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Linde

Fume and gases.

Contents.

Summary.

In all welding processes, air pollutants are created in the form of fume and gases. The fume consists mainly of metal oxides and is formed when metal vapour condenses and oxidizes. Gases are created due to the high temperature and ultraviolet radiation from the arc. Examples of hazardous gases formed in welding include ozone, nitrogen dioxide, nitric oxide and carbon monoxide. The level of emission of air pollutants and their composition depends on a number of different factors such as; welding method used, welding parameters, filler metal and surface coatings or contaminants on the base metal surface.

Air pollutants have different effects on man. In order to evaluate the hazards, many substances have hygienic threshold values. These values can be used in assessing the quality of the breathing air.

Introduction.

In gas metal arc welding, as with all other forms of welding, unless the proper precautions are taken the welder will probably be exposed to health hazards. Examples of health hazards related directly to the welding process are air pollutants (fume and gases), intensive arc radiation and in certain cases high levels of noise such as during pulsed-arc welding.

Other health hazards not directly associated with the welding process itself include noise, difficult and tiring work positions and draughts. By using protective clothing and equipment, local extraction and ergonomic aids, the welder can help reduce or totally eliminate these hazards.

The employer can also improve the situation by ensuring that the premises are well organized, that they incorporate adequate lighting and ventilation, that it is possible to separate the work stations by screens and that protective equipment and clothing are available.

The employer shall also make sure that personnel are well trained and are kept informed about the risks of the work they are doing.

This report deals with air pollutants formed during welding. It provides details on the composition of the air pollution, how it is formed and how levels and composition of air pollution can be affected by the welding method and by the welding parameters. In addition the report discusses the influence of air pollution on man, hygienic threshold values and various protective measures.

Air pollutants in welding.

In many welding processes, air pollutants are generated and take the form of dust, fume and gases. Dust includes particles which are larger than 1 μm in diameter (1). Dust particles fall in close vicinity to the arc and consist largely of welding spatter. By fume is meant particles less than 1 μm in size. These particles generally remain suspended in air and in that way can be carried long distances from the welding arc.

How is fume generated?
Fume particles consist mainly of oxides. Oxides are formed when the melted metal is vaporized in the arc and then condenses and oxidizes in contact with the surrounding air. Figure 1 shows conceivable sources of fume. In gas metal arc welding, it is the filler metal which is the main source of fume while the base metal contributes very little. In flux-cored arc welding, the flux in the wire also contributes to the formation of fume.

The composition of the fume depends on the yolatility of the alloying substances in the wire (2). The metal vapour found in the arc contains high levels of the most volatile of these substances. In addition, in welding with oxidizing gases, volatile oxides are also formed and incorporated in the vapour (3). When the vapour comes into contact with the surrounding air, fume is formed through condensation and oxidation. The composition of welding fume corresponds more or less directly with the chemical composition of the wire.

Spatter is a major factor in the formation of welding fume (2). The many small particles of spatter cause the total area from which vaporization takes place to increase. In addition, some of the spatter is also so small that it can remain suspended in air and is thus considered fume particles.

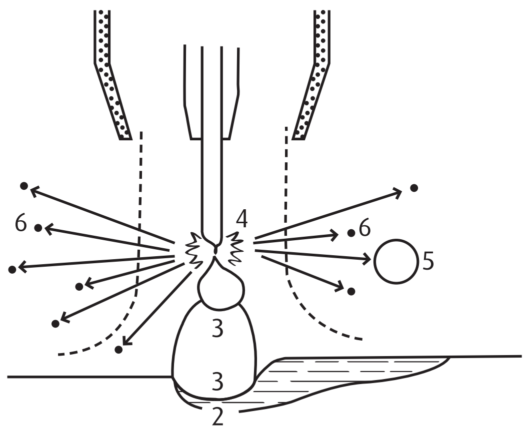

Fig 1. Sources of fume gas metal arc welding (2). 1. Droplet at of wire or during transfer. 2. Weld pool. 3. Electrode spots and anode). 4. Exploiding wire. 5. Large particles. 6. Fine metal droplets ejected by wire explosion.

Air pollutants in welding.

How are the gases formed?
During gas metal arc welding, the main causes of gas formation are the extremely high temperatures and the ultraviolet radiation emitted by the arc.

Nitric oxide, NO, and nitrogen dioxide, $N0_2$, (nitrogen oxides) are formed from oxygen and nitrogen in the surrounding air. When they come in contact with the hot arc or with the hot base metal, the following reactions take place:

$N_2 + O_2 \quad 2NO$
$2NO + O_2 \quad 2NO_2$

Ozone, O_3, is formed from the oxygen in the air as follows:

$3O_2 \quad 2O_3$

The ultraviolet radiation from the arc decomposes the oxygen molecules into free oxygen atoms. These atoms react with other oxygen molecules and form ozone molecules. Ultraviolet radiation in the 130 175 nm wavelength band is the main source of ozone formation (4). Most of the ozone forms in close proximity to the arc. The ozone is carried away from the arc in the hot plume of fume and gases which rises from the welding spot and this can be hazardous to the welder. See Figure 2.

The emitted level of ozone depends on how much ozone is formed and how much will dissipate in various ways. There are three main mechanisms which may cause the elimination of ozone:
Catalytic reactions between ozone and fume particulate. Weld fume can thus reduce the level of ozone. Chemical reaction between nitric oxide and ozone as follows:

$NO + O_3 \quad NO_2 + O_2$

During processes in which large amounts of nitrogen
oxides are formed, such as manual metal arc welding, the total amount of ozone formed is negligible. In gas metal arc welding, far lower levels of nitrogen oxides are formed, and as a result the emitted levels of ozone are much higher.

Thermal decomposition of ozone. This takes place in the zone extremely close to the arc where the temperature is 500°C or higher.
Carbon monoxide, CO, is formed mainly through the dissociation of car bon dioxide, CO_2, from the shielding gas as follows:

$2CO_2 \quad 2CO + O_2$

Gases can also be formed when surface coatings or contaminants come in contact with hot surfaces or ultraviolet radiation.

Fig 2. Rising plume of fume and gases from weld spot.

Effects on human beings.

People are exposed to the effects of many different chemical substances. In order to reduce the hazards, enormous efforts have been devoted to assessing the toxicity of these substances and defining hygienic threshold limit values.

A hygienic threshold limit value is the highest permissible concentration of a substance in the breathing air. Levels which fall below the threshold limit values represent little hazard to people. However, threshold limit values do not represent strict boundaries between hazardous and un-hazardous levels of a substance.

There are two types of hygienic threshold limit value: time weighted averages and ceiling threshold limit values. These are specified as concentrations by weight, such as mg/m3, or concentrations by volume, for example ml/m3 or ppm (parts per million).

The time weighted average, TWA, specifies the maximum permissible average level of an air pollutant in the breathing zone during a working day. This value may be exceeded during brief periods. In some countries there are recommendations, short-term values, stipulating how far these threshold limit values can be exceeded. Threshold limit value lists contain regulations on how to calculate short-term values.

For fast-acting , particularly hazardous substances, there are ceiling limit values which specify the maximum permissible average concentration of a substance over a brief period of time, usually 15 minutes. The ceiling limit value may never be exceeded.

The threshold limit values are used to determine the quality of the air at workplaces and also to plan and determine the size of ventilation systems. One of the goals in designing ventilation systems is to reduce levels well below the threshold limit values.

Table 1 presents the limit values for various substances which can occur in conjunction with welding.

In conducting an assessment of the measurement results from work places, it is important to remember that several substances are present simultaneously in the breathing zone. In many countries, including Sweden, the equation given below is used to assess the effects of the substances which have similar medical effects on the human body:

$$\frac{C1}{G1} + \frac{C2}{G2} + \frac{C3}{G3} + \ldots \leq 1$$

C stipulates the measured concentration of each substance and G stipulates the threshold limit value. In the breathing zone, the sum of the quotients should be less than 1.

Examples of substances which produce similar medical effects are ozone and nitrogen dioxide, while nitric oxide affects people in an entirely different way.

Examples of threshold limit values in Sweden.

	TWA ppm	TWA mg/m^3	CTLV ppm	CTLV mg/m^3
Beryllium and compounds	–	0,002	–	–
Cadmium and non-org. compounds	–	0,02	–	–
Calciumoxide	–	2	–	–
Carbondioxide	5000	9000	–	–
Carbonmonoxide	35	40	–	–
Chromium (chromates and chromic acid)	–	0,02	–	–
Copper and non-org. compounds	–	0,2	–	–
Fluorides	–	2	–	–
Hydrogen phosphide	0,3	0,4	–	–
Iron oxide	–	3,5	–	–
Lead and non-org. compounds	–	0,05	–	–
Manganese and non-organic compounds	–	1	–	–
Molybdenum and compounds	–	5	–	–
Nickel oxide	–	0,1	–	–
Nitrogen dioxide	2	4	5	10
Nitric oxide	25	30	–	–
Phosgene	–	–	0,05	0,2
Ozone	0,1	0,2	–	–
Silicon dioxide compounds	–	0,1	–	–
Zinkoxid	–	5	–	–

For a complete information, see ref. 14
(TWA=Time Weighted Average, CTLV=Ceiling Threshold Limit Value).

Effects of different air pollutants.

Some air pollutants can cause acute (sudden) as well as chronic (long-term) illnesses. Acute illnesses such as metal fume fever are usually transitory in nature. However, they can develop into chronic ailments.

Sometimes a single exposure to a substance can be enough to trigger the outbreak of an illness. In other cases, it could take many years between exposure and outbreak. It is also known that various substances, when combined, can produce a synergistic effect. In other words the health hazard of the combination is many times greater than the sum of the hazards of the substances individually.

Illnesses or conditions which could possibly arise as a result of the inhalation of excessive levels of fume and gases, include breathing difficulty, anemia, cancer, emphysema, headache, chronic bronchitis, pulmonary edema, metal fume fever and irritation of the mucous membranes.

In addition, the skeleton, the central nervous system, the blood, kidneys and liver can also suffer damage. (Most of these terms are explained in more detail under the heading ”Medical terminology”.)

In normal welding conditions, with proper ventilation and appropriate precautions, the welder should not be exposed to any serious health hazards. The number of welders who have suffered injury as a result of fume and gases has never been established because there are no clear statistics. The picture is further complicated by the fact that some substances do not cause problems until well into the future.

Welding fume.

Most particles in welding fume are extremely small, usually less than 0.5 µm in diameter. As a they can enter the lungs and damage the pulmonary vesicles. Some substances are enriched in the lungs which can eventually lead to the occurrence of more or less serious changes or conditions.

Below is a brief list of the most common substances in weiding fume and the effects they have on people. The threshold limit values for these substances are given in Table 1.

Barium, Ba.
There is no set Swedish threshold limit value for barium. Inhaling fume which contains barium oxide causes considerable irritation in the nose and throat. In addition it can lead to nausea. vomiting, diarrhea. stomach pains and also the risk of heart problems, muscle fatigue and cramps.

Beryllium, Be.
Beryllium is a highly toxic substance both in its metallic form and as a compound. for example as beryllium oxide in weld fume. Beryllium is present mainly in certain copper alloys and can cause a dangerous lung condition, berylliosis.

Cadmium, Cd.
Cadmium is a highly toxic substance. Cadmium oxide occurs in the welding fume during welding of cadmium-plated material, which is material that has been coated with cadmium as a corrosion protection. The symptoms of cadmium poisoning are breathing difficulty, dryness in throat, cough, chest pains and metal fume fever. These problems do not usually appear until a day or more after exposure. A person exposed repeatedly to cadmium can suffer pulmonary edema and possibly also emphyzema. The liver and kidneys can also be affected.

Calcium, Ca.
Calcium occurs in welding fume in the form of oxides in conjunction with manual metal arc welding with basic electrodes and flux-cored arc welding with basic flux as a filler material. At high concentrations calcium oxide can irritate the mucous membranes, but is not a direct health hazard during welding.

Chromium, Cr.
During the welding of chrome-alloyed steel, such as stainless steel, trivalent and hexavalent chromium are formed through oxidation. Both forms produce irritation of the mucous membranes, metal fume fever and they also affect the respiratory passages and the lungs. Hexavalent chromium is also considered to increase the risk of cancer. Hexavalent chromium is mainly formed during welding with coated electrodes.

Copper, Cu.
Copper is present both in the base metal and the filler metal. Inhalation of copper fume can cause metal fume fever and a lung condition called copperosis.

Fluoride, F.
Fluorine compounds or fluorides, are mainly formed during welding with basic coated electrodes. These compounds can also occur in conjunction with flux-cored arc welding if the flux is basic. Inhalation of fluorides can cause minor irritation of the respiratory passages and acute or chronic general poisoning. Only in confined or poorly-ventilated spaces is there a risk that the threshold limit value will be exceeded.

Iron, Fe.
Iron oxide occurs in the weld fume in conjunction with the welding of all iron metals. Exposure to iron oxide over an extended period of time can in individual cases lead to a lung condition called siderosis. On an X-ray, this resembles silicosis, but it is not as dangerous. Siderosis does not affect the health and as soon as exposure to iron oxide ceases, the lung condition does not continue to progress as it does in the case of silicosis.

Lead, Pb.
Lead is not present in large amounts in arc welding fume except in the case of the welding of certain surface-coated material. Lead may be present as a compound in the insulation of coated electrodes. Inhalation of lead fume can in symptoms such as headache, faintness, muscle pains, cramps, loss of appetite and loss of weight. At high con-centrations there is a risk of anemia and the loss of memory.

Magnesium, Mn.
Magnesium occurs as an alloying element in steel and welding electrodes. Weld fume containing high concentrations of magnesium oxide is toxic. Symptoms of magnesium poisoning include irritation of the mucous membranes, shaking, stiffness in muscles, faintness and disruption of mental capacities. The nervous system and respiratory passages can also be attacked. Magnesium can also cause metal fume fever.

Molybdenum, Mo.
Breathing fume containing molybdenum can irritate the respiratory organs. Long-term, repeated exposure to molybdenum can cause aches in joints and affect the liver.

Nickel, Ni.
Nickel occurs mainly in stainless steel. Nickel oxide in welding fume can cause metal fume fever. Nickel is also suspected to be a carcenogenic.

Silicon, Si.
Some forms of silicon dioxide (quartz) can cause silicosis. However, there is no evidence that these forms of silicon dioxide occur in welding fume in hazardous concentrations.

Zinc, Zn.
Zinc oxide fume is formed during the welding of galvanized plate. Insulation of zinc can lead to metal fume fever.

Gases.

The gases with here are toxic and/or asphyxiating. They are either formed during welding or they are an element in the shielding gas. The threshold limit values for the different gases are given in Table 1.

Carbon monoxide, CO.
Carbon monoxide is a dangerous gas which is odourless and colourless. It occurs mainly in connection with welding in confined, poorly-ventilated spaces in which high concentrations of the gas can occur. Carbon monoxide prevents oxygen transport in the blood. Carbon monoxide poisoning leads to fatigue, headache, heart pain, difficulties in concentrating and eventually unconsciousness.

Nitrogen dioxide, NO_2, and nitric oxide, NO.
At concentrations above 15 ppm, nitrogen dioxide can cause irritation to the eyes and cause the eyes to water. Higher concentrations can lead to acute bronchitis, lung fibrosis or pulmonary edema. The two latter conditions can be life-threatening, but in most cases the patient's lung functions are recovered. Symptoms of poisoning include violent coughing, wheezing, wretching, nausea and loss of breath. These symptoms do not appear until between three and 30 hours after exposure.

Ozone, O_3.
Ozone is a colourless, toxic gas. Ozone affects the mucous membranes, mainly in the respiratory passages. Symptoms of ozone include itching or burning in the throat, coughing, chest pain and wheezing.

Phosgene, $COCl_2$.
In concentrations above 10 ppm phosgene causes a burning sensation in the mouth and throat. It also produces chest pains and vomiting. Inhaling phosgene chloride can lead to pulmonary edema.

Phosphine, PH_3.
Phosphine is a highly toxic gas. It causes irritation to the eyes, nose and skin. Inhalation of the gas can cause diarrhea, fatigue and headache. The gas can be fatal in concentrations above 100 ppm. Phosphine can also affect the nervous system and kidneys.

Measurement and measuring units.

When measuring emission, the level of a given substance produced per time unit is measured. Welding trials are usually performed in some sort of a chamber. A given air flow is drawn through the chamber. The fume is collected in a filter and weighed. Fume emission is specified in, for example, g/min. After weighing, the collected fume can be chemically analyzed in order to determine its composition. Concentrations of the different gases are measured using special instruments. The level of emission can be determined by multiplying the concentration of the gas bythe flow ofairandthis isgiven as, e. g., ml/min.

When conducting hygienic comparisons of different welding methods, the term dilution ratio is used. This unit is also called NHL (Nominal Hygienic Air demand, L stands for the Scandinavian and German word ”Luft” for air). Dilution ratio is the theoretical amount of air needed to dilute contaminants down to the hygienic threshold limit level. This value is obtained by dividing the measured emission value by the threshold limit value for the substance in question.

Measurements can also be conducted in the form of concentration mea surements at a fixed point next to the rising plume of fume and gases. Results of these measurements can be misleading, however, because they depend on the position of the measurement point in relation to the plume. The position of the plume and its shape are largely determined by air movements, type of shielding gas and shielding gas flow. For example, air velocities of 0.1 - 0.2 m/s are sufficient to shift the plume to one side or other.

The influence of various factors on emissions.

The emission of air pollutants during welding as well as the composition of the air pollutants depends on a number of different factors. In addition to the weiding method, the following factors also are essential:

- Welding parameters (current, voltage, shielding gas and shielding gas flow)
- Base and filler metal
- Coating or contaminants on surface of plate

In this chapter, the effects of these factors will be discussed in more detail.

MIG/MAG welding.

In MIG/MAG welding (gas metal arc welding), the main source of fume emission is the filler metal. The base metal has a negligible effect, as long as it does not contain substances which are highly volatile or possess some form of coating which is vaporized during welding.

Fume emission is a complex function of the welding parameters and the shielding gas. The higher the energy of the are, the higher the temperature and the greater the amount of metal vapour formed, which in turn forms welding fume. Several studies indicate, however, that fume emissions are not only a function of power, but is also affected by the form of metal transfer through the arc (3, 7). The form of metal transfer depends basically on current level, and the type of shielding gas used.

If low current/voltage is used, metal is transferred in short-circuiting drops, short-arc welding. Very little fume is formed. and is mainly a result of metal vaporization in connection with the short circuiting period. The stability of the arc is of major importance. An unstable arc produces more fume than a stable arc.

At somewhat higher current/voltage, the filler metal is transferred through the arc in the form of a mixture of non-short-circuiting drops and short-circuiting drops of varying size. This mode is called the globular transfer, Metal transfer is irregular and there is much spatter leading to fume formation. Welding result is poor.

It is possible to achieve good welding results in this zone with pulsed-arc welding and even to reduce fume emissions to levels as low as in TIG welding (6), or with 80% compared with short-arc welding of stainless steel (5). Pulsed-arc welding can, however, produce higher ozone emissions than conventional MIG/MAG welding.

Fume emission as a function of current level in MAG welding.

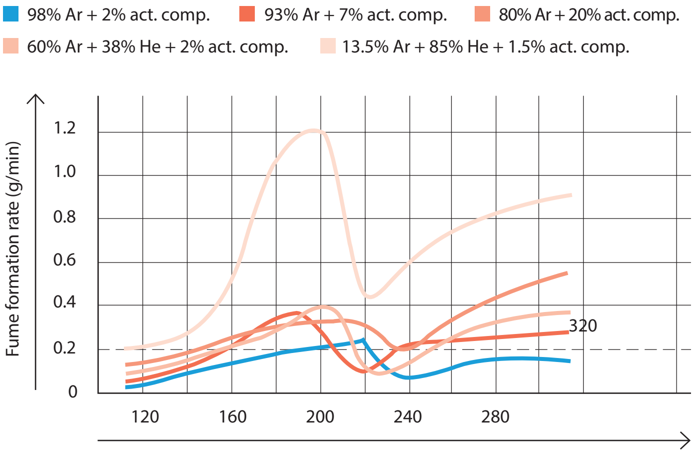

Fig 3. Fume emission as a function of current level in MAG welding of stainless steel with different shielding gases (7). – act. comp. = active components.

CO_2 shielding gas 0.045" E70S-2.

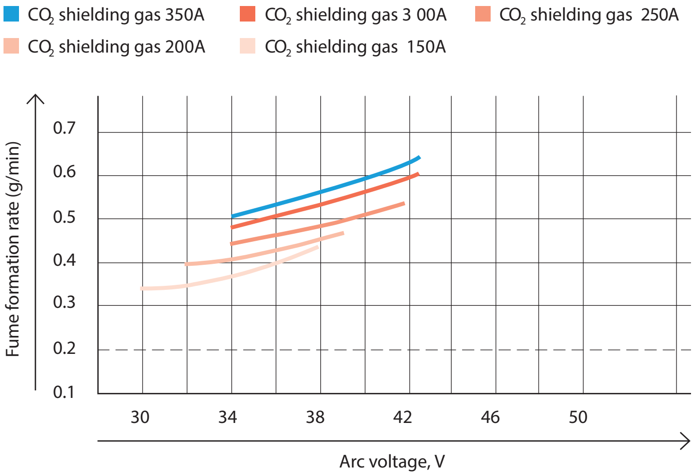

Fig 4. Effect of current and arc voltage on fume emissionin MAG welding of mild steel using carbon dioxide as the shielding gas (3).

MIG/MAG welding.

Increasing current and even more enables spray-arc transfer to be used. The molten metal is transferred in the form of small droplets which do not short-circuit the arc. In the transition from globular to spray transfer are, fume emission declines, reaching its lowest point just when a stable spray arc is established, see Fig 3. An additional increase in current/ voltage results in a formation of more fume again because the arc receives more power, causing more metal to be vaporized. The current level required to establish a spray arc depends on the type of electrode wire, wire diameter, arc stick-out and shielding gas used. Some shielding gases, containing more than 30% CO_2, do not allow a spray transfer arc at all.

This is why it is not possible to achieve a corresponding decrease in fume emission at higher current levels when CO2 is used as the shielding gas, see Fig 4.

The rate of shielding gas flow also affects fume emissions. If the gas flow rate is too high or too low, air can enter the arc causing an increase in fume emission.

Weld parameters affect not only the level of fume but also its composition. For instance, in MAG welding of stainless steel, the level of hexavalent chromium is lower during spray transfer arc welding than during short circuit arc welding or globular transfer welding. See Figure 5 (7, 8).

During MAG welding , lower levels of nitrogen oxides (NO and NO_2) are formed than during manual metal arc welding. The levels formed depend on the current. The higher the current the more nitrogen oxides are formed. Ozone emission (O_3) is highly dependent on the production of nitrogen oxides and fume as was previously discussed. The more nitrogen oxides and/or fume which are produced, the lower the ozone level.

Hexavalent chromium in fume.

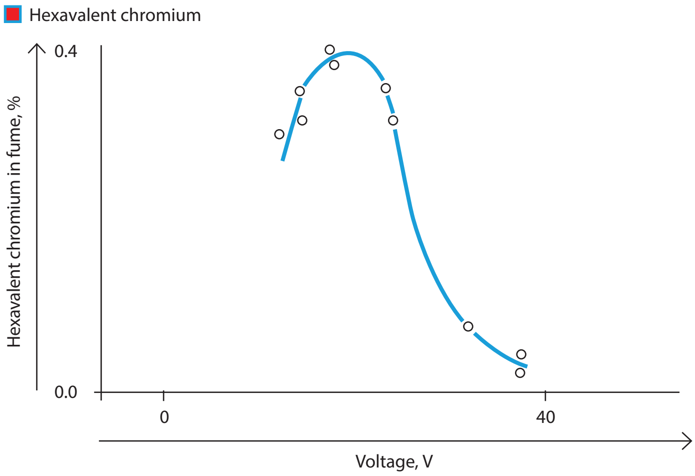

Fig 5. Level of hexavalent chromium as a function of arc voltage in MAG welding of stainless steel (8).

Flux-cored arc welding.

In flux-cored arc welding, the level of fume and its composition are highly dependent on the type of flux-cored electrode used. In other words, whether it contains flux or metal powder and whether it is designed for use with or without shielding gas. The gas-shielded, metal-powder cored wire electrodes produce the least amount of fume while the rutile cored electrodes generate slightly more fume.

The highest amounts of fume are generally produced by the self-shielded cored wire electrodes. These are the electrodes designed to be used without a shielding gas (11). Emissions of ozone and the nitrogen oxides are the same for MAG welding using solid wire electrodes, at least in the case of gas-shielded cored wire electrodes (6).

TIG welding.

During TIG welding (Tungsten Inert Gas welding), very little fume is generated. Nevertheless, the content of the fume must be taken into account. TIG welding is usually performed on high-alloy steel , and nickel or aluminium alloys. As a result the fume may contain oxides of chromium, nickel and copper, all of which have very low threshold limit values.

Of the air pollutants generated during TIG welding , ozone is the component which determines the required ventilation. However, surveys indicate that emissions of ozone and nitrogen oxides are frequently lower during TIG welding than in MIG/MAG welding. The amount of ozone and nitrogen oxides emitted during TIG welding depends on current, arc length and shielding gas flow, as well as on the type of shielding gas used.

Plasma arc welding.

The literature contains little information concerning air pollutants generated during plasma arc welding. This welding method is technically similar to TIG welding and the air pollutants are therefore probably of roughly the same magnitude.

The amount of ozone formed depends on the UV-radiation emitted from the are, which in turn is affected by the elements in the are, mainly metal vapour.

One example of this is aluminium vapour which leads to extreme radiation intensity in the ozone-generated wavelength range (4). On the other hand, MIG welding of aluminium produces large quantities of ozone. See Figure 6. When TIG welding aluminium, however, ozone emissions are lower. This is because welding is performed with alternating current and more nitrogen oxides are formed instead. Nitric oxide will keep the emitted ozone levels down.

Base and filler metals.

The main source of fume formation during welding is the filler metal. The base metal is of minor significance as long as it does not contain any highly volatile elements. How-ever, the choice of filler metal is largely dependent on the base metal used.

The alloying elements in the filler metal also are present in the welding fume. Electrode coatings can have an effect. Both solid wire electrodes and flux-cored electrodes can be coated with a copper film to improve current transfer. Some of the copper is vaporized during welding and copper oxides can thus be present in the fume. In the case of flux-cored arc welding, the flux also contributes to fume formation. In this case, the presence of barium oxides has been discovered in the welding fume. Barium is a highly toxic substance and are often used in self-shielded flux-cored electrodes (11). The purpose of the barium addition is to improve welding properties.

Ozone emission rate.

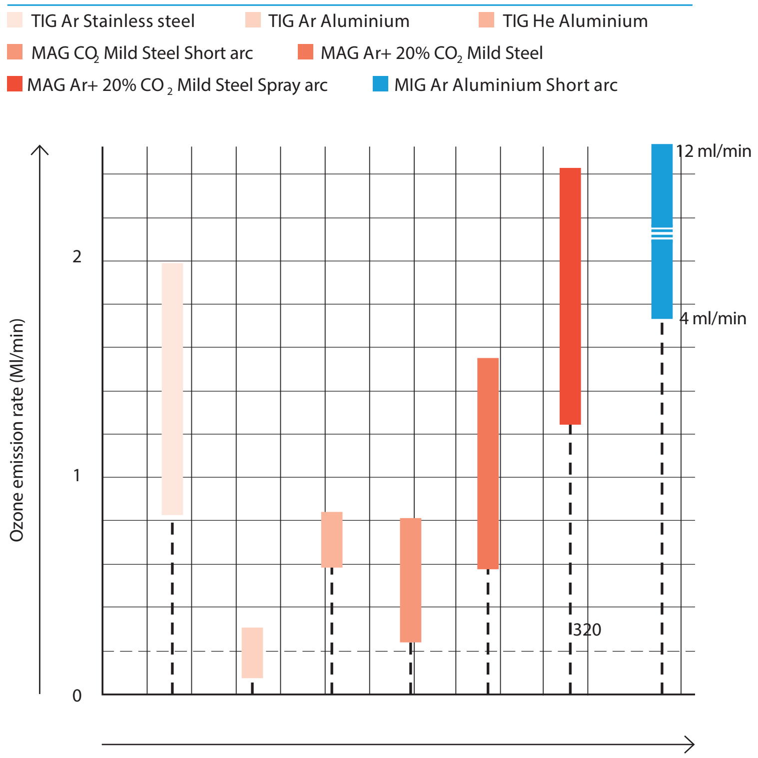

Fig 6. Emissions of ozone measured during welding trials in a laboratory (4).

Surface coatings.

In several cases the surfaces of material that will eventually be welded or cut are treated or finished mainly to provide corrosion protection. Surface coating processes include painting, enamelling, galvanizing, phosphating, cadium-plating or oiling. When surface-coated material is welded, hazardous fume or gases can form. As a result, surface coatings should be removed before welding. If this is not possible, adequate ventilation or local point extraction should be provided. Most surface coatings can be removed by blasting or grinding. Cadmium, however, should be removed chemically or in some other similar manner due to its high level of toxicity (12). The coating should be removed in an area of 25-50 mm on both sides of the joint. The wider zone is for higher current levels (200 A and higher). Below is a description of the most common surface coatings and the health hazards associated with them.

Phosphating
Phosphating is used to provide corrosion protection or a good base primer for painting. During welding of phosphated plate or sheet, phospine gas, PH3, is formed, which is extremely hazardous.

Galvanizing
Galvanizing is employed to provide good corrosion protection. During welding, zinc oxides form which can cause metal fume fever. Galvanized material is easy to confuse with cadmium-plated material.

Cadmium-plating
Cadmium-plating is also a corrosion protection. During the welding of cadmium-plated material, a fume is formed containing cadmium oxides. Breathing this fume, even in tiny amounts, can cause metal fume fever which could also lead to more serious illnesses. The strictest precautions must be taken during welding of cadmium-plated material. This should include the use of a respirator.

Other metal coatings
Other metal coatings which could also cause problems are chrome-plating and nickel-plating.

Paints and plastics
Paints can contain lead, chromium, zinc and in marine situations, mercury, and should therefore be removed before welding. Other plastic coatings should also be removed because they produce hazardous gases during welding. In many cases plastics also often contain metals. Examples of this are shop primers which are used to protect steel surfaces against corrosion. During the welding of primer-coated plate, zinc and iron oxides could form.

Surface contaminants.

The workpiece could be coated with a number of different contaminants such as rust and oil. Oil is decomposed during welding and vaporizes. However, there is no evidence that these gases become hazardous at the levels here.

Nevertheless, if only to prevent pores from forming in the weld, oil should be removed prior to welding.

One common method of doing this is using a solvent such as a chlorinated hydrocarbon. If this kind of solvent comes in contact with a hot surface or is exposed to ultraviolet radiation, dangerous phosgene gas, COCI2, is formed. For this reason, the solvent should not be allowed to come close to the arc. Surfaces to be welded should be dried long enough to ensure that all solvent has evaporated.

Precautions.

Any precaution is justified if it improves the working situation of the welder. A welder can avoid exposure to contaminants and pollutants which form during welding in a number of different ways. Examples of precautions include good general ventilation, local extraction, various forms of breathing protection, and good working position and use of a suitable shielding gas.

The type of precautions employed depends on whether the welding will be performed outdoors or indoors in confined areas, on the size of the workpiece and so on.

General ventilation.

For indoor welding, general ventilation should be sufficient to ensure that air pollutants are adequately diluted. An acceptable ventilation level for welding fume is 2 mg/m^3 (13). In large workshops with high ceilings, the natural air movements ensure that general ventilation is usually sufficient. Otherwise an additional ventilation system should be added.

Local extraction.

Wherever general ventilation is inadequate, local extraction should also be used in order to improve the situation of the welder. Positioning local extraction as close to the weld site as possible prevents the spread of contaminants throughout the workshop. See Figure 7. One of the advantages of local extraction is that less air is required for general ventilation.

The drawbacks of local extraction devices is that they can be difficult to use properly. In order to work, a local extraction device must be positioned close to the are, but then it might be in the way of the welder. In welding large objects, it must always follow the welding work. Local extraction is more suitable for working with smaller objects which are welded in a fixed working station.

Some welding equipment is available with a local extraction device installed on the welding gun. See Figure 8. However, this increases the weight of the gun, making it less manage-able. Also the extraction does not always work in all welding positions. Finally, powerful local extraction is inadvisable because it could disrupt shielding gas flow. This also applies to ordinary local extraction.

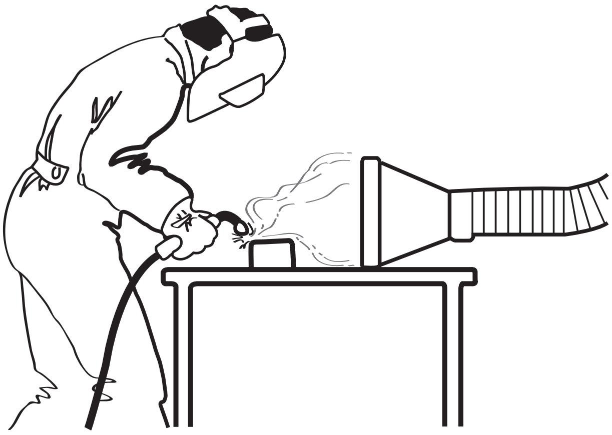

Fig 7. Example of local extraction.

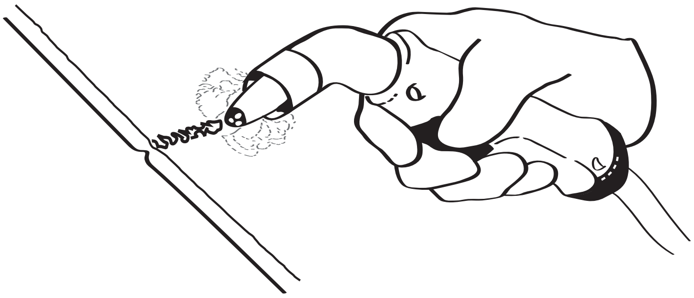

Fig 8. Local extraction on welding gun.

Breathing protection.

In special cases, some form of breathing protection can be employed. If the type of contaminant is known, a filter mask can be used. The filter only removes the fume while the gases pass through it. A welding helmet with an external air supply, see Figure 10, dilutes the contaminants in the welder's breathing zone.

For work in confined areas where there is a risk of asphyxiation, a respirator with an external air supply should be used. It is important to remember to provide the welder with suitable training in the use of all types of breathing protection.

Fig 9. Filter mask.

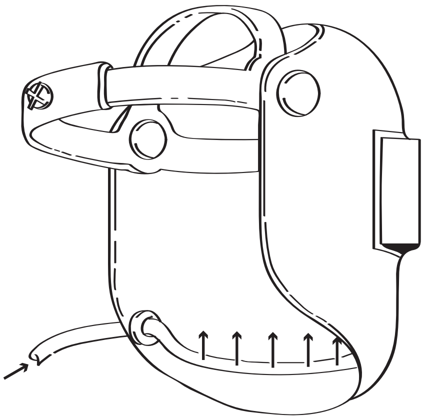

Fig 10. Welding helmet with supply of fresh air.

Other.

In the case of manual welding, the welder is positioned close to the arc and the plume of contaminants which from the weld site. As a result, the welder could inhale large amounts of fume and gases. By changing his working position and keeping his head out of the plume of fume and gases, the welder can help to reduce the health hazards. See Figure 11. During outdoor welding, the welder should be aware of the direction of the wind, and position himself accordingly. However, it is not advisable to use gas metal arc welding in high winds, because the wind disrupts the gas shield.

A properly designed welding helmet or shield considerably reduces the concentrations of air pollutants in the welder's breathing zone. The helmet or shield should cover the throat and parts of the chest (9). Exa - mples of recommended helmets and shields are shown in Figure 12, C and D.

The choice of shielding gas affects the level of contaminants. Carbon dioxide and other oxidizing gases cause the formation of more welding fume than if argon or helium is used as a shielding gas (2), Adding nitric oxide, NO, to argon reduces ozone levels during MIG/MAG and TIG wel- ding, (6). This reduction occurs as a result of the fast reaction between nitric oxide, NO, and ozone, O3, during the formation of nitrogen dio xide, NO2 and oxygen, O2, Nitrogen dioxide is also a hazardous gas but not as hazardous as ozone.

The choice of welding parameters also affects the level of contamination. A stable arc which does not produce spatter generates the least amount of fume. For this reason, the globular transfer zone should be avoided during MIG/MAG welding (2).

Fig 11. The welder should keep his head outside of the rising plume of air pollutants.

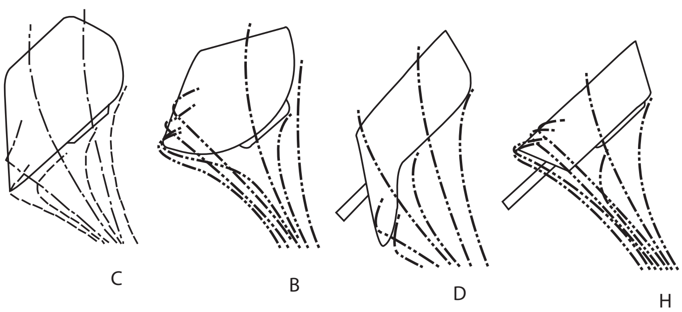

Fig 12. Various types of helmets and shields. Examples C and D provide the most efficient protection against air pollutants in the welder's breathing zone (15).

Medical terminology.

Acute

Acute is whenever a condition occurs suddenly, such as the sudden onset of an ailment or illness.

Allergy

By allergy is meant oversensitivity. An allergic reaction occurs when an allergic substance (an antibody) in the mucous membranes of the body reacts to some external substance (an antigen) which is foreign to the body. Allergies are apparently hereditary but people are not allergic to a substance from birth. For the antigen to cause formation of antibodies, contact with the substance is necessary over a period of time. Depending on the organ in which reaction between the antibody and the antigen takes place, various types of conditions can arise such as hay fever or eczema.

Anemia

Anemia is in quantitative or qualitative deterioration in the blood. Certain chemical substances such as lead can cause anemia.

Bronchitis

By bronchitis is meant an inflammatory process in the respiratory passages (bronchial tubes). Bronchitis can be acute or chronic and is often caused by a virus or bacteria. Chemical or mechanical irritation can also give rise to bronchitis. Experiments on animals have shown that the inhalation of ozone can produce bronchitis. Symptoms of bronchitis are sustained coughing and coughing-up of a yellow/white or pussy secretion.

Cancer

Cancer is a form of malignant tumor. A tumor can grow when the normal cell begins to multiply abnormally quickly. High concentrations of hexavalent chromium, which is formed during the welding of stainless steel, are carcinogenic. However, there is no evidence to indicate that welding causes cancer.

Chronic

Chronic is another word for long-term.

Emphysema

Emphysema is a sickness which results in a reduction in lung capacity. This causes a deterioration in blood circulation and also in oxygen exchange in the lungs. Symptoms include blueish lips, nails and mucous membranes and breathing difficulty. Long-term inhalation of ozone and cadmium can cause emphysema.

Lung conditions

Lung conditions caused by particulate are collectively known as pneumoconiosis. The various conditions are named after the particulate or dusts causing them such as aluminosis, copperosis, siderosis and silicosis.

Metal fume fever

Metal fume fever is a condition which manifests itself in much the same way as the flu. Symptoms are fever, shivers, sweating and nausea. These problems generally disappear after about 24 hours. Metal fume fever is caused by the inhalation of various metal oxides, usually zinc oxide, but also copper, magnesium, aluminium, iron, manganese and nickel.

Pulmonary edema

Acute pulmonary edema is caused when blood clogs the lungs substantially disrupting oxygen exchange. Symptoms include breathing difficulty and violent coughing with a discharge of pink, foaming liquid. Lips, nails and mucous membranes turn blue, indicating a low level of oxygen in the blood. This is a serious condition and requires immediate attention. Pulmonary edema can be caused by the inhalation of ozone, nitrogen oxides and cadmium.

Synergism

By synergism is meant a magnification of the simultaneous impact of toxic substances. The effect is thus greater than the sum of the effects of the individual substances. This is also called the multiplicative effect.

References.

1. Arbeitsschutz beim Schweißen. Deutscher Verlag für Schweißtechnik (DVS), GmbH, Düsseldorf, 1985.

2. Gray, C.N., Hewitt, P.J., Dare, P.R.M. New approach would help control weld fumes at source. Welding and Metal Fabrication, October 1982.

3. Heile, R. F., Hill, D. C. Particulate Fume Generation in Arc Welding Processes. Welding Research Supplement, July 1975.

4. The problem of ozone in gas-shielded arc welding. Linde AB. Report GM144e.

5. Eichhorn, F., Oldenburg, Th. Welding fumes emitted during welding of high-alloyed materials. International Conference on Hazards and Biological Effects of Welding Fumes and Gases, Copenhagen, February 1985.

6. E. Emission of fume and gases in gas metal arc welding. Linde AB, Internal report.

7. Hilton, D.E., Willingham, D.C. Some Aspects of Fume Emissions from MIG Welding Stainless Steel. Welding and Metal Fabrication, July 1986.

8. Gray, C.N., Hewitt, P J. Control of particulate emissions from electric arc welding by process modification. Ann. Occup. Hyg., Vol. 25, No 4, 1982.

9. Press, H., Florian, W. Formation of toxic substances in gas shielded arc welding. Welding in the World, Vol. 23, No 1/2 1985.

10. Beck Hansen, E. Luftförureningen ved synergisk MIG/MAG puls-svejsning af ulegeret stål. Afsnit 8 ur Synergisk puls MIG svejsning. Rapport: 85.28, Svejscentralen. Denmark.

11. Bengtsson, P. Self shielded flux cored wire welding. Linde AB. Internal report.

12. Health and safety in welding and allied processes. The Welding Institute, Abington Hall, Abington, Cambridge, CB1 6AL, 1983.

13. The facts about fume. The Welding Institute, Abington Hall, Abington, Cambridge, CB1 6AL, 1986.

14. Hygieniska gransvarden. (Hygienic limit values). AFS 1987:12, Arbetarskyddsstyrelsen, Sweden.

15. Farwer, A. Schutz vor Rauchen und Gasen beim Metall-Aktivgasschweiß – was ist in der Praxis zu beachten? Der Praktiker 6/84.

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