EDUCATION PROGRAM WELDING - SAFETY AND HEALTH DESCRIPTIONS

SAFETY AWARNESS FOR EMPLOYEES EVERY DAY

Purpose - The Safe Program is a safety awareness process designed to assist in eliminating and reducing the risk of accidents, injuries, illnesses and unsafe conditions while protecting and preserving our environment.

Concept - The Safe Program adopts the principle that the task performer's personal commitment and accountability must be promoted through his/her involvement in the safety task planning.

Goal - The Company's mission of safety excellence can be achieved by empowering the entire work force in the planning and decision making process. This will inspire the enthusiasm necessary for each employee to accept ownership of a safety process that is focused on continuous improvement.

Scope:

- The Supervisor and the task performer(s) together review the Job Safety Analysis (JSA) to analyze the assigned task for hazards at the task location. After the hazards have been identified, the front line Supervisor and the Task performer(s) discuss the proper method to perform the assigned task.
- This process has been developed for each employee to recognize the importance of the Safe Program, encourage teamwork, promote participation in hazard recognition and identify safe work procedures that will assist in eliminating injuries and or illnesses for every employee before execution of the tasks. To elevate the awareness of the Company's safety process by promoting teamwork that requires the task performer(s) to analyze the task in relation to safe work practices, health and environmental compliance and give feedback to the front line supervisor/foreman, who in turn will cover any hazards that have been overlooked or not recognized by the task performer(s). The Project Management or Foremen is responsible and accountable for the task performed and will ensure all tasks are performed in a safe manner.

Exhibit(s)

A. Safety Awareness for Employees Instructions

B. Safety and Health Management System

"SAFETY is a Communication and Awareness Process"

INTRODUCTION

This guidance gives advice on asphyxiant gases used when welding metal fabrications and pipes, and in particular a technique known as purge damming, (containment of purging gasses in the area being worked on). It will be useful for employers and workers planning this type of work, and for inspectors assessing whether the controls in place are adequate to control the risks to health and safety.

The consequences of exposure to an oxygen deficient atmosphere can be fatal, yet with reasonably practicable controls, as explained below, the risk can be reduced to an acceptable level.

Accident history indicates that multiple workers are often affected. This is mainly as a result of the rescuer attempting a rescue, but getting into difficulties themselves due to the reduced oxygen levels.

Types of gas and their properties

For smaller jobs the welder may purge air from behind the weld using the same gas supply as for the welding gun. This may be a proprietary mix such as argon/ helium or argon/ helium/ CO2. Mixed gases tend to be significantly more expensive than pure argon, as a result larger scale purging operations tend to use argon.

Although metal active gas (MAG) welding does not use a true inert gas (often carbon dioxide or a mixture of gases) the gases used do not contain sufficient oxygen to sustain life. Similarly nitrogen is not a true inert gas as it can chemically react with metal at welding temperatures. However it is cheap so may be used to purge air, particularly if large quantities of gas are needed to purge a large void.

Physical properties of welding gases

Gas	Colour	Odour	Relative density*
Argon	None	None	1.38
Helium	None	None	0.14
Nitrogen	None	None	0.97
Carbon dioxide	None	None	1.53
Oxygen	None	None	1.11
Propane	None	'Natural gas'	1.21
Acetylene	None	Garlic-like	0.48

*density of air = 1

Whilst acetylene and propane have distinctive smells, the other gases are odourless and their direct measurement difficult. All are colourless. Detection tubes are available for some, and the flammable gases can be detected with suitably calibrated flammable gas-detection equipment. The most appropriate detection method when checking oxygen levels is the use of a suitably calibrated oxygen meter.

Gases denser than air can collect in tank bottoms, vessels, pits and other low-lying areas. In very still air conditions the denser gases, eg argon, can act almost like a liquid and will form dense, low-lying layers which will disperse only slowly. Lighter gases may collect in high-level spaces which could pose a risk if this is at head level.

Although dense gases will tend to sink, and light gases rise, the movement is easily disrupted. For example a pressurised gas leak or intentional release of a jet of gas will entrain the surrounding air and may form a homogenous mixture or concentration 'gradient' within a confined space. Similarly the movement of people, plant or convection currents can cause sufficient air turbulence to disrupt the natural tendency of a particular gas to rise or sink. While the density of the gas used is important when considering possible hazardous areas, safe systems of work should not rely on the asphyxiant gas sinking or rising.

4. WELDING HEALTH EFFECTS

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 alkalinity 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.

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.

Hazards on Kidney- Substantial exposure to metals and solvents may be nephrocarcinogenic. Chromium can deteriorate renal function because of accumulation in the epithelial cells of the proximal renal tubules and induce tubular necrosis and interstitial changes in animals and humans. Tubular dysfunctions have been identified in subjects occupationally exposed to Cr (VI). Welders exposed to heavy metals like cadmium and nickel have also experienced kidney damage. Pesch et al. indicated that there was an excess nephrocarcinogenic risk involved with soldering, welding, milling in females. So, it can be considered an evidence for a gender-specific susceptibility of the kidneys.

Hazards on Skin - Erythema, pterygium, non-melanocytic skin cancer, and malignant melanoma are the adverse health effects of welding on the skin among which erythema is a common one. The intense UV as well as visible and infrared radiations are produced by welding arc machines. Exposure to UV can lead to short- and long-term injuries to the skin. Some metals like beryllium, chromium and cobalt can cause direct effects (irritation and allergic impacts) on the skin. Also, they may be absorbed through the skin and cause other health effects such as lung damage. When the particles are small and there are cuts or other damages to the skin, the absorption through the skin is raised. Chromium (VI) may cause irritating and ulcerating effects when contacting with skin. An allergic response including eczema and dermatitis may be induced in sensitized individuals exposed to Cr (VI).

Hazards on the visual systems - Most welding processes emit intense ultraviolet as well as visible and infrared radiations. Adverse effects on the eyes may be induced by these optical radiations. In addition, Tenkak reported that, welding may cause photokeratitis and some types of cataract. Erhabor et al. showed the most frequent symptoms among the welders were eye irritation (95.43%). Exposure to UV radiation can lead to short- and long-term injures to the eyes. Acute overexposure to UV radiation can result in the photokeratitis and photoconjunctivitis that are the inflammation of the cornea and the conjunctiva, respectively. These responses of the human eye to UV radiation are commonly known as snow blindness or welder’s flash.

Hazards on Reproductive System - In the past, some studies have indicated the increased risk for infertility and reduced fertility rate in mild steel welders. There are some evidences that reduced fecundity can be related to exposure to hexavalent chromium and nickel. According to new investigations, damages to male reproduction system have been reported less than before, probably because of decreasing the exposure levels in the developed countries. However, some special tasks like stainless steel welding may impair welders' reproduction system. A study by Bonde showed that mild steel welding, but not stainless one, resulted in significant effects on the fertility during years. Mortensen observed a greater risk for poor sperm quality among welders compared to controls, especially welders who worked with stainless steel. Therefore, welding in general, and specifically with stainless steel, may cause the reduced sperm quality. According to Sheiner, impaired semen parameters can be associated with the exposures to lead and mercury.

Hazards on the nervous system - Memory loss, jerking, ataxia and neurofibrillary degeneration have been attributed to exposure to aluminum. The accumulation of aluminum in the brain may develop some neuropathological conditions, including amyotrophic lateral sclerosis, Parkinsonian dementia, dialysis encephalopathy and senile plaques of Alzheimer's disease. A review of literatures by Iregren suggests that occupational exposure to manganese results in the central nervous system damage that is generally irreversible. Although there are multiple toxic agents in welding, more literatures have dealt with manganese as an important agent of toxicity. Welders are also exposed to high concentrations of carbon monoxide and nitrogen dioxide. Carbon monoxide can cause the neurological impairments of memory, attention, and visual evoked potentials. Both central and peripheral nervous system damages may be induced by exposure to welding fumes. Some neurobehavioral impairments associated with exposure to lead and manganese have been indicated by Wang.

Carcinogenic effects - There are some concerns regarding the presence of carcinogens in the welding fumes and gases. Sufficient evidences for carcinogenicity of nickel, cadmium, and chromium (VI) have been reported through experimental and epidemiological studies. These three metals have been categorized as carcinogen "Class 1" by the International Agency for Research on Cancer. Ozone has been introduced as a suspect lung carcinogen in experimental animals, but there are very few documents about its long term effects on welders. The ultraviolet emissions resulting from welding arc can potentially cause skin tumors in animals and in overexposed individuals, however, there is no definitive evidence for this effect in welders.

Other health problems - Welding on surfaces covered with asbestos insulation may lead to risk of asbestosis, lung cancer, mesothelioma, and other asbestos-related diseases in exposed welders. The intense heat and sparks of welding can cause burns. Eye injuries are possible because of contact with hot slag, metal chips, and hot electrodes. Lifting or moving heavy objects, awkward postures, and repetitive motions result in strains, sprains and musculoskeletal disorders. High prevalence of musculoskeletal complaints (back injuries, shoulder pain, tendonitis, carpal tunnel syndrome, and white finger) is seen in welders.

5. Exposure standards for welding emissions

Usually, exposure standards apply to long term exposure to a substance over an eight hour work per day for a normal working week, over an entire working life. Some organizations like American Conference of Governmental Industrial Hygienists (ACGIH), National Institute for Occupational Safety and Health (NIOSH), and Occupational Safety and Health Administration (OSHA) have published the exposure standards for various components in welding fumes and gases (table 2). According to Work Safe Australia exposure standards cannot be used as a fine dividing line between a healthy and unhealthy workplace. Adverse health effects below the exposure limits might be seen in some people because of individual susceptibilities and natural biological variation. ACGIH, however, recommends a TLV-TWA (Threshold Limit Value-Time Weighted Average) of 5 mg/m^3 for total welding fume, assuming that it contains no highly toxic components. Each metal or gas within the welding has its own exposure standard. As Table

2 indicates, biological media, Biological Exposure Index (BEI), and carcinogenicity class have been proposed for some welding emissions.

Substance	OSHA PEL-TWA (mg/m3)	NIOSH REL-TWA (mg/m3)	ACGIH TLV-TWA (mg/m3)	ACGIH BEI	Carcinogenicity
Aluminum Fume	15 (Total) 5 (res)	5	5		
Arsenic	0.01	0.002 (Ceiling)	0.01	35 µg As/L	A1
Barium	0.5	0.5	0.5		
Beryllium	0.002	0.5 (Ceiling)	0.002		A1
Cadmium Fume	0.005	LFC (Ca)	0.01 (Total) 0.002 (Res)	5 µg Cd/g creatinine	A2
Cobalt	0.1	0.05	0.02	15 µg Co/L	A3
Chromium(VI)	--	0.001	0.05	25 µg Cr/L	A1
Chromium metal	1	0.5	0.5		A4
Copper Fume	0.1	0.1	0.2		
Iron Oxide	10 (as Fe)	5	5		A4
Lithium	--	--	--		
Manganese	5 (Ceiling)	1	0.2	range 0.5 to 9.8 mg/L; up to 50 mg/L for occupational exposure	
Molybdenum	5(Soluble) 15 (Insoluble)	--	5 (Soluble) 10 (Insoluble)		
Lead	0.05	0.1	0.05	30 µg /dL (whole blood)	A3
Nickel	1	0.015 (Ca)	1	10µmol/mol creatinine	Elemental (A5) Insoluble inorganic (A1)
Platinum	0.002 (Soluble)	1(Metal) 0.002 (Soluble)	1		
Selenium	0.2	0.2	0.2		

Substance	OSHA PEL-TWA (mg/m3)	NIOSH REL-TWA (mg/m3)	ACGIH TLV-TWA (mg/m3)	ACGIH BEI	Carcinogenicity
Silver	0.01	0.01	0.1		
Tellurium	0.1	0.1	0.1		
Thallium	0.1	0.1(Soluble)	0.1	50 µg Th/g creatinine	
Titanium Dioxide	15	LFC (Ca)	10		
Vanadium Pentoxide	0.1 (Ceiling)	0.05(Ceiling)	0.05	50 µg V/g creatinine	
Zinc Oxide	5	5	5		
Zirconium	5	5	5		
Total fumes	--	LFC (Ca)	5		
Carbon monoxide	50 ppm	35 ppm	25 ppm	3.5% of (Hemoglobin) 20 ppm (end-exhaled air)	
Nitrogen dioxide	5 ppm (ceiling)	5 ppm (ceiling) 1ppm (STEL)	3 ppm		
Ozone	0.1 ppm	0.1 ppm	0.08 ppm		

Table 2.

Exposure limit of each individual constituent of welding components

LFC=lowest feasible concentration; Res=Respirable; Ca=NIOSH potential occupational carcinogen

6. WELDING MONITORING AND RISK ASSESSMENT

6.1. Monitoring of welding emissions

Managing the risks of pollutants generated by welding process is carried out in some steps inculing identifying hazards, assessing the risks arising from these hazards, eliminating or minimising the risks via proper control ways, and checking the effectiveness of controls. Monitoring the welder's exposure is a main component of risk management process. Welding process leads to chemical exposures to fumes and toxic gases in enormous quantity. The hazard identification and risk assessment are necessary to work safely in a welding environment. Enough information, education, training and experience are required in this respect. In addition to the full-time welders, a large number of part-time welders who work in small shops and workers in the vicinity of the welding process may also be exposed. There is a greater potential for exposure due to welding in confined spaces with poor ventilation such as ship hulls, metal tanks and pipe, therefore, monitoring such welders should be seriously considered.

As it was stated previously, the level of welder's exposure to welding emission depends on some factors like the process type, process parameters, and consumables used. Materials and consumables used in welding determine the chemical composition of welding emissions. The specific toxicity of each element and the synergetic effect of generated constituents must be considered to evaluate the exposure status of welders. There are some other workplace specific factors, including the ventilation condition, welder position or posture, and the volume of welding room, that influence the exposure level. The emission rate and also its concentration in the breathing zone of the welder or in the work environment are directly related to the mentioned factors. When it is probable that the welders' exposure will be exceeded the prescribed limits, or when the workers' health and the environment are at risk, the monitoring of hazards and the risk assessment program are required. To evaluate the hazards caused by different welding emissions, collecting various information is recommended. Air monitoring and measuring related pollutants via personal and environmental sampling, biological monitoring, workplace assessment with regard to physical and chemical hazards, and occupational medical findings can be used to evalute the welder's exposure status compeletely.

Air Monitoring -Airborne pollutants generated by welding can threaten the worker's health and safety. Thus, during the health and safety program, air monitoring is used to identify and quantify welding emissions. To evaluate air contaminants, a sampling strategy is used for collection of exposure measurements. The choice of the best strategy is based on site-specific conditions. In a sampling strategy, some parameters like selection of workers for personal monitoring, sampling duration and required number of samples are important. The measurement of contaminants is carried out in the breathing zone of selected worker. The collected samples must be representative of the normal work activity and exposure of welder, because the sampling results are used to prevent overexposures. Air monitoring in welding processes includes the sampling and analysis of welding fumes and welding gases.

Within recent years, standard practices have been developed to monitor exposures considering the occupational exposure limits for elements. Most measurements are made using personal monitoring systems with a pump at a proper flow rate connected to a cassette containing a membrane filter for a suitable period of time. To obtain the accurate result, filter cassette must be placed inside the welding helmet. Time-weighted average concentrations of total fumes is obtained by weighing the filter before and after exposure; the concentrations of elements are determined by chemical analysis methods provided by related organizations like American Welding Society and British Standards Institution, NIOSH Manual of Analytical Methods (NMAM) for metals in air and urine and OSHA Sampling and Analytical Methods are used to monitor the welding workplaces. In these methods, analysis of metals is performed by Inductively Coupled Argon Plasma-Atomic Emission Spectroscopy (ICP-AES) after sample preparation by acidic ashing. It is worth mentioning that the microwave digestion can be used instead of acidic ashing to prepare samples, leading to reduction in ashing time up to 90 percent, as well as cost saving and providing a healthier work environment for laboratory operators. Golbabaei et al. used the microwave digestion to prepare urine samples before urinary metal analysis by graphite furnace atomic absorption spectrometry.

As it was stated previously, there are different workplace conditions for workers who are welding in confined spaces compared to other welders. Limited access and little airflow or ventilation are the characteristics of a confined space. Hazardous concentrations of welding emissions can accumulate very quickly in such small spaces. Hazardous concentrations of welding emissions can accumulate very quickly in such small space. Thus, confined spaces should be monitored for toxic, flammable, or explosive emissions to evaluate welders' exposure. In some situations, continuous air monitoring may be necessary when workers are welding in a confined space with special conditions. Golbabaei et al. conducted an investigation to assess the risk related to welding pollutants for welders who work in confined spaces. Almost for all analyzed metals, there were significant differences between back welders and controls. Back welding is a task that workers perform welding inside the pipe as a confined space. Based on risk assessment, back welding was a high risk task. These authors in another study assessed the welder's exposure to carcinogen metals (Cr, Cd, and Ni). The NIOSH methods were used for sampling and measurement of metals. Back welders group had maximum exposure to total fume and mentioned elements.

Determination of occupational exposures to gases must be based on workplace measurements, because the local ventilation and workplace design can affect the actual concentrations of toxic gases (ozone, carbon monoxide, nitrogen oxides) in the welders' breathing zone. Hariri et al. surveyed the appropriate personal sampling methods to measure the welding emissions in small and medium enterprises. They proposed NIOSH methods to evaluate the fumes and direct reading instruments for measurement of gases. Also, they offered some guidelines for correct assessment of welding workplaces. Choonover et al. showed welders were exposed to higher concentrations of NO_2 and O_3 than controls. These gases were collected on pre-treated filters with proper solutions. Then, NO_2 and O_3 were analyzed by spectrophotometry and ion chromatography (IC), respectively. Azari et al. conducted a study to evaluate exposure of mild steel welders to ozone and nitrogen oxides during TIG and MIG welding. OSHA ID214 and NIOSH 6014 methods were used to evaluate ozone and nitrogen oxides, respectively. High exposure of welders to these gases was reported in the study. Golbabaei et al. also used OSHA and NIOSH methods as well as direct reading instruments for sampling and measurement of various gases.

Although there are various techniques for monitoring of welding emissions (both fumes and gases) in air samples, selecting the proper ones depends on some parameters. Availability of sampling media, sample storage time, and the simplicity, cost, time and sensitivity of analytical technique are essential to planning proper sampling strategies. It is necessary to consider those workers who probably have the highest exposures due to used materials and processes, the characteristics of their tasks, their postures during welding, the conditions of work environment, and other pollutants from processes in the vicinity of welding environment. It is known that high concentrations of some welding fumes and gases can also be explosive; therefore, the workplace should be tested to ensure a safe working environment.

Biological Monitoring - Biological monitoring means the measurement of the concentration of a contaminant, its metabolites or other indicators in the tissues or body fluids of the worker. In some cases, biological monitoring may be a supplementary monitoring for the personal assessment. Another advantage of the biological monitoring is the detection of biological effects of the chemical by monitoring reversible and irreversible biochemical changes. It can be used in the medical treatment to identify the real exposures of chemicals absorbed into the body of employees suspected of over-exposing to a chemical. Airborne contaminants measurement and biological monitoring are complementary procedures used to prevent occupational disease, assess the risk to workers' health, and evaluate the effectiveness of control ways. Biological monitoring must be conducted based on a proper strategy. Careful considerations are required to select the best biological matrix for each component. To obtain valid results, timing sample collection, sample preparation and analytical method used to determine the concentration of components are critical. There are different methods for biological monitoring of some welding emissions. As it is indicated in Table 2, biological media and biological exposure indices (BEIs) have been recommended for some metals and gases emitted by welding processes. Totally, complete information can be provided by biological monitoring and air monitoring to assess the worker exposure to welding emissions.

Ellingsen et al. studied the concentration of manganese in whole blood and urine in welders. Concentration of Mn in whole blood (B-Mn) was about 25% higher in the welders compared to the controls. The increase in B-Mn and the dose-response relation between air-Mn and B-Mn in the welders are strong indicators of Mn. Long-term high exposure to welding fumes may lead to alterations of the urinary excretion of certain cations that are transported through the DMT1 transport system (divalent metal transporter 1 that is found on the surface of the lung epithelial cells). Kiilunen study showed the metal concentration in post shift urine samples were correlated with the personal air monitoring results. There were statistical significant correlations between urinary concentrations of chromium and nickel and the related total metal concentration in air in wire welding processes. Also, in MIG/MAG welding, chromium is accumulated in the body with a long half life. There is an association between the airborne concentration of nickel and its post shift urinary concentration. In welding, the nickel concentration in post shift urine samples can indicate the body burden. In a study conducted by Hassani et al. the correlation between airborne Mn and urinary Mn was significant for all exposed subjets. The obtained result can introduce the urinary Mn as a biomarker for exposure to this element. Azari et al. measured the serum level of malondialdehyde in welders. Serum MDA of welders was significantly higher than that of the control group. A significant correlation was detected between ozone exposure and level of serum MDA, but the correlation was not observed for nitrogen dioxide exposure. Rossbach recommended the determination of Al in urine for biological monitoring because of the higher sensitivity and robustness of this marker compared to Al in plasma. Golbabaei et al. analyzed the urinary metals among the different groups of welders. According to the results, exposure of welders to fume components leads to more accumulation of them at welders' bodies. Based on different studies, the soluble metal compounds are accumulated in the body, affecting the critical organs. Urinary concentration of metal is used as a biomarker of metal exposure. Therefore, biomonitoring serves as an appropriate tool to monitor both the recent and past exposure and it can be related to the total chemical uptake through all exposure routes.

Health monitoring - In addition to the assessment of the airborne concentration of a particular contaminant and its comparison with standard limit, health monitoring may also be done for some hazardous chemicals to assess risks to exposed workers. Health monitoring means monitoring workers exposed to hazardous pollutants to identify changes in their health status and evaluate the effects of exposure. Health monitoring can provide effevtive information to implement proper ways for eliminating or minimizing the risk of exposure and improving control measures. Health monitoring considers all routes of exposure to contaminants. Some tests including spirometry (lung function), audiometry (hearing), biochemical tests (e.g. kidney or liver function), cardiac function tests (heart function), nerve conduction velocity and electromyography tests (nerve and muscle function), and neurobehavioural tests (nerve and brain function) may be used in health monitoring. The type of test used will depend on the occupational hazards that the employee are exposed to. Donaldson and Antonini surveyed lung functions in exposed welders and showed that exposure to welding fumes is associated with both pulmonary and systemic health endpoints, including decrease in pulmonary function, increased airway responsiveness, bronchitis, fibrosis, lung cancer and increased incidence of respiratory infection. In addition to these pulmonary effects, metal fume fever is frequently observed in welders. Exposure to metal fumes and irritating gases cause chronic obstructive pulmonary disease (COPD). Health monitoring of welders can help detect breathing problems and reduced lung functions in early stages, resulting in prevention of further damages. Spirometric tests are used by an occupational phisycian to assess lung functions. Totally, health monitoring may include simple observation of the worker's skin to complicated tests in special cases. Health monitoring must be done by the experienced medical practitioner. An occupational physician can provide specialist services and testing such as spirometric tests, respiratory screening and chest X-rays. It is necessary to do the health monitoring before beginning work with a hazardous chemical to provide enough information for following changes in the worker's health during periods of exposure.

6.2. RISK ASSESSMENT OF WELDING EMISSIONS

Risk is defined as the possibility of occurance of an event leading to clear concequences. Evaluating risks to workers' safety and health is conducted in risk assessment process. It is performed in some steps including:

- Hazards identification and those at risk
- Evaluating the risks (qualitative or quantitative)
- Elimination or minimization of risks via implementing control measures and taking actions
- Monitoring and reviewing the effectiveness of adopted controls

The severity of hazard and the exopsure level determine the health risk and the type of chemical and nature of work are important factors in this regard. All workers in the vicinity of a special activity should be considered to assess the risk associated with chemical hazards, because they may potentially be at risk of chemicals emmitted by that activity.

In welding environments, employers are resposible to ensure the safety and health of welders and take proper measures for their protection. Although, preventing the occupational risks is the main purpose of risk assessment, it is not possible in all situations; therefore, risks should be reduced using control measures. There are different hazards related to welding process resulting in risks to welders. Chemical hazards, physical hazards, and those associated with ergonomics threaten the health of welders. Since this text deals with air pollution, the risk assessment of welding emissions i.e. fumes and gases is considered. Hazardous chemicals in the workplace result in different risks to workers.

There are different methods to do risk assessment of chemicals in which some principles should be considered. These principles include addressing all relevant hazards and risks and beginning the elimination of risks, if it is possible.

The ministry of manpower of Singapore has published a guideline intitled “semi-quantitave method to assess occupational exposure to harmful chemicals”. This method may be useful to assess the risks resulting from welding emissions. Risk assessment is conducted for following purposes:

- Identifying the hazards related to each harmful chemical
- Evaluating the degree of exposure to chemical of interest
- Determining the likelihood of chemical adverse effects

A risk rating to different tasks can be designate using the mentioned method. After that, using risk rating matrix, hazards are ranked as negligible, low, medium, high and very high (legends 1 to 5) and required actions are prioritized to select appropriate controlling plans. This guideline deals with the health risk to workers exposed to chemicals via inhalation. There are eleven steps for hazard identification and rating, exposure evaluation, and assessing risk. The actual exposure level is required for determination of exposure rating and risk level. A step by step flow chart for assessing the risk, forms needed for completing some steps, and different tables and equations for evaluating the risk have been provided by guideline. All components to assess the risks are available in guideline and it can be used for risk assessment of welding emissions in a simple and fast way. Following, the process flow chart has been presented to understand the consept of risk assessment.

Golbabaie et al. used mentioned guideline to assess the health risks arising from metal fumes on back welders. Risk assessment was performed according to the steps previously explained. Cadmium concentration was ranked as “very high” group. Also, total fumes, total chromium, and nickel were ranked as “high” legend. Findings indicated back welding is a high risk task. High concentration of metals confirmed that working in confined spaces creates a great risk for welders. In some cases as in cadmium despite the rather low concentration of the pollutants, the risk is ranked as “very high” due to the carcinogenisity nature of this element. Therefore, it is not always possible to judge the health hazards of the pollutants based on their concentrations.

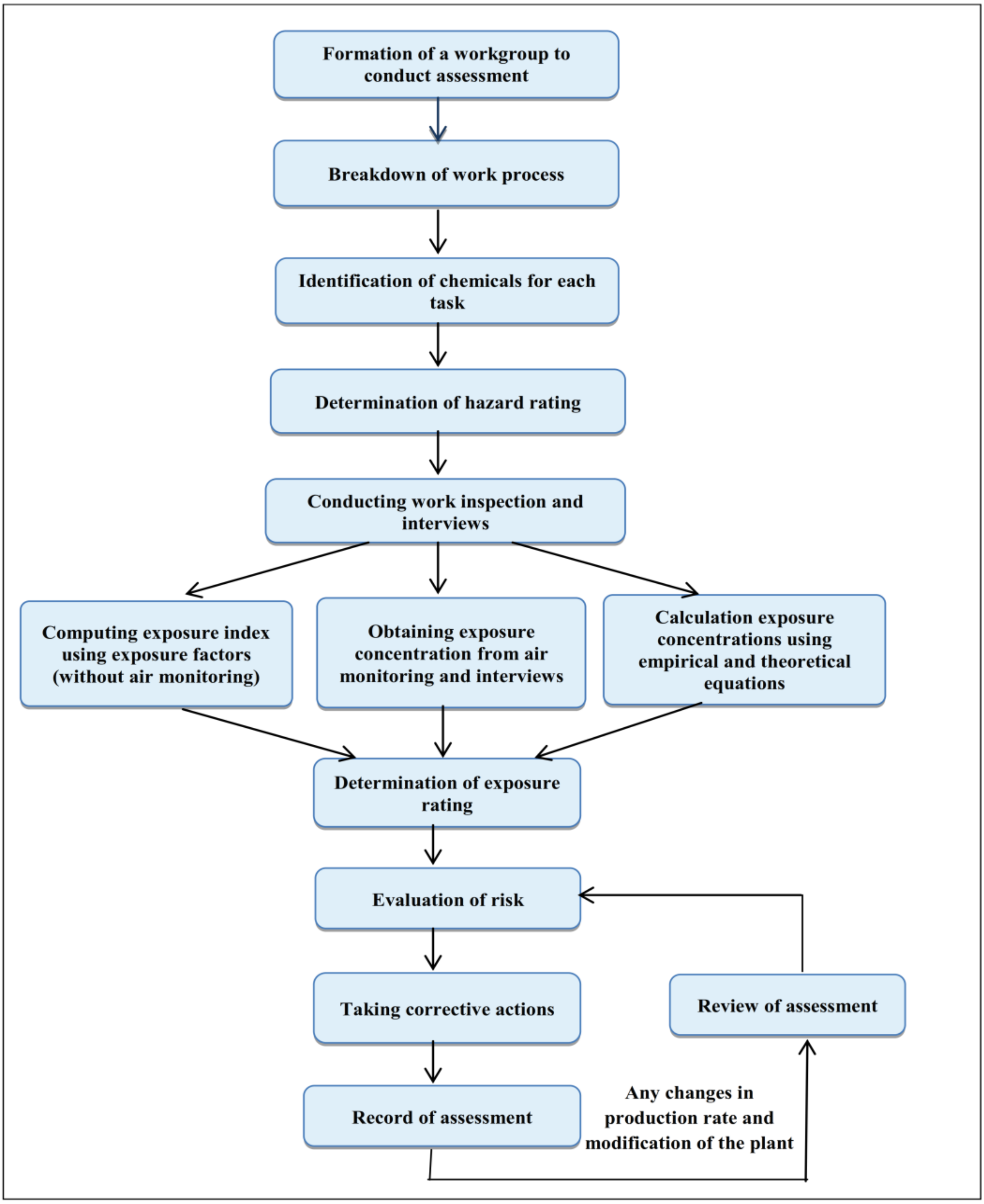


Figure 2. - Process flow chart of semi quantitave method for chemicals risk assessment

Following the risk assessment, employers can decide on required preventive measures, the working and production procedures, and also improving the level of welder protection. To complete risk assessment of welding chemicals, data related to air monitoring, biological monitoring, and health monitoring may be required for true judgement. Totally, risk assessment in workplace can result in some advantages. Workers do their tasks in a safe manner;

employers provide appropriate programs to prevent high exposure and increase job satisfaction; regulators and related organizations can reliably present health and safety standards. The process of risk assessment is a basis for risk management to reduce welding hazards by choosing correct actions.

WELDING SAFETY HAZARDS

Welding operations present several hazards to both those undertaking the activity and others in the vicinity. Therefore, it’s important that you are aware of the risks and hazards welding poses, and understand what precautions you can take to protect yourself.

ELECTRIC SHOCK

During the arc welding process, live electrical circuits are used to create a pool of molten metal. Therefore, when welding, you are at risk of experiencing an electric shock. Electric shock is the most serious hazard posed by welding and can result in serious injuries and fatalities, either through a direct shock or from a fall from height after a shock. You are also at risk of experiencing a **secondary electric shock** should you touch part of the welding or electrode circuit at the same time as touching the metal you are welding.

You are particularly at risk if you work in electrically hazardous conditions. These include welding:

- In damp conditions.
- While wearing wet clothing.
- On metal flooring or structures.
- In cramped conditions where you are required to lie, kneel or crouch.

NOISE HAZARDS

When carrying out welding activities, you are likely to be exposed to loud, prolonged noises. A loud noise is considered to be above 85 dB(A), and welding activities such as flame cutting and air arc gouging can produce noise levels of over 100 dB(A). This can be very damaging to the ears and can result in hearing impairment. Regular or immediate exposure to loud noises can cause permanent noise-induced hearing loss.

Noise-induced hearing loss can have the following side effects:

- Ringing in the ears, known as tinnitus. Occasional dizziness, known as vertigo.
- Increased heart rate.
- Increased blood pressure.
- Exposure to UV and IR Radiation

Looking at the intense bloom of UV light produced when welding, without appropriate PPE or welding curtains, can result in a painful and sometimes long-lasting condition called arc-eay. Many factors can affect the severity of a flash burn injury, such as distance, duration and the angle of penetration. Long-term exposure to arc flashes could also potentially result in cataracts and lead to a loss of vision.

Other forms of eye damage include:

- **Foreign bodies** entering the eye, including grit, sparks and dust.
- **Particulate fumes and gases,** which could lead to conjunctivitis.

Exposure to Fumes and Gases

Undertaking welding activities will expose you to invisible gaseous fumes, including ozone, nitrogen oxides, chromium and nickel oxides, and carbon monoxide which can easily penetrate into your lungs. Depending on the gas or fume, the concentration and duration of your exposure, the resultant damage can be severe.

Illnesses caused by welding fumes and gases include:

Pneumonia. Regular exposure to welding fumes and gases can result in a lung infection which could then develop into pneumonia. While antibiotics can usually stop the infection, severe pneumonia can result in hospitalisation, serious illness and fatalities.

Occupational asthma. Chromium oxides and nickel oxides produced by stainless steel and high nickel alloy welding can both cause asthma.

Cancer. All welding fumes are internationally considered 'carcinogenic'.

Metal fume fever. Welding or hot work on galvanised metal and high steel weld fume exposure can often result in 'flu-like' symptoms, which are usually worse at the start of the working week. You might have heard that drinking milk before welding will help you avoid developing metal fume fever, but this is a **myth.**

Throat and lung irritation, including throat dryness, tickling of the throat, coughing and tight chests.

BURNS

The combination of high-temperature welding arcs, UV rays and molten metal means you are susceptible to severe burns when welding. These burns can affect the skin or eyes and can be very serious. They can also happen **very** quickly.

Burns usually occur when welders think they can skip taking precautions for a few quick welds. This is bad practice. If you follow our outlined precautions, you should be able to prevent burns.

Welding Safety Precautions

Ensuring high levels of safety is vital when undertaking any welding activity. Ignoring your PPE and safe working practices can have serious repercussions and might even lead to fatalities. Therefore, you should follow the safety precautions below to protect yourself at work.

Always Wear Appropriate PPE

Your employer or manager has a duty to provide you with appropriate Anex 3-6 [Personal Protective Equipment (PPE)](). The PPE you receive will include:

Welding helmets with side-shields. Welding helmets protect you from UV radiation, particles, debris, hot slag and chemical burns. It's important that you wear the right lens shade for the work you are carrying out. follow the manufacturer's guidelines and gradually adjust the lens filter until you have good visibility that does not irritate your eyes. You should also use a fire-resistant hood under your helmet to protect the back of your head.

Respirators. Respirators protect you from fumes and oxides that the welding process creates. Your respirator must be suitable for the work you are carrying out.

Fire resistant clothing. Fire resistant clothing protects you from heat, fire and radiation created in the welding process and shields you from burns. It should have no cuffs, and pockets must be covered by flaps or taped closed. You should not use synthetic clothing. Instead, opt for leather and flame-resistant treated cotton.

Ear protection. Ear protection protects you from noise hazards. It's important you wear ear protection that is appropriate for the noise created in your workplace, and use fire resistant ear muffs if there is a risk of sparks or splatter entering the ear.

Boots and gloves. Insulated, flame resistant gloves and rubber-soled, steel toe-capped safety shoes shield you from electric shocks, heat, fire, burns and falling objects.

To receive full protection from your PPE, you must not:

Roll up sleeves or trousers. Rolling up your clothes will leave you susceptible to molten metal or sparks getting caught in the folds, which could potentially lead to severe burns. You should also never tuck your trousers into your work boots.

Remove your helmet while welding. You must always wear your helmet when welding and when in the vicinity of another welder. While the intensity of the radiation produced decreases the further you are from a welding arc, those less than 10 metres away are still susceptible to arc-eye. Therefore, it's important that you remain behind welding curtains or wear the correct PPE, even if you aren't the worker carrying out the welding operation.

Receive Appropriate Training

Prior to starting any welding work, it's important that you receive adequate training in the use and safety of your work. E-learning courses provide an easy, cost-effective and flexible training opportunity.

Ensure Your Workspace is Well Ventilated.

Good ventilation is important when welding as it removes airborne gases and particles from your work area. You may need to employ a combination of ventilation strategies to combat all the pollutants created in the welding process. You might also need to use respirators if your ventilation strategies don't reduce your exposure enough.

Ensure Your Workspace is Free of Flammable Material.

You should avoid keeping flammable materials in the vicinity of welding processes as sparks, heat and molten metal splatters produced in the welding process could potentially set flammable material on fire.

7. OCCUPATIONAL CONTROL

Air pollution control deals with the reduction of air pollutants emitted into the atmosphere using different technologies. Sometimes, managing the production process is used to control air pollutant emisstion, therefore, checking the production process can be useful for beginnig the air pollution control. Elimination of a hazard is the first aim to control related risk. In essence, keeping the pollutant emission at the minimum level during the process is the main purpose of controling the air pollution. Based on the risk assessment results, employers can decide for control of risk using proper ways. There are various ways to control the risk of chemicals like welding emissions. If the hazard elimination in not reasonably practicable, other approaches are used to minimize the risk. Substitution, isolation, engineering controls, work practices, and personal protective equipment (PPE) are used to reduce risks to the lowest practicable level in order of priority. Using personal protective equipment is the least recommended control way. To provide a layered safety net, a combination of several control ways may be adopted for preventing risks. In the case of welding, if the elimination of fumes is not practicable, other controling measures should be applied. Modifying the welding process, improving working practices, ventilation, and using PPEs are considered in order to control of fumes.

7.1. Choosing or modifying the welding process

Employers can choose the welding type for production process based upon its efficiency, weld quality, available equipment, and economics. For instance, TIG welding generates less fume compared to MMA, MIG and FCAW processes, so, it can be a proper choice for welding operations. In order to modify the welding process, selecting consumables with minimum fume emissions and considering the welding parameters to minimize the emissions are recommended to employers. The generation of welding fumes is minimized using the lowest acceptable amperage. To optimize the process modification, paying attention to consumables, equipment, and control system is necessary. Selecting proper consumbles leads to minimizing the environmental impacts and controling risks to welders. Welding on non-painted or coated surfaces can also reduce the production of emissions. Process modification in welding results in decreasing needs for administrative controls and other expensive procedures, and also simplifying the process of risk assessment.

7.2. Improvement of working practices

Working practice, the way used to do work, can be improved for control of workers' exposure. Safe work practices are provided by company or organization to perform a task with minimum risk to workforce, environment, and process. Such practices control the manner of performing work and complete engineering measures. Placing the workpiece, as an improving measure, can keep the welders away from plume rising above the weld. Minimizing the welding in confined or enclosed spaces leads to reduction of exposure to pollutants. Proper training programs, housekeeping, maintenance, and doing task on time are the safe welding habits to reduce exposure. Consequently, welding based on safe practices and instructions results in healthier workplace and diminishing the risks of exposure to hazardous emmisions.

7.3. Ventilation

Ventilation is the most effective way for removing welding emissions at source to reduce exposure to fumes and gases in welding operations. Designing the ventilation system in accordance with the types of hazardous emissions results in providing a safe atmosphere in the workplace. This control procedure is classified into dilution (general) ventilation and local exhaust ventilation (LEV). The most efficient method to control welding emissions is the combination of LEV and dilution ventilation.

General or Dilution Ventilation -This type of ventilation uses the flow of air into and out of a working environment to dilute contaminants by fresh air. The required fresh air can be supplied by natural or mechanical ways. Dilution ventilation may not be sufficient to control exposure to welding emissions, because it cannot provide enough air movement to prevent the entry of fumes and gases into the welder's breathing zone before removing them from welding environment. In fact, the general ventilation is not suitable for controlling the toxic substances, specially when the worker is downstream of contaminant. To ensure the efficiency of the system, measuring airflow regularly and sampling contaminants to assess exposure are required. A well designed dilution system can be approprite for situations in which welding is done on clean, uncoated, mild steels. In dilution ventilation, draft fans or air-movers, wall fans, roof vents, open doors and windows may be used to move air through the work environment. Totally, if the generated contaminant is in low concentration and can be controlled to the standard exposure level, dilution systems will be effective enough as a control measure.

Local Exhaust Ventilation - Local exhaust ventilation (LEV), as a primary engineering control, is used to remove contaminants before entering the breathing zone of workers. LEV can be used to control welding emissions close to the generation source. To be effective, LEV system should be well designed and installed, used correctly and properly maintained. Type of generated contaminants and characteristics of the process and work environment are crucial to design LEV. To design a suitable system in welding process, some parameters should be considered, such as fume generation rate, arc- to-breathing zone distance, work practices and worker's exposure. Various parameters related to type of welding have important roles in the fume generation rate and fume composition. Therefore, considering these parameters is necessary to design LEV system.

For welding processes like stainless steel or plasma arc welding in which fumes containing heavy metals are generated, the LEV system can effectively be used to control worker's exposure. A local exhaust ventilation consists of a hood, fan, duct, and air cleaner. All parts of LEV system must be designed according to correct rules and requirements to remove air pollutants with appropriate efficiency. For instance, the ducting material and structure, air velocity through ducts, the number of branches, and the probability of the leakage and corrosion are important factors related to duct that can affect the LEV system. There are some considereations to select a suitable fan for the system. Some variables such as pressure, flow rate, power, noise, and rotation speed are the main characteristics influencing on the fan performance. Air cleaner is a device to capture welding emissions before it can escape into the ambient air. To select an appropriate air cleaner, some design considereations need to be addressed. Size and shape of welding space, pollutants generation rate, pollutant composition, cost of devices, process type, and the availability of equipment may be effective factors in this respect. In welding processes, source capture systems can be the ideal choise to control fume contaminants using the least air flow rate. In some situations, a source capture system cannot be used. For example situations in which worker has to work on mobile positions; there are a large number of small welding points producing hazardous emissions; welding must be done in confined spaces; and there are some obstructions like overhead cranes leading to problems with ducting installation. Dust collectors (filtration units) and electrostatic precipitators (ESP) can also be used as air cleaners to capture welding emissions before escaping into the environment. ESPs are ideal to collect submicron particles, especially in carbon steel welding. Although the efficiency of ESP is lower than filtration system, it needs very little maintenance and also there is no cost for filter replacement. ESPs are not recommended for stainless steel welding.

Some general considereations should be addressed to design a LEV system. Ducting system should be resistant to the captured emissions; the risks of contaminants accumulation and fire propagation in ducting system should be taken into account; exhausted air containing welding emissions should not be discharged where other workers or people are present; any draught from open doors or windows should be considered because of interference with hood performance. In addition, a maintenance program is required to ensure that control measures remain effective. For instance, regular inspections of LEVsystems should be carried out to check their effectiveness. As an other maintening plan, periodic air monitoring is done to ensure the system has proper performance. Therefore, as well as correct and completed design of LEV system, other elements like employee training, proper use, cleaning, and maintenance are required to achieve the effective protection.

Portable Systems - In some situations, portable systems may be used. These systems are used where welding is infrequently performed and the existing sysrem can be shared between working stations. Also, small mobile units may be used in confined spaces where installing the usual systems is not practical. In these cases, installing the hood close to the emissions point of origin, the hood placement and its distance from the source of welding emissions should be considered. Adequate ventiltion is essential in confined spaces, because the accumulation of hazardous emissions may lead to oxygen deficiency and also adverse effects related to generated fumes and gases. Commercially, there are different portable ventilation systems to use in confined spaces. Flexible air ducts and different kinds of portable fans are available for a variety of ventilation applications. In general, approximately 10 air exchanges per hour should be provided by ventilation in confined spaces. The volume of space and the flow rate of fan determine the time of each exchange. Before entry into the confined space for welding, that space should be ventilated for a minimum of five minutes. It is important to select a proper fan with enough capacity and position it in correct place. Some related organizations have provided procedures and instructions related to working in confined spaces, including ventilation equipment, confined spaces entry, emergency action plan, permit forms, and other requirements for working in these spaces.

7.4. Respiratory protection equipments

Personal protective equipment (PPE) should not be used instead of other control measures, but sometimes they may be required along with engineering controls and safe work practices. Respiratory Protection Equipments (RPEs) are used to protect the workers against inhalation of hazardous emissions in the workplace, where exposures cannot adequately be controlled by other ways.

Using a respirator not selected appropriately leads to a false sense of protection for wearer and exposure to hazardous substances. It must be specific to the pollutant and fitted, cleaned, stored and maintained based on provided standards and guidelines for respirators. Each RPE has a protection factor (PF) that is determined as the ratio of the concentration of the pollutant outside the respirator to that inside the respirator. There is a wide range, from low to high, for protection factors. Some organizations like NIOSH have provided required equations and tables to calculate protection factors for respirators. There are different types of respirators and it is possible to select the most appropriate type for existing circumstances. In welding processes, respirators should be selected in accordance with generated emissions, welding type, welding task, and working conditions. For example, NIOSH recommends a self-contained breathing apparatus for welding in confined spaces because the oxygen concentration in the space may be reduced due to welding. Also, a combination of particulate/vapour respirator may be used because of the generation of both of fumes and gases during welding. A standard program is needed for using raspiratory protection devices. Some requirements are followed in this program including hazard assessment, selecting the appropriate respirators in respect of pollutants, respirator fitting test, worker training on how to use respirator correctly, inspection and maintenance of respirator, and recordkeeping. There are two types of RPE. The first type is respirators that clean workplace air before being inhaled and the second type is air-supplied respirators in which air supply is separate from workplace atmosphere. Totally, the suitable RPE for welding processes should be selected by an expert and based on fume concentration, presence of toxic gases, and the probability of oxygen deficiency.

Selecting air-purifying respirators with correct filtration cartridge results in protection of welders from low levels of metal fumes and welding gases.

8. Conclusion

Air pollution is contamination of the indoor or outdoor environment, leading to changes in the natural characteristics of the atmosphere. In all welding processes, various types of air pollutants are generated. Air pollutants created by welding include fumes and gases whose composition and emission level depend on some factors such as the welding method, welding parameters (current, voltage, shielding gas and shielding gas flow), base metal and other consumables. Exposure to excessive levels of fume and gases can cause different adverse health effects on workers. Since a large number of workers are exposed to welding emissions and also the generated pollutants have negative impacts on environment, a risk assessment program is required to protect workers and environment by suitable procedures. In an effective program, worker's safety and health is considered by management as a fundamental value.Taking different precautions can improve the welder's work situation. There are various techniques for evaluating and monitoring welding pollutants in air samples and biological matrices and also different procedures for their control. Selecting the proper engineering controls can lead to protection of workers and environment. During the risk assessment program and selection of control measures, it is necessary to consider nanoparticles emitted by welding operations. Particle sizes and size distributions of welding emission are critical to determine the efficient control devices. In some cases, breathing zone protection can be used. Health hazards can be reduced by choosing a correct welding helmet and by using the proper shielding gas and welding parameters. It is worth mentioning that proper information should be provided for workers about hazards of their tasks. The welder should be informed of operating techniques and all procedures that reduce welding fumes. The training programs should be included proper ways to perform tasks and proper work practices to reduce fumes. This program includes safety training, monitoring the good safety practices and good environmental practices. Also, the respirator and cartridge selection, fit-testing and respirator maintenance and storage are considered in a suitable training program. Furthermore, employers must be informed about industrial hygiene programs at workplaces and quantitative risk assessment for workers exposed to hazardous compounds. In recent years, different organizations have focused on climate change and environmental impacts of all industrial activities including welding. Various laws, instructions, and guidelines have been provided for protecting the air, environment, and water. Employers are responsible for the purchase of proper welding equipment to meet environmental requirements and choose more environmentally friendly processes.

Incident Investigation

What is an incident and why should it be investigated?

The term incident can be defined as an occurrence, condition, or situation arising in the course of work that resulted in or could have resulted in injuries, illnesses, damage to health, or fatalities.

The term "accident" is also commonly used, and can be defined as an unplanned event that interrupts the completion of an activity, and that may (or may not) include injury or property damage. Some make a distinction between accident and incident. They use the term incident to refer to an unexpected event that did not cause injury or damage that time but had the potential. "Near miss" or "dangerous occurrence" are also terms for an event that could have caused harm but did not.

Please note: The term incident is used in some situations and jurisdictions to cover both an "accident" and "incident". It is argued that the word "accident" implies that the event was related to fate or chance. When the root cause is determined, it is usually found that many events were predictable and could have been prevented if the right actions were taken - making the event not one of fate or chance (thus, the word incident is used). For simplicity, we will now use the term incident to mean all of the above events.

The information that follows is intended to be a general guide for employers, supervisors, health and safety committee members, or members of an incident investigation team. When incidents are investigated, the emphasis should be concentrated on finding the root cause of the incident so you can prevent the event from happening again. The purpose is to find facts that can lead to corrective actions, not to find fault. Always look for deeper causes. Do not simply record the steps of the event.

Reasons to investigate a workplace incident include:

- most importantly, to find out the cause of incidents and to prevent similar incidents in the future
- to fulfill any legal requirements
- to determine the cost of an incident
- to determine compliance with applicable regulations (e.g., occupational health and safety, criminal, etc.)
- to process workers' compensation claims

The same principles apply to an inquiry of a minor incident and to the more formal investigation of a serious event. Most importantly, these steps can be used to investigate any situation (e.g., where no incident has occurred ... yet) as a way to prevent an incident.

Who should do the investigating?

Ideally, an investigation would be conducted by someone or a group of people who are:

- experienced in incident causation models,
- experienced in investigative techniques,
- knowledgeable of any legal or organizational requirements,
- knowledgeable in occupational health and safety fundamentals,
- knowledgeable in the work processes, procedures, persons, and industrial relations environment for that particular situation,
- able to use interview and other person-to-person techniques effectively (such as mediation or conflict resolution),
- knowledgeable of requirements for documents, records, and data collection; and
- able to analyze the data gathered to determine findings and reach recommendations.

Some jurisdictions provide guidance such as requiring that the incident must be conducted jointly, with both management and labour represented, or that the investigators must be knowledgeable about the work processes involved.

Members of the team can include:

- employees with knowledge of the work
- supervisor of the area or work

- safety officer
- health and safety committee
- union representative, if applicable
- employees with experience in investigations
- "outside" experts
- representative from local government or police

Should the immediate supervisor be on the team?

The advantage is that this person is likely to know most about the work and persons involved and the current conditions. Furthermore, the supervisor can usually take immediate remedial action. The counter argument is that there may be an attempt to gloss over the supervisor’s shortcomings in the incident. This situation should not arise if the incident is investigated by a team of people, and if the worker representative(s) and the investigation team members review all incident investigation findings and recommendations thoroughly.

Why look for the root cause?

An investigator or team who believe that incidents are caused by unsafe conditions will likely try to uncover conditions as causes. On the other hand, one who believes they are caused by unsafe acts will attempt to find the human errors that are causes. Therefore, it is necessary to examine all underlying factors in a chain of events that ends in an incident.

The important point is that even in the most seemingly straightforward incidents, **seldom, if ever, is there only a single cause**. For example, an "investigation" which concludes that an incident was due to worker carelessness, and goes no further, fails to find answers to several important questions such as:

- Was the worker distracted? If yes, why was the worker distracted?
- Was a safe work procedure being followed? If not, why not?
- Were safety devices in order? If not, why not?
- Was the worker trained? If not, why not?

An inquiry that answers these and related questions will probably reveal conditions that are more open to correction.

What are the steps involved in investigating an incident?

First:

- Report the incident occurrence to a designated person within the organization.
- Provide first aid and medical care to injured person(s) and prevent further injuries or damage.

The incident investigation team would perform the following general steps:

- Scene management and scene assessment (secure the scene, make sure it is safe for investigators to do their job).
- Witness management (provide support, limit interaction with other witnesses, interview).
- Investigate the incident, collect data.
- Analyze the data, identify the root causes.
- Report the findings and recommendations.

The organization would then:

- Develop a plan for corrective action.
- Implement the plan.
- Evaluate the effectiveness of the corrective action.
- Make changes for continual improvement.

As little time as possible should be lost between the moment of an incident and the beginning of the investigation. In this way, one is most likely to be able to observe the conditions as they were at the time, prevent disturbance of evidence, and identify witnesses. The tools that members of the investigating team may need (pencil, paper, camera or recording device, tape measure, etc.) should be immediately available so that no time is wasted.

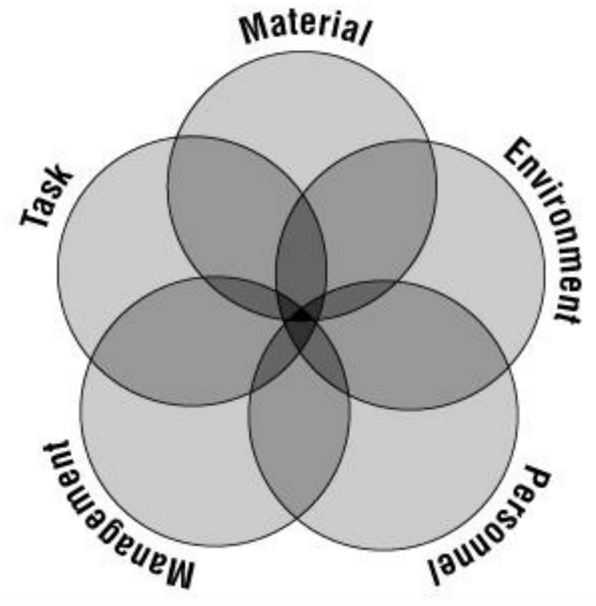
What should be looked at as the cause of an incident?

Causation Models

Many models of causation have been proposed, ranging from Heinrich's domino theory to the sophisticated Management Oversight and Risk Tree (MORT).

The simple model shown in Figure 1 attempts to illustrate that the causes of any incident can be grouped into five categories - task, material, environment, personnel, and management. When this model is used, possible causes in each category should be investigated. Each category is examined more closely below. Remember that these are sample questions only: no attempt has been made to develop a comprehensive checklist.

Figure 1: Incident Categories



Task

Here the actual work procedure being used at the time of the incident is explored. Members of the investigation team will look for answers to questions such as:

- Was a safe work procedure used?
- Had conditions changed to make the normal procedure unsafe?
- Were the appropriate tools and materials available?
- Were they used?
- Were safety devices working properly?
- Was lockout used when necessary?

For most of these questions, an important follow-up question is "If not, why not?"

Material

To seek out possible causes resulting from the equipment and materials used, investigators might ask:

- Was there an equipment failure?
- What caused it to fail?
- Was the machinery poorly designed?
- Were hazardous products involved?
- Were they clearly identified?
- Was a less hazardous alternative product possible and available?
- Was the raw material substandard in some way?

- Should personal protective equipment (PPE) have been used?
- Was the PPE used?
- Were users of PPE properly educated and trained?

Again, each time the answer reveals an unsafe condition, the investigator must ask **why** this situation was allowed to exist.

Work Environment

The physical work environment, and especially sudden changes to that environment, are factors that need to be identified. The situation at the time of the incident is what is important, not what the "usual" conditions were. For example, investigators may want to know:

- What were the weather conditions?
- Was poor housekeeping a problem?
- Was it too hot or too cold?
- Was noise a problem?
- Was there adequate light?
- Were toxic or hazardous gases, dusts, or fumes present?

Personnel

The physical and mental condition of those individuals directly involved in the event must be explored, as well as the psychosocial environment they were working within. The purpose for investigating the incident is **not** to establish blame against someone but the inquiry will not be complete unless personal characteristics or psychosocial factors are considered. Some factors will remain essentially constant while others may vary from day to day:

- Did the worker follow the safe operating procedures?
- Were workers experienced in the work being done?
- Had they been adequately educated and trained?
- Can they physically do the work?
- What was the status of their health?
- Were they tired?
- Was fatigue or shiftwork an issue?
- Were they under stress (work or personal)?
- Was there pressure to complete tasks under a deadline, or to by-pass safety procedures?

Management

Management holds the legal responsibility for the safety of the workplace and therefore the role of supervisors and higher management and the role or presence of management systems must always be considered in an incident investigation. These factors may also be called organizational factors. Failures of management systems are often found to be direct or indirect causes. Ask questions such as:

- Were safety rules or safe work procedures communicated to and understood by all employees?
- Were written procedures and orientation available?
- Were the safe work procedures being enforced?
- Was there adequate supervision?
- Were workers educated and trained to do the work?
- Had hazards and risks been previously identified and assessed?
- Had procedures been developed to eliminate the hazards or control the risks?
- Were unsafe conditions corrected?
- Was regular maintenance of equipment carried out?
- Were regular safety inspections carried out?
- Had the condition or concern been reported beforehand?
- Was action taken?

This model of incident investigation provides a guide for uncovering all possible causes and reduces the likelihood of looking at facts in isolation. Some investigators may prefer to place some of the sample questions in different categories; however, the categories are not important, as long as each question is asked. Obviously there is considerable overlap between categories; this overlap reflects the situation in real life. Again it should be emphasized that the above sample questions do not make up a complete checklist, but are examples only.

How are the facts collected?

The steps in the investigation are simple: the investigators gather data, analyze it, determine their findings, and make recommendations. Although the procedures are seemingly straightforward, each step can have its pitfalls. As mentioned above, an open mind is necessary in an investigation: preconceived notions may result in some wrong paths being followed while leaving some significant facts uncovered. All possible causes should be considered. Making notes of ideas as they occur is a good practice but conclusions should not be made until all the data is gathered.

Physical Evidence

Before attempting to gather information, examine the site for a quick overview, take steps to preserve evidence, and identify all witnesses. In some jurisdictions, an incident site must not be disturbed without approval from appropriate government officials such as the coroner, inspector, or police. Physical evidence is probably the most non-controversial information available. It is also subject to rapid change or obliteration; therefore, it should be the first to be recorded. Based on your knowledge of the work process, you may want to check items such as:

- positions of injured workers
- equipment being used
- products being used
- safety devices in use
- position of appropriate guards

- position of controls of machinery
- damage to equipment
- housekeeping of area
- weather conditions
- lighting levels
- noise levels
- time of day

You may want to take photographs before anything is moved, both of the general area and specific items. A later study of the pictures may reveal conditions or observations that were missed initially. Sketches of the scene based on measurements taken may also help in later analysis and will clarify any written reports. Broken equipment, debris, and samples of materials involved may be removed for further analysis by appropriate experts. Even if photographs are taken, written notes about the location of these items at the scene should be prepared.

Witness Accounts

Although there may be occasions when you are unable to do so, every effort should be made to interview witnesses. In some situations witnesses may be your primary source of information because you may be called upon to investigate an incident without being able to examine the scene immediately after the event. Because witnesses may be under severe emotional stress or afraid to be completely open for fear of recrimination, interviewing witnesses is probably the hardest task facing an investigator.

Witnesses should be kept apart and interviewed as soon as possible after the incident. If witnesses have an opportunity to discuss the event among themselves, individual perceptions may be lost in the normal process of accepting a consensus view where doubt exists about the facts.

Witnesses should be interviewed alone, rather than in a group. You may decide to interview a witness at the scene where it is easier to establish the positions of each person involved and to obtain a description of the events. On the other hand, it may be preferable to carry out interviews in a quiet office where there will be fewer distractions. The decision may depend in part on the nature of the incident and the mental state of the witnesses.

Interviewing

The purpose of the interview is to establish an understanding with the witness and to obtain his or her own words describing the event:

DO...

- put the witness, who is probably upset, at ease
- emphasize the real reason for the investigation, to determine what happened and why
- let the witness talk, listen
- confirm that you have the statement correct
- try to sense any underlying feelings of the witness
- make short notes or ask someone else on the team to take them during the interview

- ask if it is okay to record the interview, if you are doing so
- close on a positive note

DO NOT...

- intimidate the witness
- interrupt
- prompt
- ask leading questions
- show your own emotions
- jump to conclusions

Ask open-ended questions that cannot be answered by simply "yes" or "no". The actual questions you ask the witness will naturally vary with each incident, but there are some general questions that should be asked each time:

- Where were you at the time of the incident?
- What were you doing at the time?
- What did you see, hear?
- What were the work environment conditions (weather, light, noise, etc.) at the time?
- What was (were) the injured worker(s) doing at the time?
- In your opinion, what caused the incident?
- How might similar incidents be prevented in the future?

Asking questions is a straightforward approach to establishing what happened. But, care must be taken to assess the accuracy of any statements made in the interviews.

Another technique sometimes used to determine the sequence of events is to re-enact or replay them as they happened. Care must be taken so that further injury or damage does not occur. A witness (usually the injured worker) is asked to reenact in slow motion the actions that happened before the incident.

Other Information

Data can be found in documents such as technical data sheets, health and safety committee minutes, inspection reports, company policies, maintenance reports, past incident reports, safe-work procedures, and training reports. Any relevant information should be studied to see what might have happened, and what changes might be recommended to prevent recurrence of similar incidents.

What should I know when making the analysis and recommendations?

At this stage of the investigation most of the facts about what happened and how it happened should be known. This data gathering has taken considerable effort to accomplish but it represents only the first half of the objective. Now comes the key question - why did it happen?

Keep an open mind to all possibilities and look for all pertinent facts. There may still be gaps in your understanding of the sequence of events that resulted in the incident. You may need to re-interview some witnesses or look for other data to fill these gaps in your knowledge.

When your analysis is complete, write down a step-by-step account of what happened (the team's conclusions) working back from the moment of the incident, listing all possible causes at each step. This is not extra work: it is a draft for part of the final report. Each conclusion should be checked to see if:

- it is supported by evidence
- the evidence is direct (physical or documentary) or based on eyewitness accounts, or
- the evidence is based on assumption.

This list serves as a final check on discrepancies that should be explained.

Why should recommendations be made?

The most important final step is to come up with a set of well-considered recommendations designed to prevent recurrences of similar incidents. Recommendations should:

- be specific
- be constructive
- identify root causes
- identify contributing factors

Resist the temptation to make only general recommendations to save time and effort.

For example, you have determined that a blind corner contributed to an incident. Rather than just recommending "eliminate blind corners" it would be better to suggest:

- install mirrors at the northwest corner of building X (specific to this incident)
- install mirrors at blind corners where required throughout the worksite (general)

Never make recommendations about disciplining a person or persons who may have been at fault. This action would not only be counter to the real purpose of the investigation, but it would jeopardize the chances for a free flow of information in future investigations.

In the unlikely event that you have not been able to determine the causes of an incident with complete certainty, you probably still have uncovered weaknesses within the process, or management system. It is appropriate that recommendations be made to correct these deficiencies.

The Written Report

The prepared draft of the sequence of events can now be used to describe what happened. Identify clearly where evidence is based on certain facts, witness accounts, or on the team's assumptions.

If doubt exists about any particular part of the event, say so. The reasons for your conclusions should be stated and followed by your recommendations. Do not include extra material that is not required for a full understanding of the incident and its causes such as photographs that are not relevant and parts of the investigation that led you nowhere. The measure of a good report is quality, not quantity.

Always communicate your findings and recommendations with workers, supervisors and management. Present your information 'in context' so everyone understands how the incident occurred and the actions needed to put in place to prevent it from happening again.

Some organizations may use pre-determined forms or checklists. However, use these documents with caution as they may be limiting in some cases. Always provide all of the information needed to help others understand the causes of the event, and why the recommendations are important.

What should be done if the investigation reveals human error?

A difficulty that has bothered many investigators is the idea that one does not want to lay blame. However, when a thorough worksite investigation reveals that some person or persons among management, supervisor, and the workers were apparently at fault, then this fact should be pointed out. The intention here is to remedy the situation, not to discipline an individual.

Failing to point out human failings that contributed to an incident will not only downgrade the quality of the investigation, it will also allow future incidents to happen from similar causes because they have not been addressed.

However never make recommendations about disciplining anyone who may be at fault. Any disciplinary steps should be done within the normal personnel procedures.

How should follow-up be done?

Management is responsible for acting on the recommendations in the investigation report. The health and safety committee or representative, if present, can monitor the progress of these actions.

Follow-up actions include:

- Respond to the recommendations in the report by explaining what can and cannot be done (and why or why not).
- Develop a timetable for corrective actions.
- Monitor that the scheduled actions have been completed.
- Check the condition of injured worker(s).
- Educate and train other workers at risk.
- Re-orient worker(s) on their return to work.