gas. The gas gets ionized after passage of electric current through it and it becomes a conductor of electricity. In ionized state atoms break into electrons (−) and cations (+) and the system contains a mixture of ions, electrons and highly excited atoms. The degree of ionization may be between 1% and greater than 100% i.e.; double and triple degrees of ionization. Such states exist as more electrons are pulled from their orbits. The energy of the plasma jet and thus the temperature is dependent upon the electrical power employed to create arc plasma. A typical value of temperature obtained in a plasma jet torch may be of the order of 28000 °C (50000 °F) against about 5500 °C (10000 °F) in ordinary electric welding arc. Actually all welding arcs are (partially ionized) plasmas, but the one in plasma arc welding is constricted arc plasma.

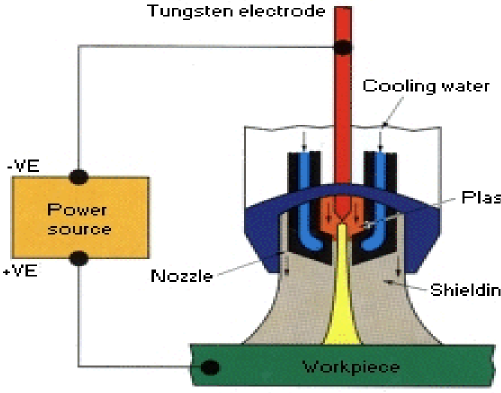

Figure 3.7 Plasma Arc Welding

3.1.8 Resistance Welding

Resistance welding is a welding technology widely used in manufacturing industry for joining metal sheets and components. The weld is made by conducting a strong current through the metal combination to heat up and finally melt the metals at localized point(s) predetermined by the design of the electrodes and/or the work pieces to be welded. A force is always applied before, during and after the application of current to confine the contact area at the weld interfaces and, in some applications, to forge the work pieces.

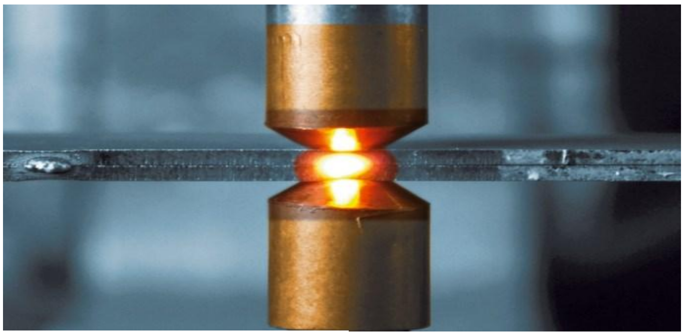

Figure 3.8 Resistance Welding

3.1.9 Spot Welding

Spot welding is one of the oldest welding processes. It is used in a wide range of industries but notably for the assembly of sheet steel vehicle bodies. This is a type of resistance welding where the spot welds are made at regular intervals on overlapping sheets of metal. Spot welding is primarily used for joining parts that are normally up to 3 mm in thickness. Thickness of the parts to be welded should be equal or the ratio of thickness should be less than 3:1. The strength of the joint depends on the number and size of the welds. Spot-weld diameters range from 3 mm to 12.5 mm.

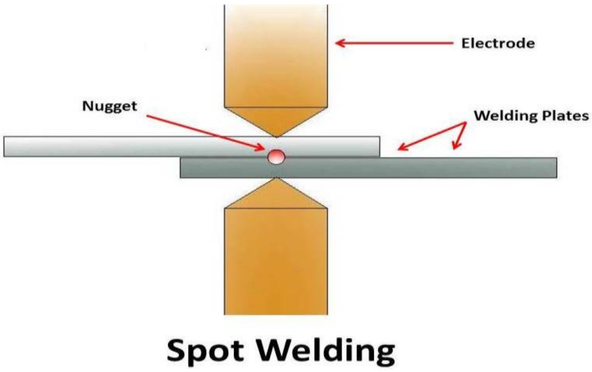

Figure 3.9Spot Welding

3.1.10 Flash welding

Flash welding is a type of resistance welding that does not use any filler metals. The pieces of metal to be welded are set apart at a predetermined distance based on material thickness, material composition, and desired properties of the finished weld. Current is applied to the metal, and the gap between the two pieces creates resistance and produces the arc required to melt the metal. Once the pieces of metal reach the proper temperature, they are pressed together, effectively forge welding them together.

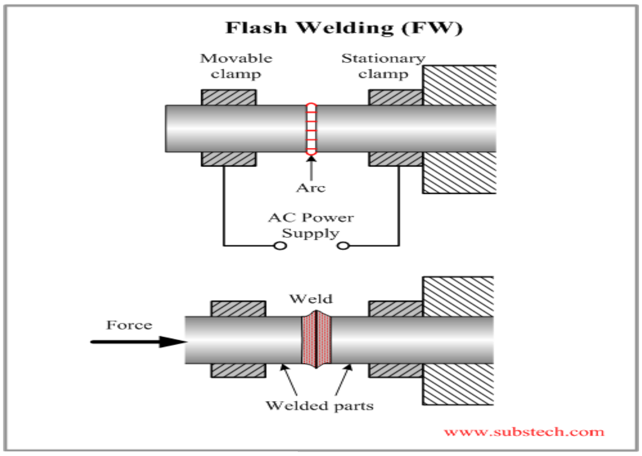

Figure 3.10Flash Welding

The work pieces are positioned end-to-end. As a general rule, the flash butt welding process is sub-divided into pre-flashing, pre-heating, flashing and upsetting. Pre-flashing is used to handle problems when the two surfaces to be joined are not parallel. Pre-heating is carried out under low welding pressure. When the welding joint has been heated to a certain temperature, flashing starts and the surface material is burned off, resulting in an even and clean joint surface. The flash consists of molten and oxidized material. After flashing, upsetting starts and presses the two surfaces together with high force to produce a good joint.

4. ARC WELDING HAZARDS

Normally operations are not hazardous but a completely safe work-place is something nonexistent in the world. Because welding generally requires the use of electric current (including high frequency high voltage current) and compressed gases as well as it involves burning of fluxes, coatings, and gases therefore it may lead to accidents due to negligence and thus prove hazardous. The profession is regarded as the most hazardous and not all welders are aware of all the Hazards. The hazards which are more or less peculiar are: fumes and gases; arc radiation; fire and explosion; electric shock; and compressed gases.

4.1. WELDING FUMES AND GASES/DUST

Shielded Metal Arc Welding (SMAW), Submerged Arc Welding (SAW), Gas Tungsten Arc Welding (GTAW), and Gas Metal Arc Welding (GMAW), cause very small particles that are formed when the vaporized metal rapidly condenses in air, and are typically too small to be seen by the naked eye, but collectively, form a visible plume. These fumes can be harmful if inhaled through the nose and mouth of the welder. The content of the fumes may be either asphyxiating or toxic. The electric arc welding processes generate dust and particulate fumes, which when inhaled regularly over long periods can result in serious effects of the welder's health. The fumes and dust generated during arc welding may be carried into the zone around the welder's face by convection currents rising from the arc. Metallic vapours, mostly oxides and silicates of metals, react with atmospheric oxygen resulting in the formation of fine dust. Especially dangerous are the oxides of zinc, lead, cadmium, beryllium, and copper formed during welding copper, brass and bronze. Also during arc welding, the atmosphere surrounding the welder is contaminated with manganese compounds, nitrogen oxides, ozone, carbon monoxide, and fluorides. Some fluxes on melting give off oxides of manganese in dust form as well as hydrogen chlorides and fluorides. In carbon dioxide (CO2) welding, carbon monoxide may be produced by decomposition of CO2 in the shielding gas or of carbonates in flux cored wire. Some of the effects of fumes on welder and surrounding people including irritation of the respiratory tract resulting in dryness of the throat, coughing, chest tightness, and breathing difficulties. In this respect cadmium fumes have the worst effect. It can also result, in acute influenza-like illness called metal fever. Continuous exposure to metallic fumes and dust can lead to systematic poisoning and fibrosis causing the formation of fibrous or scar tissues in the lungs. Therefore, health effects associated with metal fumes depend on the specific metals present in the fumes, but there is a concern that these may range from short-term illnesses, such as metal fume fever (i.e. flu-like symptoms), to long-term lung damage and/or neurological disorders, such as lung cancer and/or Parkinson's disease. Fine particles are more hazardous than coarse particles because they can pass through the nose and throat and lodge in the lungs, causing lung damage and premature death in persons with heart or lung disease. The most breathable particles are of sizes from 0.1 to 5 μm; particles with more than 5 μm in size are deposited in the upper respiratory tract and those with less than 0.1 μm in size are mainly removed from the body by exhalation. Thus, welding fume particles are among the most breathable ones. Figure shows particle sizes for a number of familiar pollutants.

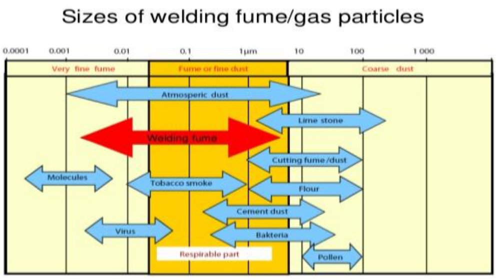

Figure 4.1 Particle Sizes for Different Pollutants

The concentration of respirable particulates in breathing zone of welders and non-welders. The average concentration of respirable particulates in the breathing zones of welders was four times as high as in the breathing zones of non-welders Fumes and gases are minimized by: working in a well ventilated area; wearing proper respirator when necessary; using materials and welding process which generate fewer fumes; Keeping the head out of the fumes, and avoiding breath the fumes

4.2 ELECTRIC ARC RADIATION

An electric arc gives off visible light (wavelength 0.4 to 0.75 μm) of high intensity with brilliance 10,000 times the safe glare level of the eyes. The intensity of emitted light depends upon the current level, and the presence of flux. The welding arc also emits ultra violet(UV) and infra-red rays with wave length less than 0.4 μm and higher than 0.7 respectively. UV rays can damage both eyes and skin. Even an accidental exposure to UV light from an arc can cause a condition known as arc eyes. This is characterized by painful gritty feeling as if sand has gone under the eye lids. This painful condition does not develop immediately after exposure and may take 4 to 8 hours and normally takes 24 to 48 hours to disappear. Radiation in the visible and near infrared spectrum (400-1400 nm) penetrates the eye, to be absorbed by the retina where, given sufficient intensity and duration, causes thermal or photochemical damage which may be permanent and sight threatening. Welders' face shields are fitted with shaded lenses that help to protect their eyes from ultraviolet (UV) radiation, which prevent arc eye or welder's flash. Unfortunately, some other crafts do not have the protecting gears and many passerby and residents leaving near the welding shops do not even know that the arc's bright light can burn their eyes in just a few seconds. In fact, many welding-related eye injuries each year are to bystanders, passerby and residents who are watching someone that welds. A summary of actinic UVR hazards are posed to persons working around electric arc welding processes as follows:

• **Hazar dous Exposure.** The level of hazardous exposure affecting welders' helpers and other personnel forklift and overhead crane operators, for example) located in the vicinity of open arc welding can now be determined. The intensity and wavelengths of nonionizing radiant energy produced depend on many factors such as the process type, welding parameters, electrode and base metal composition, fluxes, and any coating or plating on the base material.

• **Exposure Time.** Exposure to actinic UVR is considered to be cumulative with each exposure over an 8 hours workday and within a 24 hours period. Therefore, two 5 min exposures during workday could be considered as a single 10 min exposure.

• **Reflections.** Actinic UVR can reflect significantly from some common surfaces and these reflections might also create potentially harmful exposure to unprotected personnel. Unpainted metals (particularly aluminium) and concrete floors readily reflect actinic UVR. On the other hand, lightly coloured paints often use pigments of zinc oxide or titanium oxide and have a low reflectance of actinic UVR.

• **Safety Information.** Welders, welders' helpers, and their supervisors should periodically include a discussion of actinic UVR hazards in normal safety reviews and within written safety procedures. Concern for actinic UVR is especially important to discuss with new employees and personnel who work in the vicinity of open arcs.

• **Nearby Persons.** Persons in the vicinity of welding operations can be protected from exposure to actinic UVR by use of screens, curtains, or adequate distance from aisles, walkways, etc. Welders' helpers, overhead crane operators, and forklift operators who have a line of sight to any open arcs should consider wearing appropriate safety equipment such as safety glasses with side shields or even a clear, full-face shield and long-sleeved shirts.

• **Skin Protection.** While standards exist for welders and their helpers, skin protection has not been uniformly prescribed for other personnel who work in the vicinity of open arcs. Fabric measurements have shown that natural materials (leather, cotton, wool) are better for absorbing actinic ultraviolet radiation than synthetic materials (polyester, nylon). Incidental personnel should consider wearing a long-sleeved shirt.

• **Warning Signs.** Warning signs are useful when persons unfamiliar with actinic UVR and other welding hazards are nearby. Such warnings are especially important to have on portable welding screens that can be used at field sites near the general population. A suitable sign could simply state "Danger" or "Warning" and be posted conspicuously at entry points or doors to welding areas. Such signs might also include the warning "Avoid Exposure of Eye and Skin to Arc and Harmful Ultraviolet Emissions."

4.3 FIRE AND EXPLOSIONS

Fire in a welding area can be caused by the ignition of inflammable or combustible materials lying in the vicinity of the welding zone, and also due to electrical short-circuit. Electric arcs, hot metal, slag, sparks and spatter are sources of ignition and explosion if precautionary measures are not followed. A safe distance for welding in the general area of combustible materials is normally considered to be 10.7 m. Many of industrial fires have been caused by sparks that can be flying to a certain area with combustible materials. Sparks and molten metal can travel greater distances when falling. Sparks can pass through or become lodged in cracks, clothing, pipe holes, and other small openings in floors, walls, or partitions. Typical combustible materials inside buildings include: wood, paper, rags, clothing, plastics, chemicals, flammable liquids and gases, and dusts. Parts of buildings such as floors, partitions, and roofs may also be combustible. Typical combustible materials outside buildings include dry leaves, grass, and brush. Welding can cause explosions in spaces containing flammable gases, vapors, liquids, or dusts. Special precautions are needed for any work on containers. The following measures have to be taken to avoid fire and explosion hazards Remove combustible materials for a minimum radius of 35 feet (10.7 metres) around the work area or move the work to a location well away from combustible materials. If relocation is not possible, protect combustibles with covers made of fire resistant material. If possible, enclose the work area with portable, fire-resistant screens. Cover or block all openings, such as doorways, windows, cracks, or other openings with fire resistant material. Do not weld material having a combustible coating or internal structure, such as in walls or ceilings, without an appropriate method for eliminating the hazard. After welding, make a thorough examination of the area for evidence of fire. Keep appropriate fire extinguishing equipment nearby, and know how to use it. Do not weld in atmospheres containing reactive, toxic, or flammable gases, vapours, liquids, or dust. Do not apply heat to a work piece covered by an unknown substance or coating that can produce flammable, toxic, or reactive vapours when heated. Do not apply heat to a container that has held an unknown substance or a combustible material unless container is made or declared safe. Provide adequate ventilation in work areas to prevent accumulation of flammable gases, vapours, or dusts. No smoking should be allowed in the welding area where inflammable goods are being used.

4.4 ELECTRIC SHOCKS

Electric shock is defined as a sudden violent response to electric current flow through any part of a person's body. Electrocution is death caused by electric shock. Primary electrical injury(230, 460 V) is tissue damage produced directly by electrical current or voltage. Secondary injuries (20 – 100 V), such as falls, are common Electric shock may occur in welding if current happens to pass through the welder's body; the magnitude of the current depends upon the resistance offered by the body. A current of 0.1 A or above, be dc or ac, is taken to be lethal to humans. Since the human body resistance is a maximum of 600 ohms, the lethal current is provided by voltage of 60 V (V = IR). In human body the maximum resistance is offered by the skin, however, wet skin has lower resistance than the dry skin. Generally, it is taken that current up to 0.002 A do not produce pain, those between 0.002 and 0.05 A do so and are dangerous, and those higher than 0.05 A cause heavy shock and can be lethal. To avoid electric shocks, Read all instructions, labels, and installation manuals before installing, operating, or servicing the equipment and train all personnel involved in welding operations to observe safe electrical work practices also touching the live electrical parts should be avoided. Have all installation, operation, maintenance, and repair work performed properly and only by qualified people and input power cord for damage or bare wiring should be inspected and replaced immediately if damaged. Further, do not work alone where there are electrically hazardous conditions. Wear dry, hole-free, insulating gloves in good condition and protective clothing. Do not touch the electrode with a bare hand. Insulate yourself from the work piece and ground using dry insulating mats or covers big enough to prevent any physical contact with the work or ground and the electrode holder has to be well insulated and dry. Do not allow the electrode holder or electrode to come in contact with any other person or any grounded object and not wrap cables carrying electric current around any part of the body. Special care must be taken when welding in confined spaces like inside a boiler, tanks or pipes which usually have ample contact with the ground; due to low contact resistance even a low open circuit voltage (OCV) of the welding power source may become dangerous to the operator. Extra precautions are also needed when welding outdoors after rain or snow. In all these casesit is imperative to use protective means like dielectric gloves and rubber mats atc.

4.5 COMPRESSED GASES

Gases used in arc welding processes are the shielding gases. Shielding gases used in arc welding are argon, helium, and carbon dioxide. The gases have a remarkable effect on the overall performance of the welding system. The main function of these gases is to protect the weld pool from adverse reactions with atmospheric gases. Oxygen, nitrogen and water vapour present in ambient air can cause weld contamination. Weld shielding, always involves removal of potentially reactive gases from the vicinity of the weld, preventing the detrimental effects on the molten metal of the surrounding atmosphere. Shielding gases can also stabilize the arc and enhance the metal transfer mode in arc welding processes. The shielding gas also interacts with the base and filler metal and can thus change basic mechanical properties of the weld area, such as strength, toughness, hardness and corrosion resistance. Shielding gases moreover have important effects on the formation of the weld bead and the penetration pattern. The application of different shielding gases can result in different penetration and weld bead profiles. However, apart from all these important effects the gases have to be handled with care. These gases are stored in compressed gas cylinders which are potentially hazardous because of the possibility of sudden release of gas by removal or breaking off of the valve. High pressure gas escaping from such a cylinder causes it to be like a rocket which may smash into people and properties. In storage, transport and operation of compressed gas cylinders it is imperative to observe the following rules whether in use or stored, the cylinders should be kept vertical and secured to prevent falling by means of chains and clamps. Hammers or wrenches should not be used to open cylinder valves. Proper trolley should be used for moving cylinders from one point to another in the workshop. The cylinder should never be carried on shoulders because in case it falls it can notonly injure the person but may also explode. Compressed gas should not be exposed to sunlight or heat as this may lead to increase the pressure leading to explosion. The temperature of gas cylinder should not be allowed to exceed 54 ^{o}C. Cylinder valve should be opened gradually without jerk otherwise it may damage the regulator diaphragm. Cylinders should be provided with their caps during storage and transport.

Figure 4.2 Workers Working Without Proper PPE

5. EFFECTS OF ARC WELDING PROCESS

5.1 EFFECTS OF ARC WELDING PROCESS

Environment considerations today tend to control, guide and develop engineering processes affecting both men and environment. The melting of filler metal, base metal and the coating on base metal during welding processes and subsequently the gases formed release minute, solid particles into the air creating a plume and is called welding fume. Compared to other industrial production processes, welding is fairly dangerous. Welding processes involve the potential hazards for inhalation exposures that may lead to acute or chronic respiratory diseases. Risks include asphyxiation due to dangerous inhalants, damage to skin and eye due to ultraviolet light, chemical or electrical fires, and long-term negative effects from fumes. This article is adapted from recent print and online resources to provide an overview of welding fumes, health effects and the measures to protect welders from welding fumes. This review describes the information currently available on air pollutant effects in welders, as the result of experimental studies. Results from the analysis shows that most of the welders' posses limited knowledge of welding fumes hazard. The toxic effects of welding fumes documented by individual efforts and spread awareness about the environmental and health hazards of welding fumes.

The hazards involved in welding and cutting operations may be divided into two groups, viz.,

(i) Fire and Explosion Hazards and

(ii) Health Hazards

5.1.1 Fire and Explosion Hazards

Welding, cutting and allied processes produce molten metal, sparks, slag and hot work surfaces. These can cause fire or explosions if precautionary measures are not followed. During the operations, sparks and spatter fly-off. Flying sparks are the main cause of fires and explosions in welding and cutting. The sparks and molten metal can travel greater distances when falling. It may be kept in mind that the sparks can travel up to 36 feet from the work area. Sparks can even pass through or lodged in cracks, pipe holes, and other small openings in floors, walls or partitions, and roofs leading contact with combustibles. The combustible material inside a workplace or buildings include: wood, paper, rags, clothing, plastic, chemicals, flammable liquids and gasses & dusts. Parts of workplaces or buildings such as: floors, partitions, and roofs may also be combustible. The typical combustible materials outside workplaces or buildings include dry leaves, dry gas, and bush.

Figure 5.1 Fire and Explosion Hazards

5.1.2 Health Hazards

Fume and gases emitted during welding pose a threat to human health while welding. The exposures may be varied depending on where the welding is done (on the ship, in confined space, workshop, or in the open air). The welding process and metal welded affect the contents of welding fumes. On the other hand, physical and chemical properties of the fumes and individual worker factors are effective on deposition of inhaled particles. In this respect, particle size and density, shape and penetrability, surface area, electrostatic charge, and hygroscopicity are the important physical properties. Also, the acidity or alkalinities of the inhaled particles are the chemical properties that may influence the response of respiratory tract. Welding gases can be classified into two groups; some gases are used as a shielding gas and the others are generated by the process. Shielding gases are usually inert, therefore, they are not defined as hazardous to health but they may be asphyxiants. Gases generated by welding processes are different based on welding type and may cause various health effects if over-exposure occurs. Welding emissions depending on some factors like their concentration, their properties, and exposure duration can lead to health effects on different parts of human body.

5.1.3 Hazards on Respiratory System

The inhalation exposures may lead to acute or chronic respiratory diseases in all welding processes. In the occupational lung diseases, the various reactions produced in respiratory tract depend on some parameters such as the nature of the inhaled matter, size, shape and concentration of particles, duration of exposure, and the individual workers susceptibility. Chronic bronchitis, interstitial lung disease, asthma, pneumoconiosis, lung cancer, and lung functions abnormalities are some hazardous effects on respiratory systems. The pulmonary disorders are various based on the differences in welding metals and their concentrations. Ozone, at low concentrations, irritates the pulmonary system and can cause shortness of breath, wheezing, and tightness in the chest. More severe exposures to ozone can lead to pulmonary edema. Exposure to nitrogen dioxide may cause lung function disorders like decrements in the peak expiratory. Kim JY in a study showed the PM2.5 concentration for welders (1.66 mg/m3) was significantly greater than that for controls (0.04 mg/m3), and the exposure of healthy working population to high levels of welding fumes resulted in the acute systemic inflammation.

6 . SAFETY HAZARDS OF WELDING

6.1 ELECTRICAL HAZARDS

Even though welding generally uses low voltage, there is still a danger of electric shock. The environmental conditions of the welder (such as wet or cramped spaces) may make the likelihood of a shock greater. Falls and other accidents can result from even a small shock; brain damage and death can result from a large shock. Dry gloves should always be worn to protect against electric shock. The welder should also wear rubber-soled shoes and use an insulating layer, such as a dry board or a rubber mat, for protection on surfaces that can conduct electricity. The piece being welded and the frames of all electrically powered machines must be grounded. The insulation on electrode holders and electrical cables should be kept dry and in good condition. Electrodes should not be changed with bare hands, with wet gloves, or when standing on wet floors or grounded surfaces.

6.2 FIRES AND EXPLOSIONS

The intense heat and sparks produced by welding, or the welding flame, can cause fires or explosions if combustible or flammable materials are nearby. Welding or cutting should be performed only in areas that are free of combustible materials, including trash, wood, paper, textiles, plastics, chemicals and flammable dusts, liquids and gases (vapors can travel several hundred feet). Those that cannot be removed should be covered with a tight-fitting flame-resistant material. Doorways, windows, cracks and other openings should be covered. Never weld on containers that have held a flammable or combustible material unless the container is thoroughly cleaned or filled with an inert (non-reactive) gas. Explosions, fires, or release of toxic vapors may result. Containers with unknown contents should be assumed to be flammable or combustible. A fire inspection should be performed before leaving the work area and for at least 30 minutes after the operation is completed. Fires extinguishers should be nearby.

6.3 DANGEROUS MACHINERY

All machines with moving parts must be guarded to prevent workers' hair, fingers, clothing, etc. from getting caught. When repairing machinery by welding or brazing, power must be disconnected, locked out, and tagged so that the machinery cannot start up accidentally.

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7. REMARKS FROM DIFFERENT RESEARCHERS

7.1 ARC WELDING RESEARCH

To minimize ocular injury and promote eye health among industrial welders, it is recommended that work safety intervention programs should be carried out by eye care providers through leaflets, posters, and television and radio advertisements.

- The education and training of employers and employees on Occupational Health and Safety (OHS) issues, a great European challenge, needs to be expanded in order to address also the highly demanding field of radiation. Radiation experts can play a critical role in highlighting the characteristics, hazards and protection approaches required to deal with this field.
- Health and safety in welding are very important issues that need to be addressed worldwide. Europe is strongly investing in clarifying the long term impact of the use of welding technologies in the human body.
- Suitable means of protection from UVR exposure while arc welding include wearing protective gloves together with clothing that covers the arms and forearms down to the gloves. However, the radiant heat from welding can be quite uncomfortable, and welding on a hot day compounds the problem. Discarding heavy welders' clothing and gloves in favour of shorts leeved shirts (unbuttoned at the top) exposes the hands, forearms, neck and manubrium to considerably increased level of UVR. Wearing protective clothing while welding is a hindrance not only for full-time welders. Other tradespeople who perform welding occasionally (e.g. motor mechanics) find it inconvenient to put on protective clothing, while sculptors and tradespeople doing highly intricate work also experience difficulty in achieving fine detail when wearing heavy clothing and thick gloves. Furthermore, while welders are invariably trained in health and safety issues, assistants or other workers in the vicinity may not be aware of the possible risks. Welders have been advised to minimize the chance of overexposure to welding fume using adequate ventilation and keeping heads out of the plume. However, welding requires close observation and many workers tend to put their head where ever necessary to see the work. This may include putting the head in the plume if required.
- In order to effectively protect welders from combined exposure to welding fumes and gases, use of the supplied air respirator, or combined use of a half-face piece dust respirator and a local exhaust system, is recommended.
- There is need for proper education of this economically viable group on workplace hazards, the types and proper use of different protective devices in order to safeguard their health. Similarly, training in ergonomics could contribute toward reduction of work-related accidents.

To minimize integumentary disorders, such as skin cancer, can be prevented by the use of suitable face screen during welding activity; respiratory, gastric, and cardiac disorders, such as lung and stomach cancer and cardiac arrhythmias, can be prevented by the use of a respirator, doing physical activities in order to facilitate gas exchange, and washing hands after working with weld to prevent ingestion of metals.

8. REDUCING THE HAZARDS OF WELDING

Before beginning a welding job, it is important to identify the hazards for that particular welding operation. The hazards will depend on the type of welding, the materials (base metals, surface coatings, electrodes) to be welded, and the environmental conditions (outside or in a confined space). Ask for material safety data sheets (MSDSs) to identify the hazardous materials used in welding and cutting products, and the fumes that may be generated. Make sure you know what you are welding before you start. Some fumes, such as those released from welding on a cadmium-plated surface, can be fatal in a short time. After identifying the hazard, appropriate control methods can be implemented.

8.1 ENGINEERING CONTROLS AND WORK PRACTICES

Substitute hazardous materials for less hazardous materials.

- Use cadmium-free silver solders.
- Use asbestos-free electrodes, gloves, and hot pads.
- Ventilation should be used to remove harmful fumes and gases. Local exhaust ventilation, which removes the fumes and gases at their source, is the most effective method. This can be provided by a partial enclosure, such as a ventilated work bench, or by hoods positioned as close to the point of welding as possible. Ventilation systems should be cleaned and maintained regularly. General ventilation uses roof vents, open doors and windows, roof fans, or floor fans to move air through the entire work area. This is not as effective as local exhaust ventilation, and may simply spread chemicals around the workplace. General ventilation is often helpful, however, when used to supplement local ventilation.
- For gas-shielded arc welding processes, local exhaust can be provided by means of an extracting gun, which can reduce worker exposure to welding emissions by 70 percent.
- Hoods and ductwork should be constructed of fire-resistant materials.

Use shielding (barriers) to protect other people in the work area from the light of the welding arc, heat, and hot spatter.

- Welding booths should be painted with a dull finish that does not reflect ultraviolet light (such as finishes that contain titanium dioxide or zinc oxide).
- Acoustic shields between the worker and the noise source can be used to reduce noise levels. Alternatively, the machinery or process can be totally enclosed.

8.2 MODIFY THE PROCESS OR FOLLOW SAFE WORK PRACTICES

So that hazards are eliminated. For example:

- Don't weld on painted or coated parts. If possible, remove all surface coatings before you weld.
- Use a water table under the plasma arc cutting to reduce fume and noise levels.
- Grind parts instead of air arcing.
- Use the sub arc process to minimize light and fumes created by a visible arc.
- Position yourself while welding or cutting so that your head is not in the fumes.
- Remove all nearby flammable or combustible materials before striking an arc or lighting a flame.
- Make sure that equipment is properly maintained. Replace worn insulation and hoses.
- Welding areas should be kept free of equipment and machines that could cause trips or falls.
- Minimize the production of welding fumes by using the lowest acceptable amperage and holding the electrode perpendicular and as close to the work surface and possible.
- Arc welding should never be performed within 200 feet of degreasing equipment or solvents.

8.3 PERSONAL PROTECTIVE EQUIPMENT (PPE)

Personal protective equipment should always be used along with, but never instead of, engineering controls and safe work practices! Eye protection should be used for all welding operations to protect the eyes from bright light, heat, ultraviolet light, and flying sparks. For the best protection, wear face shields or helmets and goggles. To keep slag and particles out of your eyes when removing your face shield, tip your head forward and keep your eyes closed. Welding helmets, goggles, or other eye protectors must contain special filter plates or lenses for workers exposed to arc welding or cutting processes, oxyfuel gas welding, brazing, or cutting. The OSHA welding standard requires that employees performing welding and cutting operations shall be protected with filter lenses or plates conforming to the specifications

8.3.1 Protective clothing

Which should be worn during welding (by welders and nearby workers) includes: fire-resistant gauntlet gloves, head cap, high-top, hard-toed shoes, leather apron, face shield, flame-retardant coveralls, safety glasses, and helmets and leggings or high boots. Protective clothing should be made of wool, which does not ignite easily, or specially-treated cotton fabrics. Sleeves and collars should be kept buttoned, and pants and shirts should be uncuffed. Capes and hard hats may also be required. Workers should use welding helmets (with appropriate filter lenses), not hand-held screens. When welding overhead, extra protection should be used, such as fire-resistant shoulder covers, aprons, head covers, leggings and suits. Ear plugs should be worn when sparks or hot spatter may get in the ears. Since welders work with highly toxic materials, lockers should be provided so that work clothes are stored separately from street clothes. Work clothes should be laundered by the employer. Showers and locker rooms should be provided so that workers can change into clean clothes at the end of the work shift.

8.3.2 Hearing protection

Ear plugs or ear muffs Should be used during noisy operations such as air arcing and grinding.

8.3.3 Respirators

Must be specific to the hazard and fitted, cleaned, stored and maintained in accordance with OSHA's respirator standard. In addition, workers must receive training on how to use respirators properly. The National Institute for Occupational Safety and Health (NIOSH) recommends that respirators be worn whenever a carcinogen (cancer-causing agent) is present at any detectable concentration, or if any other conditions are present that might be immediately dangerous to life or health. A self-contained breathing apparatus should be worn when welding in confined spaces because welding may reduce the oxygen concentration in the air.

9. RECOMMENDATION

OSHA has a construction standard that applies to welding work (1926.354 Welding, cutting, and heating in way of preservative coatings). It states: "*In enclosed spaces,* all surfaces covered with toxic preservatives shall be stripped of all toxic coatings for a distance of at least 4 inches from the area of heat application, or the employees shall be protected by air line respirators, meeting the requirements of Subpart E of this part."

- This is a correct directive, but "in enclosed spaces" is misleading. All of the events previously described occurred in the open air, and all but the first one involved short duration exposures. People reading the directive could assume that outside enclosed area precautions are unnecessary.

- The balance of the OSHA directive addresses the issue of flammability which while a relevant safety issue, is not related to the problem at hand. The OSHA General Industry Standard, 1910. 252 addresses a variety of safety and fire related issues, but does not address the toxic coating issue.
- In modern times, people who are curious about health hazards, usually turn to the internet. A review of internet comments about welding/burning on epoxy paints/coatings is mostly unhelpful. Much of it is devoted to the hazards of welding on lead containing materials, which is not relevant to the toxic coatings issue. One site briefly addressed the industrial hygiene issues with the following comments:
- "Every effort should be made to try and remove all protective coatings. There are instances where metal is sandwiched together and it is impossible to access the backside of the metal or the beam extends into the building structure. In these instances as much paint as possible must be removed, proper respiratory protection worn, and proper ventilation must be used to capturefume at the point of operation."
- Here again, the information is correct but misleading. Since it suggests proper exhaust ventilation be used to capture fumes, a typical user might assume that since the work is being done outside there is proper ventilation and the hazard is removed (proper exhaust ventilation is a meaningless concept to the average person, but outside is usually assumed to be adequate).
- Our recommendation is that all workers who may find themselves welding/burning on painted surfaces of any type be told about the potential hazards of burning paint. Since production demands will require them to do this work, they either need local exhaust ventilation designed by an industrial hygienist or qualified engineer, or at least they to position themselves where they will receive the least exposure (upwind). In this situation they must wear a respirator. A supplied air respirator may not be available, but a 1/2 mask organic respirator with a HEPA pre filter will significantly reduce exposure.

10. CONCLUSION

This project has shown that welding profession is very hazardous however, not all welders are aware of all the hazards. This is even worse to those who surround the welding area that are not dealing with welding works. In this respect, some welders and other people are affected by welding hazards only because they are not aware of welding hazards. To avoid the arc welding hazards, this paper has suggested some safety measures to be taken during welding activities.

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