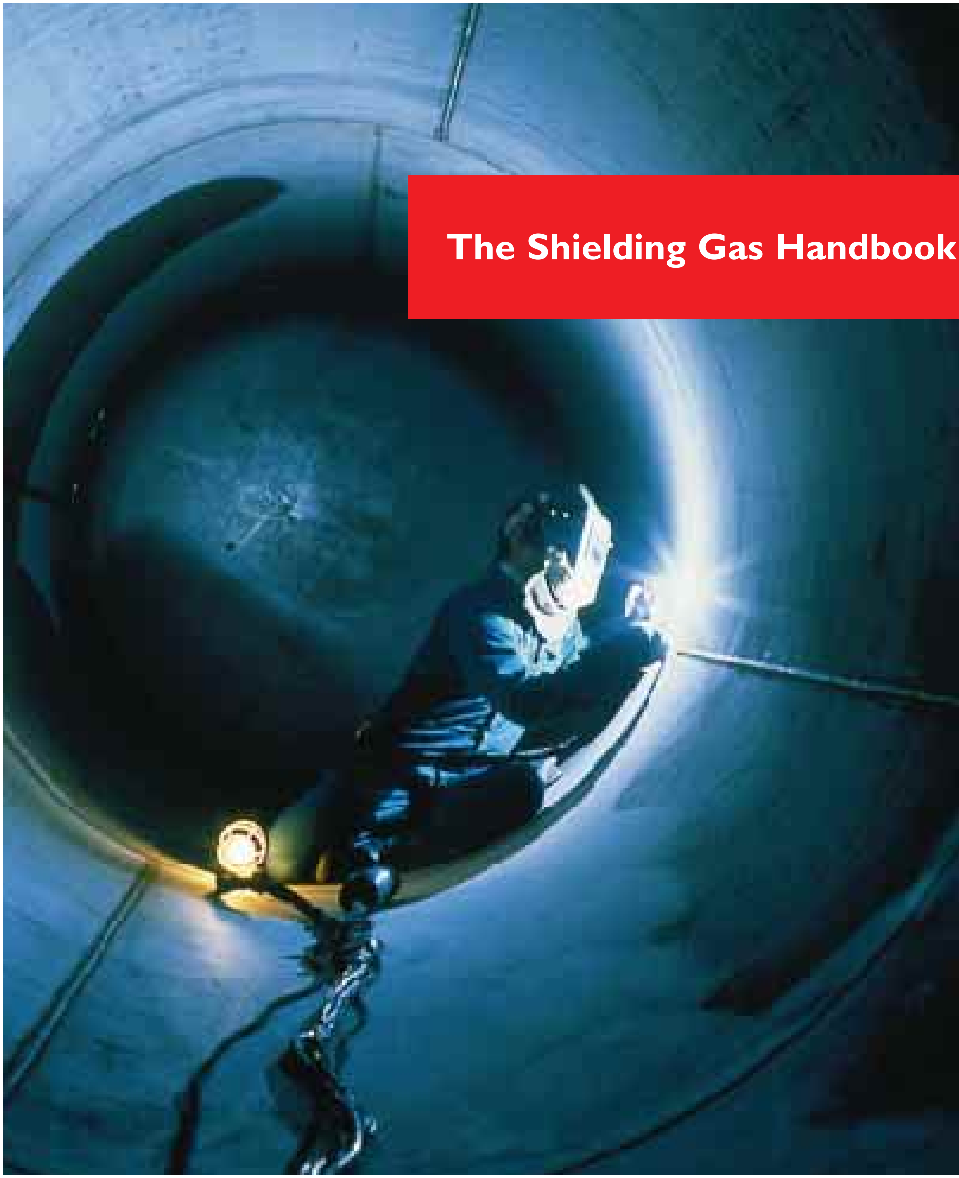

The Shielding Gas Handbook

A G A   C R E A T E S   N E W   O P P O R T U N I T I E S

AGA

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Introduction

The world of welding is experiencing continuous development in all its aspects – with new materials to be welded, new welding parameters, new electrodes and equipment and, not least, new gas mixtures.

This handbook has been compiled to provide a handy overview with answers to some of the more commonly asked questions about shielding gases, their role, their selection and their impact on the finished work.

The handbook looks at the working environment and the role of various metals and shielding gases, precautions for improving the quality of your working environment, the effect of the shielding gas on productivity and quality as well as a comprehensive selection guide for the type of shielding gas which best suits the metal being welded.

If you want to find out which shielding gas best suits the job in hand, look at sections 7 – 10. If on the other hand you wish to know which materials a specific mixture is best suited for, look under the section 11, 'The MISON® range of shielding gases'.

And if you still cannot find the answer you are looking for, your AGA representative is just a phone call away.

Throughout this handbook the term GMAW (or GMA welding) has been used to denote gas metal arc welding, comprising MIG/MAG welding. GTAW (or gas tungsten arc welding) is used for TIG welding.

1 The role of shielding gas

CONTENTS

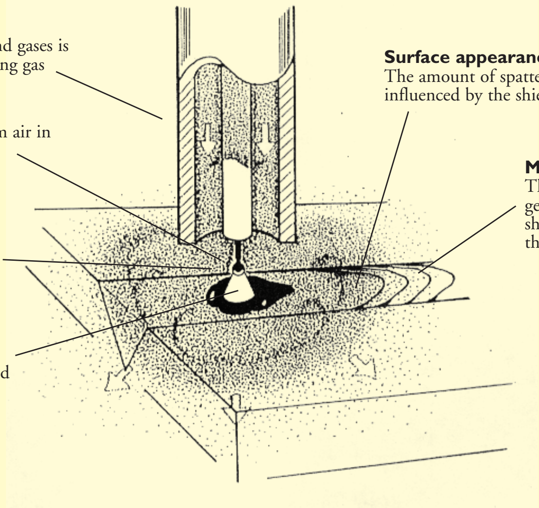
1.1 What shielding gas can do

The primary function of the shielding gas in gas shielded arc welding has been to protect molten and heated metal from the damaging effects of the surrounding air and to provide suitable conditions for the arc. If air comes in contact with the molten or heated metal, the oxygen in the air will oxidize the metal, the nitrogen might cause porosity or brittleness in the weld metal, and moisture from the air might also cause porosity.

The shielding gas composition affects the material transport from the molten electrode to the weld pool, which in turn influences the amount and size of the spatter created. It also affects the appearance of the weld bead, the weld geometry, the possible welding speed and plays a key role in the possible burn-off of alloying elements (which affects material strength) or oxide formation on the bead surface.

The figure below illustrates how the shielding gas influences the process and the results in GMA welding.

The influence of shielding gas upon GMA welding.



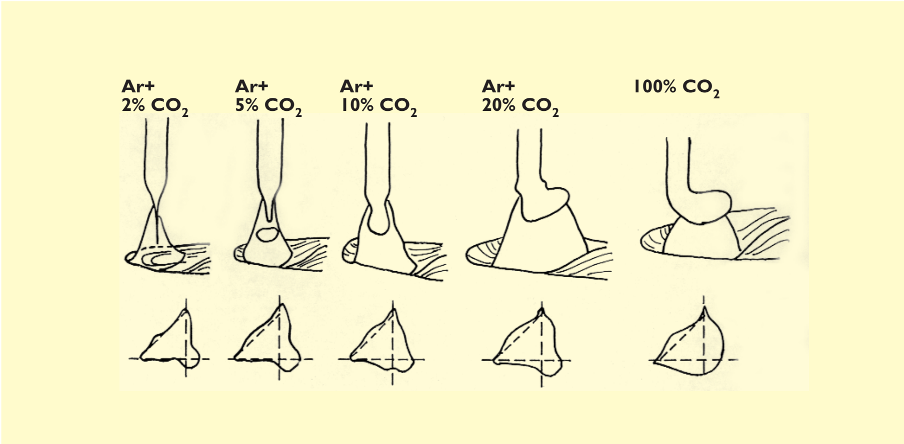
1.2 Effects of the different shielding gas components

1.2.1 Argon Argon (Ar) is an inert gas. This means that it does not oxidize and that it has no effect on the chemical composition of the weld metal.

Argon is the main component in most shielding gases for GMA and GTA welding.

1.2.2 Carbon dioxide and oxygen Pure argon cannot be used for GMA welding of steels since the arc becomes too unstable. An oxidizing gas component is therefore used to stabilize the arc and to ensure a smooth metal transfer during welding. This oxidizing component may be either carbon dioxide (CO_2), oxygen (O_2) or a combination of these gases. The amount of the oxidizing component added will depend on the steel type and application.

The electric arc in gas shielded arc welding can be divided into three parts: the arc plasma, the cathode area and the anode area. In GMA welding, where the filler metal constitutes the positive electrode (the anode), the cathode area is on the workpiece in the form of one or more cathode spots. The oxidizing additive is necessary to stabilize these cathode spots, otherwise the arc will tend to flicker around on the surface of the workpiece, forming spatter and an irregular weld bead.

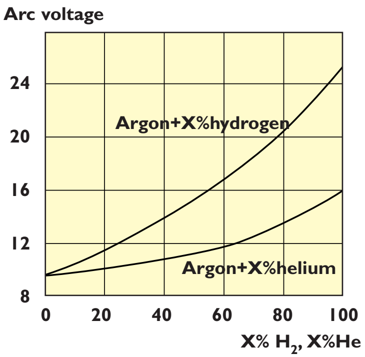


The metal transfer and penetration profile can be changed by selecting different argon-carbon dioxide mixtures. The figure shows the type of metal transfer in spray arc and typical penetration profile for mixtures with 2%CO_2 up to pure CO_2. Higher CO_2 content gives better side wall penetration but more spatter and fume. For most applications the penetration given by a few percent of CO_2 is acceptable. A spray arc cannot be achieved when using 100% CO_2.

1.2.3 Carbon dioxide or oxygen? There are often advantages in using only CO_2 in argon. One is the slight improvement in weld geometry and appearance over O_2-argon mixtures. This occurs because of the differences in weld pool fluidity, surface tension and oxides in the molten metal. With CO_2 instead of O_2 there is also less oxidation and slag formation which can have an effect on the appearance of the weld as well as the need for cleaning the weld.

Another advantage is improved penetration, especially side wall penetration. This is mainly a factor of the higher arc voltage and the energy employed when welding with CO_2 in the mixture.

1.2.4 Helium Helium (He) is, like argon, an inert gas. Helium is used together with argon and a few percent of CO_2 or O_2 for GMA welding of stainless steel. In its pure state, or mixed with argon, it is used as shielding gas for GTA and MIG welding. Compared with argon, helium provides better side wall penetration and higher welding speeds, by generating a more energy-rich arc (see the figure). The process is more sensitive to arc length variations with helium as shielding gas, however, and the arc is more difficult to strike in GTA welding.



How different shielding gases affect the arc voltage in GTAW. Helium and hydrogen give more heat to the process which improves penentration and welding speed.

Helium and helium mixtures can be used as a root protection gas in installations where it is necessary for the gas to rise in order to force out trapped air. Helium rises because it has a lower density than air.

1.2.5 Hydrogen Hydrogen (H_2) can be added to shielding gases for GTA welding of austenitic stainless steels in order to reduce oxide formation. The addition also means more heat in the arc and a more constricted arc, which improves penetration (see figure). It also gives a smoother transition between weld bead and base metal.

For root protection purposes hydrogen addition is beneficial due to its reducing effect on oxygen. Nitrogen with 10% hydrogen is commonly used for root protection. It is not recommended for root protection of austenitic-ferritic (Duplex) steels. Here argon or high purity nitrogen should be used.

1.2.6 Nitrogen Nitrogen (N_2) is used as an additive in shielding gases for GTA welding of super-austenitic and superduplex stainless steels. These steels are alloyed with up to 0.5% nitrogen in order to increase the mechanical properties and resistance against pitting. If the shielding gas contains a few percent of nitrogen, nitrogen losses in the weld metal can be prevented.

Nitrogen with 10% hydrogen is a common root protection gas that delivers a good reducing effect. Pure nitrogen will further increase pitting resistance at the root side when welding super-austenitic and super-duplex stainless steels.

1.2.7 Nitric oxide The addition of nitric oxide (NO) to the MISON® range of shielding gases reduces ozone emissions in the welding zone. This significantly enhances the quality of the welding environment and reduces the incidence of mucous irritation with possible beneficial effects on concentration, productivity and consistency in welding quality. Nitric oxide also serves to stabilize the arc to good effect when welding high alloyed stainless steels, aluminium and MIG brazing.

2 The MISON® shielding gas concept

CONTENTS

2.1 Background

The role of a shielding gas in protecting the electrode, the weld pool and the heated metal during gas shielded arc welding is well known and has been discussed in the previous section. Less well known is the extensive R & D work into the composition of shielding gases to optimize welding performance and to keep pace with the development of new materials and techniques. Most of this development work has focused solely on the role of the shielding gas in protecting the weld. AGA introduced a totally new concept by also addressing the problem of the air pollutants generated in all welding processes. That concept is the MISON - a range of shielding gases which protects the weld, and the welder.

2.2 Where is the problem?

All welding generates air pollutants in the form of fume and gases. The fume consists of metal oxide particles, while the gases are the result of high temperatures and ultraviolet radiation in the welding zone and include potentially hazardous ozone, nitrogen dioxide and carbon monoxide. Traditionally a number of methods have been used to minimize the effects – special helmets and respirators, proper ventilation, localized extraction devices etc. They should always be used to minimize the risk of hazardous exposure. The most efficient way, however, is to reduce the problem at its source. One such example is that of ozone produced during welding. Most improvements in welding performance (through reduced CO_2 content in the shielding gas or modified welding parameters, for example) are accompanied by increased levels of ozone. It seems to be the price of progress. Ozone (O_3) is particularly hazardous. By comparison, the time weighted average (TWA - the maximum permissible average level of an air pollutant in the breathing zone during a working day) allowed for ozone is 0.1 ppm, 350 times less than for exposure to carbon monoxide (CO). MISON was developed to combine optimal shielding gas performance (in terms of productivity and quality) with reduced levels of ozone in the welding zone.

2.3 Ozone: good or bad?

In the atmosphere ozone is naturally present and best known as a layer in the stratosphere reaching its greatest density at around 25 kilometres. One of its beneficial effects is in filtering ultraviolet radiation, and depletion of the layer has been linked strongly to increased incidence of skin cancer.

Closer to earth, ozone is also well known from periodic health warnings in urban areas where large concentrations of the gas are generated by a combination of sunlight, atmospheric oxygen and automotive and industrial emissions. These high ozone concentrations are potentially lethal for asthmatics and can cause widespread symptoms of burning in the throat, coughing, dry mucous membranes, chest pains and wheezing in anyone exposed to the gas. These are the same symptoms that often appear in welding. Research into the long-term effects of exposure to high levels of ozone is not yet conclusive, but there are clear indications that it could cause chronic bronchitis and emphysema.

Hazardous ozone concentrations are increasingly common near major cities during summer weather when traffic levels are high. Ozone also appears in welding.

2.4 The range of MISON shielding gases

In 1976 AGA was granted the patent for a method of reducing ozone during arc welding. A radical new shielding gas was introduced - MISON. It was found that the addition of precisely measured amounts of nitric oxide (NO) reacted readily with ozone to create oxygen (O_2) and nitrogen dioxide (NO_2). The result is an improved working environment for the welder and a significant improvement in experienced comfort.

The MISON range represents a complete range of shielding gases covering most welding applications (as can be seen in the later sections). For nearly two decades users of MISON® have reported significantly improved working conditions with subsequent improvements in productivity as well as an ability to 'work better' providing quality welding results .

2.5 The Nobel connection

Research during the seventies into the way that ozone reacts so readily with nitric oxide (as well as, to a lesser extent with freon and chlorine) led to a Nobel prize in 1995 for three scientists. Utilizing their research as a basis led AGA's research technicians to explore the practical benefits of this phenomenon as a shielding gas. The result was the MISON range of shielding gases from AGA - itself founded by Nobel prize-winner Gustaf Dalén in 1904.

3 The working environment

CONTENTS

3.1 Background

All welding processes carry health and safety risks for the welder. These include fume, gases, radiation, heat, noise and heavy lifting operations.

In recent years, interest in maintaining a safe and healthy working environment has grown. This stems from a growing environmental awareness, new regulations and also in recognition of the fact that a good, healthier working environment can lead to higher productivity which in turn can impact on the profitability of the company.

There are several reasons for this:

- the welder has an over-riding interest in his own good health
- in a poor working environment, the welder is more likely to be absent from work due to illness or injury. If a replacement is needed, he requires training and the amount of rework is likely to increase.
- poor working conditions can also cause the consistency of the performance to vary during the day, especially with regard to productivity and quality.
- motivation and job satisfaction can both improve when it is clear that the employer takes an active interest in his employees´ well-being.

Included in this handbook are many of the air pollutants generated during welding since this is the area where the choice of shielding gas can have a major impact.

3.2 Air pollutants in welding environments

Air pollutants created when welding comprise a mixture of dust, fume and gases. Of these, dust and fume are generally clearly visible, whereas gases formed during welding, though toxic, may well be invisible to the naked eye and it is important to be aware of them.

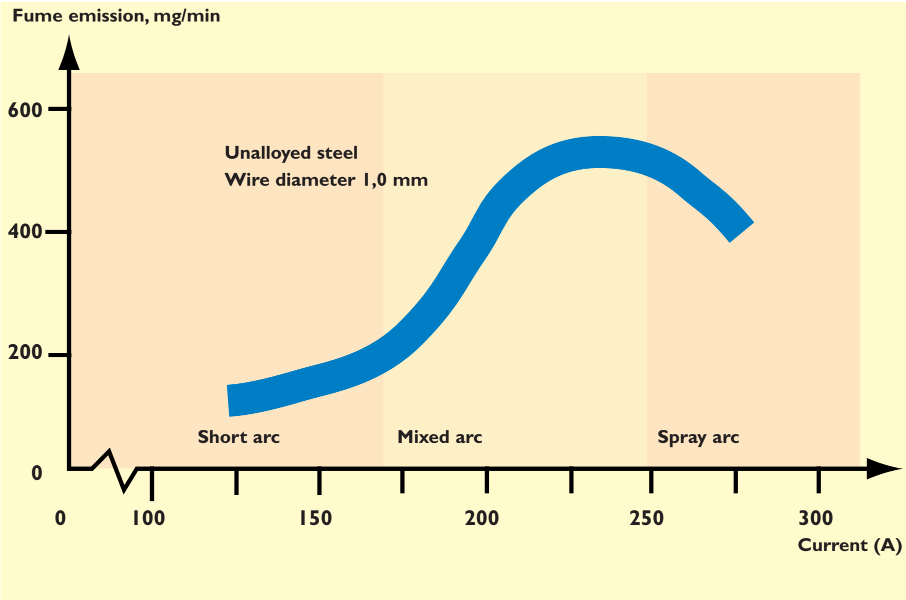
3.3 Dust and fume

In welding applications, dust can be defined as particles larger than 1 micron (0.001 mm)in size. These tend to fall close to the arc and consist largely of welding spatter. Fume refers to particles less than 1 micron in size. Fume particles generally remain suspended in the air and can be carried far from the welding arc.

Fume particles consist mainly of oxides. These are formed when the melted metal is vaporized in the arc and then condenses and oxidizes in contact with the surrounding air. In GMA welding, the filler metal 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 fume formation and the composition of this fume corresponds more or less directly with the chemical composition of the wire.

Spatter is a major factor in the formation of welding fume. The more spatter, the more fume. The quantity of spatter is closely linked to the welding parameters as well as to the composition of the shielding gas.

The potential health hazards outlined in the text that follows can generally be avoided by following certain safety precautions, some of which are referred to in section 6. Other precautions include ensuring adequate ventilation, adopting the correct welding posture, the use of local fume extraction and the choice of the MISON® range of shielding gases to reduce ozone at source.



Fume emission.
GMA welding with argon mixture and argon mixture with 0.03% NO. Compare diagram in section 3.5.1.

To minimize health hazards in the working environment the following are recommended: adequate ventilation, local fume extraction, adopting the correct welding posture, use of a helmet and the choice of MISON shielding gases to reduce ozone at source.

The degree of fume in a welding environment can vary markedly according to a number of factors. Some of these are outlined in generalized form in the table below:

Factor	Effect
MMA welding	High fume formation
GMA (MIG/MAG) welding	Fume formation depends on parameters/shielding gas
GTA (TIG) welding	Low fume formation
Filler metal	Main source of fume. Solid wires give less fume than cored wires. Greatest fume from self-shielded electrodes.
Welding parameters	Short arc = little fume Unstable arc = more fume Pulsed arc = less fume Spray arc = less fume
Shielding gas	More spatter = more fume Shielding gas with low CO_2 or O_2 content = less fume Shielding gas with high CO_2 or O_2 content = more fume

3.4 Fume composition

Chromium, Cr. During the welding of steels alloyed with chromium (e.g. stainless steel) trivalent and hexavalent chromium are formed through oxidation. Both forms produce irritation of the mucous membranes, metal fume fever and also affect the respiratory passages and the lungs.

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

Iron, Fe. Iron oxide occurs in the weld fume when welding iron materials. Exposure to iron oxide over an extended period of time can lead to a lung condition called siderosis. It is similar to silicosis but not as dangerous.

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

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

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

3.5 Gases generated during welding

Gases play a major role in the immediate welding environment. The following section describes some of the main gases, their origins and their effects.

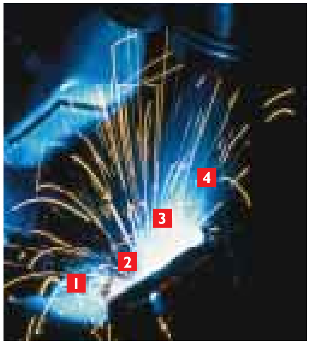
During gas metal arc welding, the main causes of gas formation are the extremely high temperatures and ultraviolet radiation emitted by the arc. The gases dealt with here are toxic and/or asphyxiating.

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

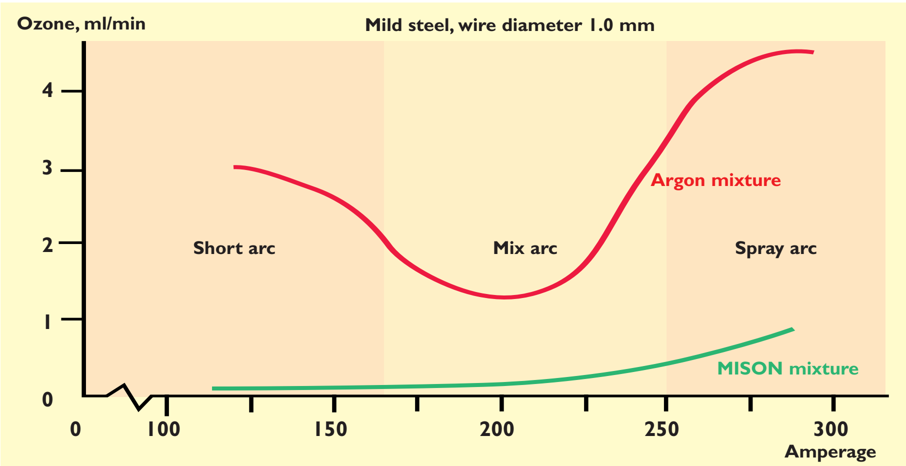
Ozone is formed from the oxygen in the air as follows:

$3\ O_2 \rightarrow 2\ O_3$

Ultraviolet radiation in the 130 - 175 nm wavelength band is the main source of ozone formation. Most of the ozone is formed close to the arc. Ozone is carried away



1. The welding arc emits high-energy ultra violet radiation.
2. Ultraviolet light strikes oxygen molecules in the air. The ultraviolet light splits the oxygen molecule to form two separate oxygen atoms. (O_2 becomes O+O).
3. When the single oxygen atom encounters a new oxygen molecule, they combine to form ozone (O_3).
4. The formation of ozone is most pronounced within a distance of 10-15 cm of the arc. The ozone rises with the hot air, and this is how it can reach the welder´s breathing zone.



Ozone-emission.
GMA welding with argon mixture and argon mixture with 0.03% NO. Compare diagram in section 3.3. Note the contrast between ozone and fume formation.

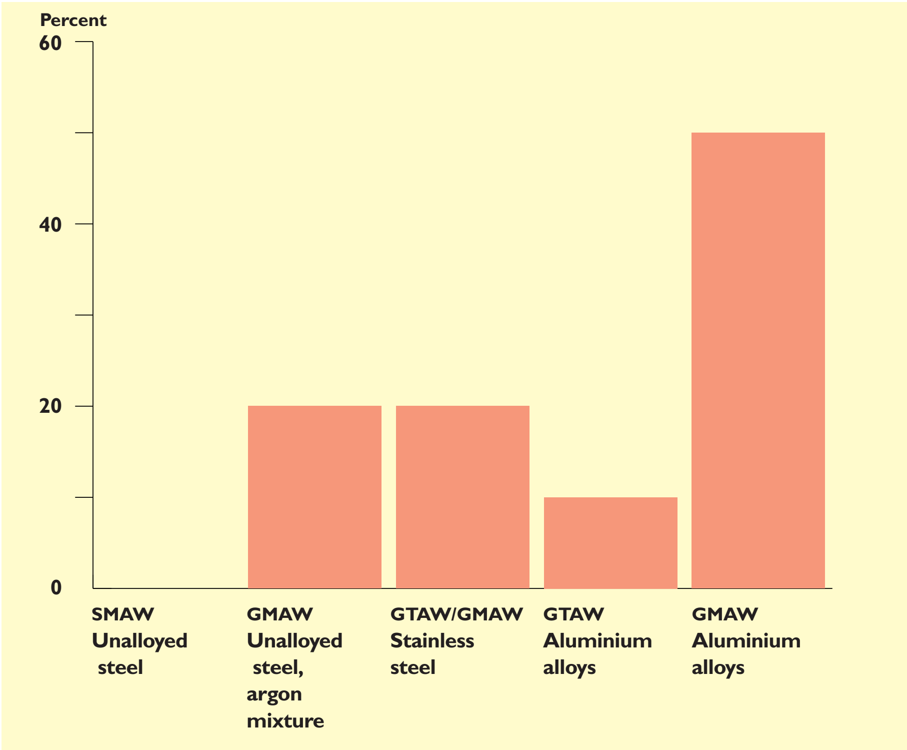
from the arc in the hot plume of fume and gases that arises from the welding spot.

The amount of ozone emitted depends on how much ozone is initially formed and how much of that ozone is reduced again to O_2 by the environment in the plume. Reduction of ozone in the plume occurs in three principal ways:

1. Thermal decomposition in the zone closest to the arc, with temperatures of 500°C and higher.
2. Catalytic reduction, catalysed by metal oxide fume particles in the plume.
3. Chemical reduction by reaction with other gases in the plume. The most effective reaction is between ozone and nitric oxide (NO): $NO + O_3 \rightarrow NO_2 + O_2$. Ozone can effectively be reduced in the welding zone by the addition of just 0.03% NO, as in the MISON range of shielding gases.

N.B. The TWA (Time Weighted Average – a recommended maximum exposure concentration during a working day) for ozone is just 0.1 ppm.

Probability of being exposed to ozone levels exceeding the TWA value (0.1 ppm) during welding with different metals and methods.



The degree of ozone in a welding environment can vary markedly according to a number of factors. Some of these are outlined in generalized form in the table below:

Factor	Effect
Welding method	Complex interaction of filler metal, shielding gas and welding parameters
Filler metal	Flux cored wires create somewhat more fume. Therefore ozone is less than when using solid wire
Welding parameters	Higher arc energy = more ozone. Pulsed arc welding = less fume but more ozone.
Shielding gas	More fume = less ozone. Low O_2 or CO_2 content = high ozone emission. MISON = low ozone emission
Spatter	Lots of spatter = more fume = less ozone
Other	More nitrogen oxides formed = less ozone

3.5.2 Nitric oxide, NO. This is formed from oxygen and nitrogen in the surrounding air. The hot arc or the hot base metal initiates the following reaction:

$N_2 + O_2 \rightarrow 2\,NO$

Nitric oxide is unstable in air, where it spontaneously oxidizes to nitrogen dioxide. However, if ozone is present, the nitric oxide reacts in the first instance with the ozone instead. The result is nitrogen dioxide and a normal oxygen molecule. This phenomenon is utilised in MISON shielding gases to eliminate toxic ozone at source.

As a general rule, the higher the welding parameters, the higher the nitrogen oxide production is likely to be. Hence short arc welding creates more nitrogen oxides than spray arc welding. The maximum is formed in the mixed (globular) region due to the unstable arc. Normally nitric oxide is not a problem in welding.

N.B. The TWA (Time Weighted Average – a recommended maximum exposure concentration during a working day) for NO is 25 ppm.

3.5.3 Nitrogen dioxide, NO_2. This is a brown gas and formed from oxygen and nitrogen in the air. $2\,NO + O_2 \rightarrow 2\,NO_2$

(The NO derives mainly from the reaction $N_2 + O_2 \rightarrow 2\,NO$). In electric arc welding, the NO (of which the NO_2 is a by-product) may be produced by the welding arc itself and/or deliberately introduced as an additive in the shielding gas (as in the case of MISON shielding gases).

N.B. The TWA (Time Weighted Average – a recommended maximum exposure concentration during a working day) for NO_2 is 2-5 ppm.

Small quantities of NO_2 produced in welding are, however, an acceptable method for reducing ozone, which is a much more serious pollutant.

MMA welding gives the highest level of NO_2, followed by GMA (MAG/MIG) welding and GTA welding in descending order.

3.5.4 Ozone vs. NO_2 The addition of NO to the shielding gas in MISON reduces the effect of ozone but it does create NO_2. In cases like this, there is a commonly used formula for determining the comparative risk for gases that have a similar effect on the human being. This is:

$$C1/TLV1 + C2/TLV2 + C3/TLV3 + \ldots\ldots \leq 1$$

Where C is the measured concentration of the substance and TLV is the hygienic threshold limit value for exposure during an entire working day. This should never exceed 1 in the breathing zone.

Since ozone has a significantly lower TLV than NO_2, it is logical to reduce the ozone concentration as the following example indicates.

Process: GMAW
Material: AISI 316L
Filler: 316L, solid wire,ø 0.8 mm
Wire feed speed: 7 m/min
Shielding gas 1: Argon + 2% CO_2
Shielding gas 2: Argon + 2% CO_2 + 0.03% NO

Shielding gas 1:	**Shielding gas 2:**
O_3 = 0.24 ppm	**O_3 = 0.03 ppm**
NO_2 = 0.01 ppm	**NO_2 = 0.23 ppm**

(Concentrations measured in the plume)
Using the formula, this gives:
0.24/0.1+0.01/2 = 2.405
for shielding gas 1, and
0.03/0.1+0.23/2=0.415 for shielding gas 2.
In other words, although the quantity of NO_2 increases by 23 times, the overall result is much better for the welder.

3.5.5 Carbon monoxide, CO. This is formed mainly through the dissociation of carbon dioxide, CO_2, from the shielding gas as follows: $2\ CO_2 \rightarrow 2\ CO + O_2$

It is a dangerous gas, odourless and colourless. High concentrations can occur in confined, poorly ventilated spaces . It prevents oxygen transport in the blood and carbon monoxide poisoning leads to fatigue, headache, heart pain, difficulties in concentrating and eventually loss of consciousness.

N.B. The recommended TWA for CO is 35 ppm.

FACTORS AFFECTING CO FORMATION:

The choice of base metal has little influence on CO formation, but when MAG welding, the choice of shielding gas can be significant. In the shielding gas, the higher the CO_2 content, the more CO will be formed. As a general rule, the higher the arc energy, the higher the temperature, and under these circumstances larger amounts of CO are formed. The surface coating of the metal and the amount of weld spatter formed do not have a significant effect on the volume of CO produced. However, high and potentially dangerous concentrations of CO can form when welding in confined and poorly ventilated spaces.

To minimize health hazards in the working environment the following are recommended: adequate ventilation, local fume extraction, adopting the correct welding posture, use of a helmet and the choice of MISON shielding gases to reduce ozone at source.

3.6 Other elements

Gases can also be formed when surface coatings or contaminants come in contact with hot surfaces or ultraviolet radiation. Surface coating primarily provides corrosion protection.

3.6.1 Phosphating provides corrosion protection or a good base primer for painting. During welding, phospine gas, PH_3, is formed, which is extremely hazardous.

3.6.2 Galvanizing provides good corrosion protection. During welding, zinc oxides form which can cause metal fume fever. Galvanized material is easily confused with cadmium plated material.

3.6.3 Cadmium, Cd, plating is also a corrosion protection. Cadmium is a highly toxic substance. Welding fume can contain cadmium oxides. Because of its toxicity, cadmium plating is less and less common.

For precautions, see section 6.

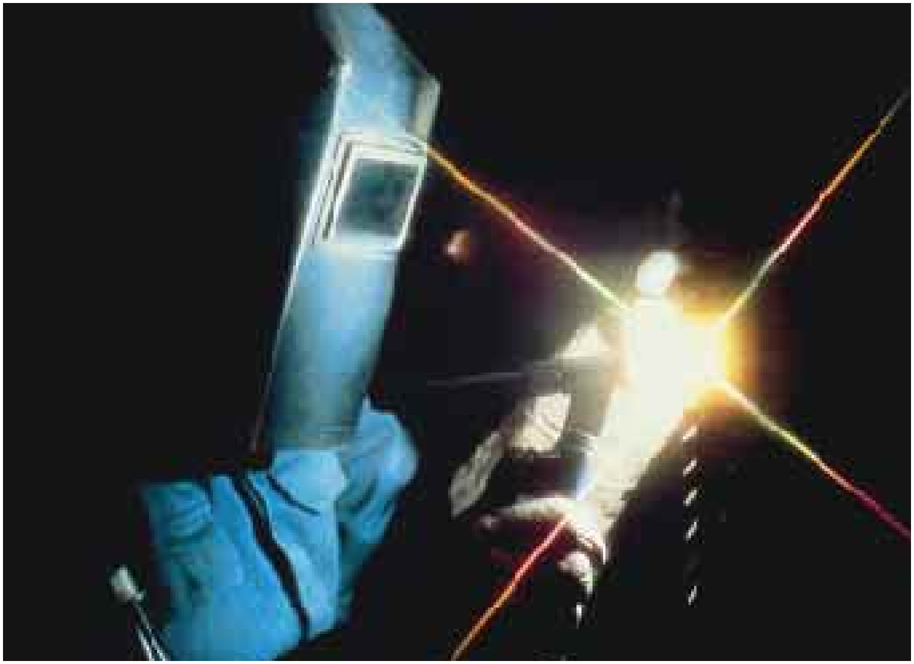
3.6.4 Chrome and nickel plating can also cause health problems.

3.6.5 Lead, Pb This is not present in large amounts in arc welding fume except in the case of the welding certain surface coated materials.

3.6.6 Oil is decomposed during welding and vaporizes. There is no evidence that these gases become hazardous at these levels.

3.6.7 Chlorinated hydrocarbon is a solvent used to remove oil. If this kind of solvent comes in contact with a hot surface or is exposed to ultraviolet radiation, dangerous phosgene gas, $COCl_2$, is formed.

3.6.8 Paints and plastics. Paints and plastics can produce hazardous gases during welding. Paints can contain lead, chromium, zinc and in marine applications, mercury. Plastics also often contain metals. Examples are shop primers. Welding of primer coated plate could form zinc and iron oxides.



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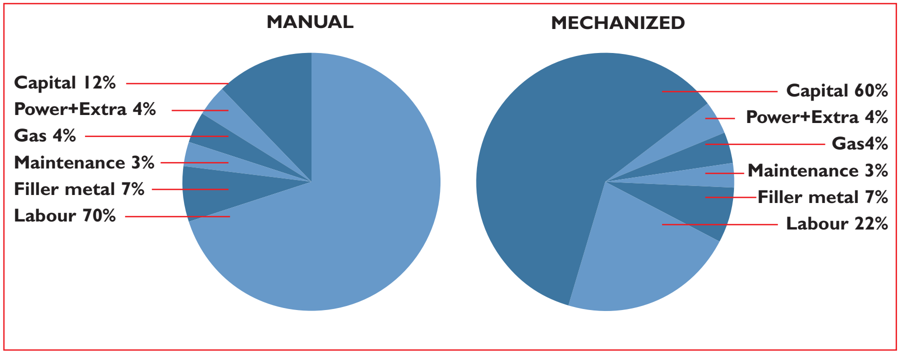
4.1 General

Profitability can be increased in welding through cost reductions in many areas. The costs are the result of many factors, as the charts below illustrate.

The costs for shielding gas, filler metal, maintenance and energy constitute only a minor part of the total welding cost. In both manual and mechanized welding, labour and capital costs together represent more than 80% of the total welding cost. This provides scope for considerable efforts to reduce welding costs.



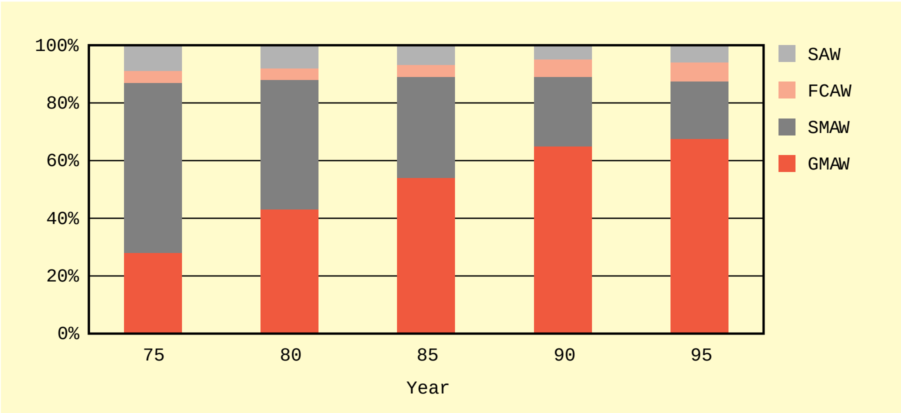
Examples on cost distribution for welding one component. (Based on welding of normal low alloyed steels). One of the most efficient ways of reducing the total cost is the choice of the optimal shielding gas for the application.

Increases in the deposition rate, the duty factor and the electrode efficiency factor will generate major reductions in the total cost per metre. All of these factors can be influenced by the welding method. In GMA and GTA welding, the choice of the shielding gas is of importance to all these factors. The deposition rate is directly related to the wire feed speed. The duty factor (the arc time factor) is influenced by the amount of work needed to remove spatter and slag. Electrode efficiency is related to the 'loss' of material through spatter and excess weld bead geometry (convexity).

In general it can be concluded that spending more on shielding gas or filler metal that can contribute to an increased deposition rate will actually be very cost effective.

4.2 Welding method

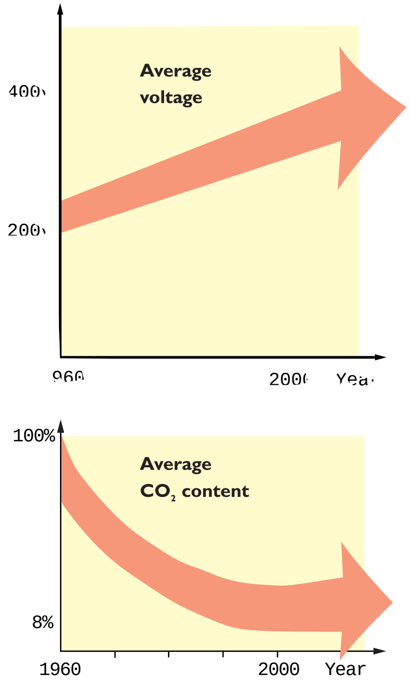
The most widely used welding method today is the GMA welding method. Since 1975, GMA welding using solid wires has doubled its market share. Growth in the popularity of GMA welding been at the expense of manual metal arc welding, MMA (SMAW).



Relative weld metal consumption per process in Western Europe 1975-1995. GMAW has developed because of its high deposition rate,the improved working environment, the lower total cost and the suitability for mechanized processes.

One reason GMA welding is so popular is the high deposition rate, as shown in the table below. The deposition rate can be further increased by using flux cored wires in certain applications or by using high-productivity welding (RAPID ARC™ or RAPID MELT™), which we will come back to in section 4.5. One additional reason for the growth of GMA welding is that it lends itself to mechanized or robotized processes.

Examples				
Mild steel Plate thickness 8mm Horizontal fillet joint Throat thickness 5mm	Electrode diameter (mm)	Deposition rate (kg/h)	Wire feed speed (m/min)	Welding speed (cm/min)
SMAW, basic electrode	5	2,6		22
SMAW, high efficiency rutile electrode	5	5,7		49
GMAW, solid wire, 100CO_2	1,2	4,2	8	36
GMAW, solid wire, 18%Ar/82%CO_2	1,2	5,8	11	50
FCAW, 18%Ar/82%CO_2, rutile for heavy deposition (E70T-1)	1,6	6,0		55
RAPID ARC, solid wire, MISON 8	1,2	9,5	18	81



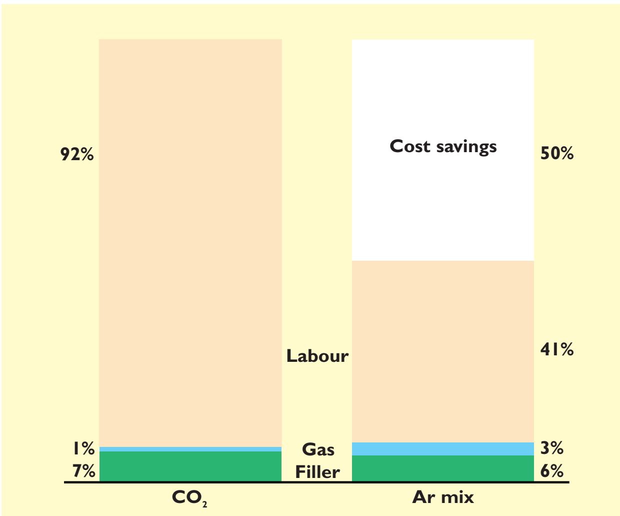
Increased welding parameters and reduced CO_2 content in the shielding gas leads to higher deposition rates and welding speeds. The drawback is that more ozone is formed.

There is a clear trend towards higher productivity. In GMA welding, higher welding speeds and deposition rates are primarily achieved by increased welding parameters and lower CO_2/O_2 content in the shielding gas. The drawback is a higher ozone emission. The MISON range of shielding gases is specifically developed to reduce ozone emission. The trend has been clearly visible over the last three decades, as can be seen in the two diagrams on the left.

4.3 The shielding gas

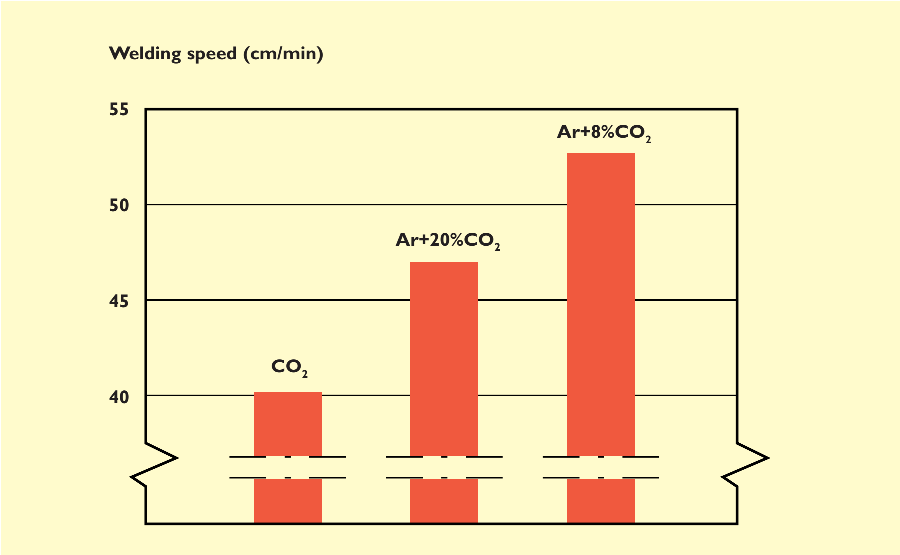
4.3.1 Ar/CO_2 mixtures versus CO_2 Carbon dioxide, CO_2, was earlier the most common shielding gas in GMA welding. The main reason was low cost, but the gas cost actually only represents a small part of the total welding cost. It is more important to study what productivity and weld quality the shielding gas can offer, as well as how the shielding gas affects the need for post-weld cleaning. Changing to argon mixtures, however, allows the process to be optimized with regard to both productivity and quality. As a result, argon mixtures have become the most widely-used shielding gas for GMA welding.

The figure below shows how the total welding cost could be reduced, despite a higher cost for the shielding gas.



Example of the welding cost relation between labour, shielding gas and filler metal when using CO_2 and argon mixture as a shielding gas. Cost reductions accrued from higher welding speed and less post-weld cleaning.

4.3.2 Welding speed and deposition rate One reason for a reduced overall welding cost is the increased welding speed with Ar mixtures. CO_2 does not allow the same welding speed, because the weld bead becomes too convex and transitions between the weld and plate are poorer. The diagram illustrates research results with different shielding gases. Welding speed was increased until the weld bead became too convex. The wire feed speed was constant. As you can see, the lower the CO_2 content, the higher the welding speed.



Example of welding speeds for fillet joints using different shielding gases. 4 mm throat thickness, 6 mm plate thickness, mild steel, wire diameter: 1.0 mm, wire feed speed: 12 m/min.

4.3.3 Spatter, post-weld cleaning

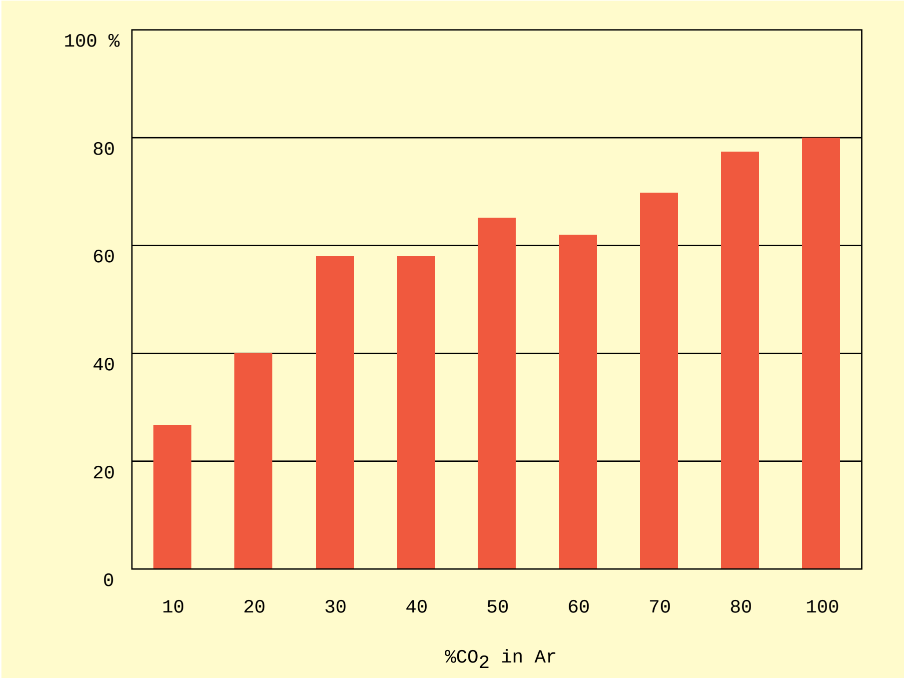
UNALLOYED AND LOW ALLOY STEELS

Post weld treatment is also a major cost factor. If welding results in spatter, this has to be removed by grinding. The larger the spatter particles, the more heat they contain and the easier they fuse to the surface of the workpiece. Research shows that the greater the percentage of CO_2 in the shielding gas, the more spatter is produced and the coarser it is.

As spatter comes from the filler metal, more spatter will also lower the electrode efficiency factor and increase the cost for filler metal.

More CO_2 creates increased and coarser spatter. Removal of spatter increases cost.

Proportion of coarse grained spatter as a function of percentage of CO_2 in the shielding gas in GMA welding. Fine grained spatter does not adhere to the plate.



STAINLESS STEELS

When GMA welding stainless steels, a small portion of oxidizing components (1-2% CO_2 in argon) are needed in the shielding gas to stabilise the arc and minimize spatter. For some high-alloy stainless steels such as super-duplex and super-austenitic stainless steels the use of shielding gases normally selected for standard stainless steels is not recommended. The plate surface will be too oxidized, and expensive post-weld operations are necessary if you want to make full use of the excellent properties of these steels.

Instead of using pure argon (with resultant unstable arc and spatter) MISON® shielding gases are recommended. These comprise argon + 0.03% NO. The small addition of NO is sufficient to stabilise the arc, and it will not generate any excessive oxidation. Post-weld cleaning is minimized, which in turn enhances productivity.

4.3.4 MIG brazing

When MIG brazing thin sheets and metal coated sheets it is important to achieve an arc with a low heat content to prevent the parent metal from melting. (In brazing processes, only the filler metal should melt) It is also important that the arc is stable to avoid defects such as spatter and porosity. An argon-mix provides a stable arc, but the heat content is too high. MISON shielding gas on the other hand provides a stable arc with a lower heat content.

Experience in the automotive industry illustrates that brazement repairs can be reduced by 70% when switching from pure argon to MISON due to the more stable arc and resultant reductions in welding defects. The appearance of the braze work is also generally enhanced.

4.3.5 Addition of helium or hydrogen

The addition of helium or hydrogen to the shielding gas gives a more energy-rich arc, thus supplying more heat to the weld and allowing the welding speed to be increased.

When adding helium to the shielding gas, as in MISON 2He and MISON N2, a wider weld with better sidewall penetration can be achieved, in addition to the increased welding speed. The addition of NO to these shielding gases also effectively reduces the ozone level during welding.

Addition of hydrogen to the shielding gas not only increases heat in the arc, it also provides a more constricted arc, for improved penetration. The shielding gas MISON H2 , intended for GTA welding of austenitic stainless steels, contains 2% hydrogen. This addition contributes to a higher welding speed, better penetration and smoother transition between weld and base metal. It also reduces the oxidation of the weld, contributing to higher productivity due to the reduced need for post weld cleaning and a better appearance.

More information about the whole range of MISON shielding gases can be found in chapter 11. The role of the different shielding gas components is described in greater detail in chapter 1.

4.4 Combined effect of filler metal and shielding gas

When deciding on the type of filler metal to be used, the main principle is that the weld metal should have the same composition and mechanical properties as the base metal. We can distinguish between solid wires and cored wires (flux-cored or metal cored). Solid wires are the most commonly used, but in certain applications such as position welding, cored wires offer some advantages.

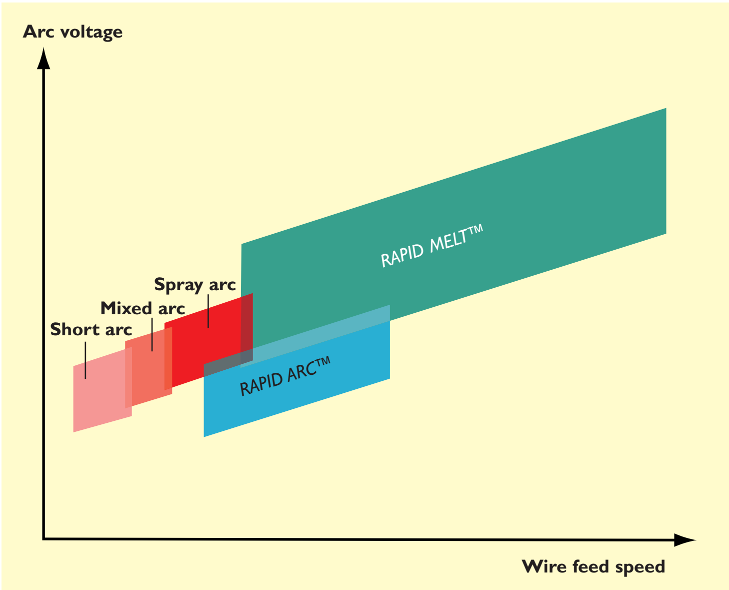
By choosing the right combination of filler metal and shielding gas, productivity can be raised through higher welding speed and/or deposition rate. Weld appearance can also be improved, which in turn raises the overall productivity; reduced spatter and surface oxides, together with smooth transitions, mean less post-weld treatments.

4.5 High-productivity GMA welding

The most important single factor in increasing productivity is the deposition rate. The average rate is between 3-5 kg/hour. It should always be possible to raise this deposition rate to between 7-10 kg/hour without the need for additional investment in new equipment.

Thus, by using unconventional welding parameter settings, we can go beyond the traditional working ranges and thus considerably raise the productivity, see below.

Working ranges for conventional GMA welding and high-productivity welding with RAPID ARC ™and RAPID MELT™



This is the thinking behind a concept for high-productivity welding developed by AGA. The concept comprises two welding procedures: RAPID ARC™, which aims at raising the welding speed in most plate thicknesses, and RAPID MELT™, which raises the deposition rate, primarily in the welding of heavier metal (e.g. 15 - 20 mm in thickness).

In many cases, the RAPID ARC technique can more than double the welding speed, depending on the application. The technique can also be performed with most existing welding equipment and is suitable for mechanized welding as well as for manual welding.

The RAPID MELT technique can provide very high deposition rates – as high as 20 kg per hour. This means wire feed speeds of up to 50 metres per minute. The technique therefore requires some new investment in the form of reliable, rapid wire feed units, and a high capacity power source. RAPID MELT is also feasible for mechanized welding.

The optimal shielding gas required for RAPID welding is MISON 8 which, with its low CO_2 content, gives a stable arc, limited adhesive spatter, low convexity, even transitions between weld and base metal and little surface oxidation. Such high productivity methods tend to generate more ozone, which MISON can reduce, thereby enhancing welder comfort.

4.5.1 Examples of RAPID PROCESSING™ applications

1. Type of production: robot welding of structural components for bus chassis.

	Previous method	RAPID MELT
Weld length	**2 X 400 cm runs**	**1 X 400 cm run**
Weld gap	**6 mm**	**5 mm**
Plate thickness	**10 mm**	**10 mm**
Filler metal	**Cored wire**	**Solid wire**
Groove area	**60 mm²**	**50 mm²**
Weight of deposited material	**2.0 kg**	**1.6 kg**

Results: higher welding speeds, lower consumption of filler metal, cheaper filler metal, improved side wall penetration and reduced deformation – all leading to reduced cost and higher quality.

Total welding time	**40 mins**	**10 mins**

2. Type of production: manual welding of bridge sections.

Results: increased welding capacity 15%, lower energy consumption, lower consumption of filler metals and shielding gas, better use of equipment available and less fume and ozone.

	Previous method	RAPID ARC
Average wire speed	**10 m/min**	**15 m/min**
Filler metal	**Solid wire**	**Solid wire**
Welding capacity		**Up 15%**
Other improvments		**Reduced consumption of electricity, filler metal and shielding gas. Less fume and ozone.**

In general terms it can be concluded that productivity tends to go hand in hand with higher welding parameters and lower CO_2 usage. This in turn generates more UV radiation and ozone. This is why AGA recommend MISON ozone-reducing shielding gases.

5 Quality and the role of the shielding gas

CONTENTS

5.1 General

5.1.1 Weld quality

Weld quality is mainly affected by the design and the fabrication procedure used, for example the method, joint preparation, welding parameters, filler metal, shielding gas etc. Shielding gas can affect the mechanical properties of the weld metal, the corrosion resistance as well as the visual quality. Changes in the mechanical properties can result from changes in the micro structure of the metal, bad transition between weld and base metal, bad penetration profile resulting in lack of fusion etc. The corrosion resistance may be affected by changes in the micro structure of the metal, oxidation of the surface etc. And the visual quality can be affected by the presence of spatter and surface slag.

Shielding gases comprise different gas components combined to improve productivity, quality and working environment.

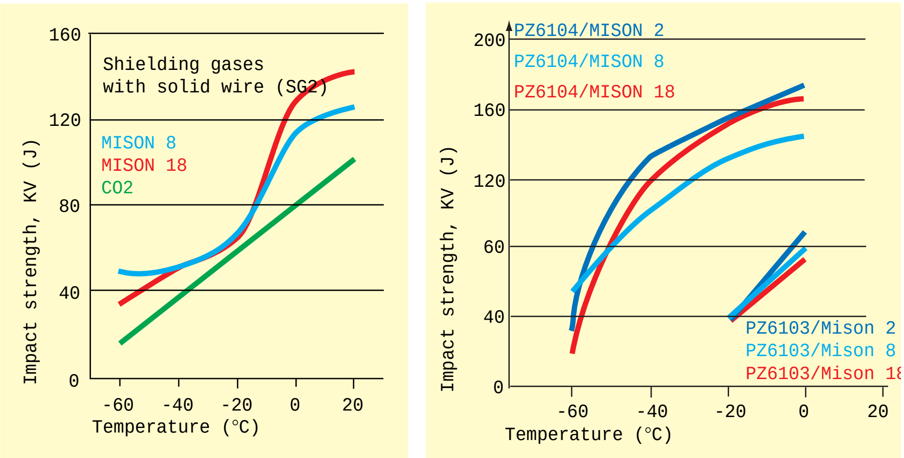
For a specific base metal and welding method, there is often one shielding gas which offers the optimal result. Other combinations of metal and welding process can offer greater flexibility in the selection.

5.1.2 Quality of the working environment The choice of shielding gas can have a significant effect on the working environment. Generation of fume and toxic gases can be reduced by careful selection of the optimal shielding gas. In particular, ozone emission in the welding zone can cause significant irritation to the welder's eyes, nose and throat. This in turn can affect the concentration of the welder with the result that work quality may be inconsistent if exposure to the ozone is excessive – near or above the Time Weighted Average (TWA) or the maximum permissible average of an air pollutant in the breathing zone during the working day. (It is worth noting that exposure to excessive ozone is regarded as being 350 times more hazardous than carbon monoxide, the toxicity of which is widely known by the layman). Efforts to enhance the quality of the working environment can be rewarded by enhanced consistency in output, both in terms of quality and productivity.

5.2 Unalloyed and low-alloy steels

Argon is normally used when GTA welding unalloyed and low-alloy steels. The small NO addition to the argon in MISON Ar has a stabilizing effect on the arc when GTA welding these steels. In order to stabilize the arc when MAG welding these steels, shielding gases containing 5-25% CO_2 or 5-10% O_2 are used. In both GTA welding and GMA welding the amount of ozone can be reduced by using the MISON® range of shielding gases which contain a small addition of NO which enhances the quality of the welder's working environment.

5.2.1 Mechanical properties The mechanical properties of the weld metal are strongly influenced by the shielding gas. The lower the CO_2 or the O_2 content of the shielding gas, the 'cleaner' the weld metal , meaning less inclusion of oxides. The micro structure also becomes more finely grained which benefits impact strength, see figure.



Impact strength for different types of shielding gases and filler metals.

PZ 6103 is a metal cored wire designated as AWS A5.20: E71T-G
PZ 6104 is a metal cored wire alloyed with Ni to improve low temperature toughness designated as AWS A5.29: E71TG-Ni1

Lower CO_2 content or O_2 content give a lower burn-off of alloying elements (see figure below), which results in higher yield and ultimate tensile strength.

The fatigue properties of the weld can also be affected by the shielding gas. Fatigue strength is mostly dependent on the weld geometry. Since welding with argon mixtures creates a weld with a smoother transition between the weld bead and base metal (see

The influence of the shielding gas on the manganese and silicon content in the weld metal. Higher CO_2 content gives a higher burn-off of alloying elements which results in lower yield and ultimate tensile strength.

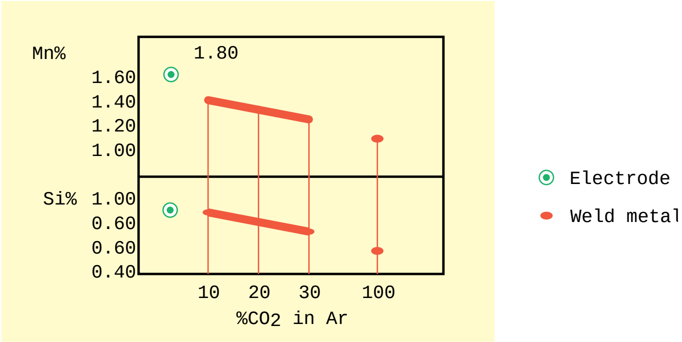


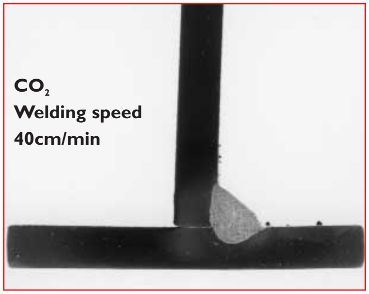
figure below), the fatigue properties are better than for welds shielded with CO_2. If the weld is likely to be subjected to dynamic loads, higher demands will be placed on fatigue strength. If the transitions between weld bead and base metal are not adequate, expensive post weld treatment such as grinding or GTA dressing will be required.

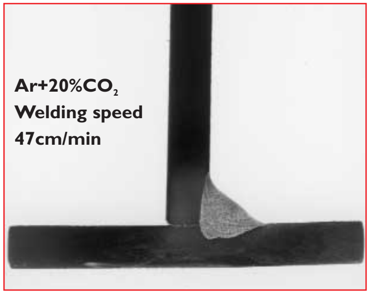
Fatigue strength may also be influenced by the number of oxide inclusions if the weld is grinded or polished. The oxide can act as starting points for cracks. The higher the CO_2 or O_2 content in the shielding gas, the more oxide inclusions will be formed in the weld metal.

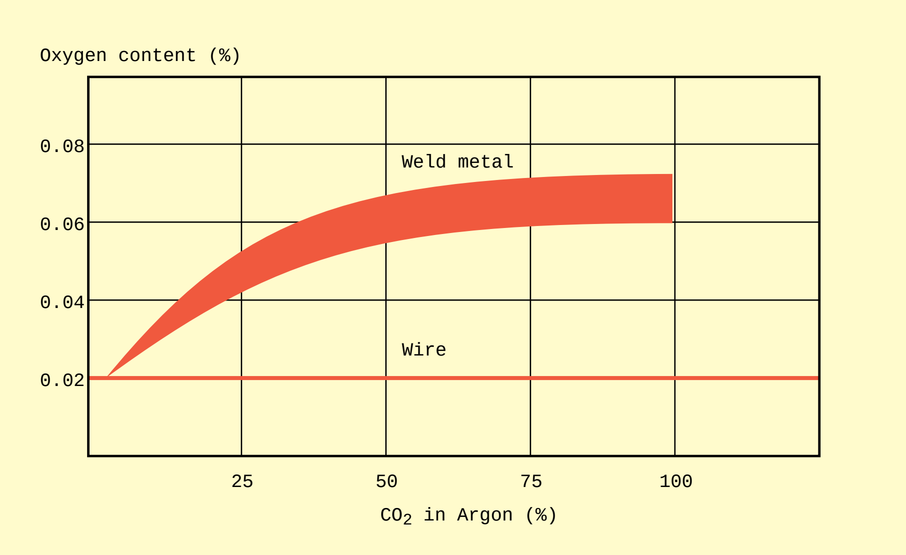
Extensive investigations show that the controlled addition of small quantities of NO in MISON shielding gases does not affect the mechanical properties.

Hydrogen can give rise to embrittlement as well as porosity, particularly in unalloyed, low-alloyed and other non-austenitic steel. However, GTA welding of unalloyed steels using shielding gases containing up to 2% hydrogen (MISON H2) is possible with higher productivity without any risk of embrittelment.

Argon mixtures give smoother transitions between weld bead and base metal than CO_2. This means better fatigue properties.







The influence of the shielding gas composition on oxygen content in weld metal. Higher oxygen content in the weld metal means more and coarser oxide inclusions. These may impair the strength of the weld metal.

5.2.2 Visual quality

SPATTER:

Apart from unsuitable welding parameters, the shielding gas is one of the factors which has the greatest influence on spatter. Pure CO_2 gives more, coarser spatter than argon mixtures. In most cases the spatter has to be removed by grinding before painting or other surface treatment.

SURFACE OXIDES:

Surface slag is composed of metal oxides which look like brownish, glassy islands on the weld bead. The stronger the oxidizing properties of the shielding gas (i.e the greater the CO_2 or O_2 content), the more oxides will form. Surface slag must be removed before painting or other surface treatment.

APPEARANCE OF THE WELD REINFORCEMENT:

Different shielding gases give different weld geometries. When argon mixtures are used for shielding, the weld pool flows out well and wets the parent metal, giving a small convexity and even transitions between weld bead and base metal. Pure CO_2 gives a high and more convex weld and poorer transitions to the parent metal.

5.3 Stainless steels

Stainless steels are divided into different types depending on their micro structure (which in turn depends on the type and amount of alloying element). We distinguish between ferritic, martensitic, austenitic, super-austenitic and ferrite-austenitic (duplex and super-duplex stainless steels). When selecting shielding gases you must consider the type of stainless steel you are dealing with. (See also section 8).

When GTA welding austenitic stainless steels, argon or argon with nitrogen or hydrogen should be used. For MAG welding of stainless steels, shielding gases containing 2-4% CO_2 or 1-2% O_2 should be used. Oxygen and carbon dioxide at higher levels create excessive oxidation. Very high alloy stainless steels have to be GMA welded with an inert gas in order to avoid excessive oxidation of the weld surface. In both GTA and GMA welding the amount of ozone can be reduced by using MISON shielding gases which contain small quantities of NO, which enhances the quality of the welder's working environment. The addition of NO also has a stabilizing effect on the arc in GTA and GMA welding (when welding with inert gases).

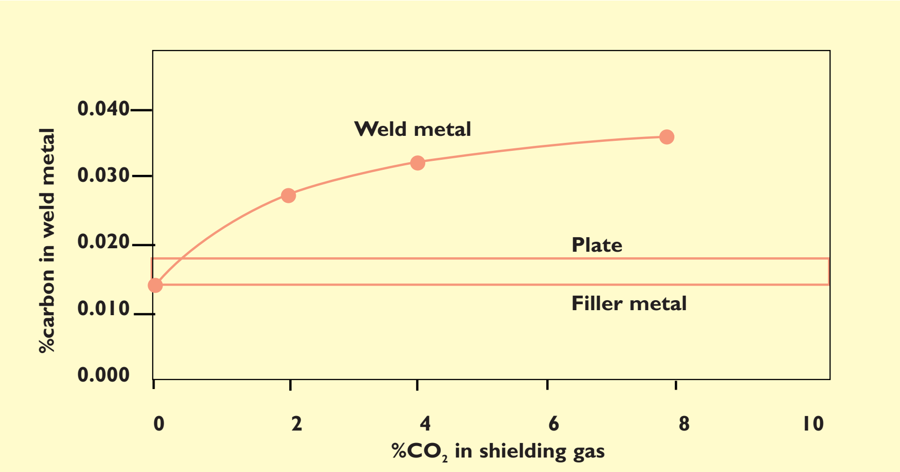
For GMA-welding with flux-cored wires, a different range of shielding gases is used. Most gas-shielded, flux-cored wires have been developed for use with a shielding gas containing 8-25% or 100% CO_2. There is no risk of carbon pick up despite the higher CO_2 content because of the chemical reaction between the flux and the gas and less risk of oxidation due to the protective slag cover.

5.3.1 Mechanical properties Provided the shielding gas matches the steel being welded, mechanical properties will not be affected. *For further information see sections 7 and 8.*

5.3.2 Corrosion resistance When welding stainless steels, the most important thing to consider is how the corrosion resistance is influenced by the welding operation.

If the carbon dioxide content in the shielding gas exceeds 3%, it can result in carbon pick-up in the weld metal, see the Figure. Chromium carbides can precipitate in the grain boundaries during welding. The areas close to the grain boundaries will get a lower chromium content and will subsequently be more sensitive to corrosion (grain boundary corrosion).

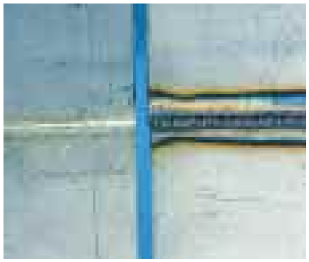
In some types of stainless steels, nitrogen is added as an alloying element in order to



Carbon pick-up in austenitic weld metal with different CO_2 additions to the shielding gas is usually not a problem.

improve the corrosion properties, but also to improve the mechanical strength. Examples of such steels are the super-austenitic stainless steels and the super-duplex stainless steels. When welding these steels a loss of nitrogen in the weld decreases the corrosion resistance. This may be compensated for in GTAW and GMAW by a proper alloying of the filler metal. In GTA welding without filler metal the loss of nitrogen has to be compensated for by using a shielding gas containing nitrogen (MISON N2) which counteracts the loss of nitrogen from the welding process.
The small addition of NO in MISON shielding gases does not affect the corrosion resistance of stainless steels. This has been shown from investigations carried out by the Institute for Metals Research in Sweden.

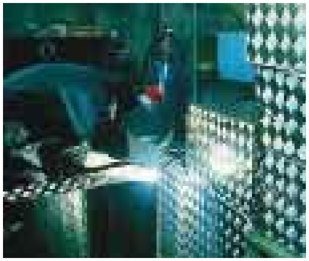
5.3.3 Root protection In some applications, the root side of the weld has to be protected. If not, an oxide layer will form that contains chromium from the metal immediately beneath this layer. This correspondingly lowers the content of this zone creating an increased risk of corrosion. Argon, argon/hydrogen and nitrogen/hydrogen are used for root protection. Argon is the most common root shielding gas. Adding hydrogen to argon provides a reducing gas that counteracts oxide formation while giving the root a smoother and more uniform shape. Nitrogen mixed with 10% hydrogen is also a common root protection gas. Nitrogen of high purity grade can be used as root protection gas when welding nitrogen-alloyed steels such as super-austenitic and super-duplex stainless steels. This will improve resistance to corrosion.



To the left: root side protected by argon-hydrogen mixture. To the right, no root protection.

MISON shielding gases should not be used for root protection due to the slight risk of oxidation caused by the NO content.

5.3.4 Visual quality In order to reduce oxidation of the weld, a shielding gas containing hydrogen can be used when GTA welding austenitic stainless steels (not ferritic or martensitic). The shielding gas MISON H2 contains 2% hydrogen. This not only results in lower oxidation of the weld, it also gives better penetration and a smoother transition between weld and base metal.



5.4 Aluminium and its alloys

For gas shielded arc welding of aluminium and its alloys, only inert gases are used. MISON shielding gas containing a small addition of NO is recommended due to its ozone reducing effect which significantly enhances the working environment. The small addition of NO has no adverse effect on the mechanical properties or the corrosion resistance of the weld metal.

In order to improve the penetration profile, helium may be added to the shielding gas. This will reduce the risk of welding defects such as poor fusion.

As aluminium and its alloys are sensitive to hydrogen and moisture, it is very important that the purity of the shielding gas is preserved all the way to the arc. Recommendations on maintaining the purity of the shielding gas are given in section 12.4.

5.5 Other metals

Only inert gases like argon and argon-helium mixtures are used for gas shielded arc welding of copper and its alloys. When welding thicker material, argon-helium mixtures can offer some advantages. Argon-helium mixtures provide a more energy-rich arc, thus supplying more heat to the weld, resulting in better penetration. It also reduces the need for preheating when welding copper. (Since copper has very good heat conductivity, preheating is often needed.)

Titanium and its alloys react readily with hydrogen, oxygen and nitrogen, causing embrittlement. Hydrogen in larger amounts also creates porosity. Only inert gases should be used for gas shielded arc welding of these metals. The small addition of NO in MISON shielding gas does not adversely affect the mechanical properties or the corrosion resistance. A discolouring of the weld may appear, however.

As titanium and its alloys are sensitive to hydrogen, oxygen and nitrogen it is very important that the purity of the shielding gas is preserved all the way to the arc. For demanding applications argon of very high purity grade (better than 99.995%) is recommended.

6 Safety precautions when welding

CONTENTS

6.1 When SMA welding (MMA)

Though not treated in depth here, in general, the fumes and the gases created are the same as for gas shielded arc welding. Some exceptions include fume from ingredients in the electrode coating. Generally SMA welding produces higher levels of fume than gas shielded arc welding.

6.2 When GMA welding mild steel

Ozone generation when welding mild steel is a complex function caused by a combination of filler metal, shielding gas and welding parameters. Carbon monoxide can be hazardous when using shielding gases with high CO_2 content in confined and poorly ventilated spaces.

6.2.1 Filler metal In general, solid wire generates less fume than flux cored wire. When welding with flux cored wire, the increased formation of fumes and nitrogen oxide actually leads to less ozone exposure.

6.2.2. Welding parameters Fume formation varies with the welding parameters. Short arc welding normally generates less fume if the parameters are set for a stable arc.In all transfer modes, set the parameters for as stable arc as possible. Avoid the mixed region (globular) where the metal transfer is unstable leading to more spatter and fume. Going from globular mode to spray arc reduces the fume formation dramatically, reaching its lowest point just when a stable spray arc is established. Additional current and voltage produces more vaporized metal and fumes. Note that shielding gases containing more than 30% CO_2 do not allow a spray arc at all. Choose mixtures with lower CO_2 content for wire feed speeds around 9-12 m/min. This is valid especially for medium and heavier thickness plate. When welding thinner materials with high productivity (RAPID ARC) it is also advisable to use lower CO_2 content (MISON 8). In optimizing the parameters for welding speed, quality and low fume formation, the ozone exposure increases. A shielding gas with ozone reduction capabilities (the MISON range) is therefore recommended. The higher the arc energy, the higher the ozone formation. Pulsed welding gives less hot droplets and lower amount of fumes but on the other hand higher ozone emissions.

6.2.3 Shielding gas Increasing the levels of oxidizing gases (CO_2 and O_2) in the shielding gas generally causes an increase in fume emission. Reduced CO_2 content gives less fume and less CO (as well as a higher welding speed). So a shielding gas that optimizes the welding speed, quality and low fume formation, actually increases the ozone exposure. In these circumstances, a shielding gas with ozone reduction capabilities (the MISON range) is therefore recommended.

6.3 GMA welding of stainless steel

Fume formation is dependent upon the welding parameters and the shielding gas used. Generally less fume results from lower CO_2 or O_2 levels, though more hazardous fumes can arise from the alloying elements such as chromium and nickel oxides. There is a risk of trivalent and hexavalent chromium in the fume, as well as nickel oxides. Ozone exposure is also a risk.

6.3.1 Filler metal Solid wire generally generates less fume than flux cored wire. When welding with flux cored wire, the increased formation of fumes and nitrogen oxide reduces the generation of ozone.

6.3.2 Welding parameters Short arcs normally give less fume if the parameters are set for a stable arc. In all transfer modes, set the parameters for as stable arc as possible. Avoid the mixed region (globular) where the metal transfer is unstable leading to more spatter and fume. Going from globular mode to spray arc reduces fume formation dramatically. Additional current and voltage results in more vaporized metal and fumes. Optimizing the parameters for welding speed, quality and low fume formation, increases the ozone exposure. A shielding gas with ozone reduction capabilities (the MISON range) is therefore recommended. The higher the arc energy, the higher the ozone formation. Pulsed welding gives cooler droplets and less fume but higher ozone emissions.

The use of respirators and fume extractors to remove toxic gases from the welding environment helps to limit exposure to excessive levels of ozone. Other precautions include welding in the correct posture or changing the type of helmet or mask being worn. In addition, you could consider adjusting your welding parameters and going for a lower CO_2 content. The advantage of using the MISON® range of shielding gases with their ozone reducing properties is that the problem is actively tackled at its source.

6.4 Aluminium

Lower fume formation is generally due to absence of oxidizing components in the shielding gas. Fume formation varies with the welding parameters. Short arcs normally give less fume if the parameters are set for a stable arc. In all transfer modes, set the parameters for as stable arc as possible. Avoid the mixed region (globular) where the metal transfer is unstable leading to more spatter and fume. Switching from globular mode to spray arc reduces the fume formation dramatically. Additional current and voltage results in more vaporized metal and fumes. Ozone exposure is a complex function of the combination of filler metal, shielding gas and welding parameters. Ozone formation depends on the type of aluminium alloy. Optimizing the parameters for welding speed, quality and low fume formation actually increases ozone exposure. A shielding gas with ozone reduction capabilities (the MISON range) is therefore recommended. Generally speaking, the higher the arc energy, the higher the ozone formation Pulsed welding gives less hot droplets and lower amount of fumes but higher ozone emissions. Ozone formation with aluminium is very high This is especially the case when welding AlSi alloys.

6.5 Copper

Fume formation depends on the parameters being used. Generally lower fume formation is due to absence of oxidizing components in the shielding gas. Copper oxides in the fume are dangerous. Ozone exposure is a function of the combination of filler metal, shielding gas and welding parameters. Precautions regarding welding parameters are the same as for aluminium. Choice of shielding gas is as for aluminium above.

6.6 When GTA welding

6.6.1 Mild steel GTA welding of mild steel generally generates low levels of fume.

The higher the arc energy, the greater the ozone formation. A shielding gas with the addition of NO (the MISON range) for reduced ozone exposure is recommended.

6.6.2 Stainless steel Fume formation is generally low, but the fumes tends to be more hazardous due to the presence of trivalent and hexavalent chromium in the fume as well as nickel and nickel oxides. The higher the arc energy, the greater the ozone formation. Shielding gas with additional NO (the MISON range) is recommended to minimize ozone exposure.

6.6.3 Aluminium Fume formation is generally low. Ozone formation strongly depends on the type of aluminium alloy. A shielding gas with additional NO (the MISON range) is recommended to minimize ozone exposure.

6.6.4 Copper Fume formation is generally low. Watch out for dangerous copper oxides in the fume. Ozone exposure is likely to be high. A shielding gas with additional NO (the MISON range) is recommended to minimize ozone exposure.

6.6.5 Nickel Fume formation is generally low. Watch out for dangerous nickel oxides in the fume. A shielding gas with additional NO (the MISON range) is recommended to minimize ozone exposure.

6.7 Surface coatings

Surface coatings should generally be removed before welding as they may add hazardous compounds to the working environment and create porosity in the weld metal. If this is not possible, adequate ventilation or local extraction should be provided. Most coatings can be removed by blasting or grinding. The coating should be removed in an area of 25-50 mm on both sides of the joint. The higher the current, the wider the zone that should be cleaned. Cadmium should be removed chemically due to its high level of toxicity. When welding cadmium plated material, the strictest precautions must be taken. These include the use of a respirator and an efficient fume extraction system.

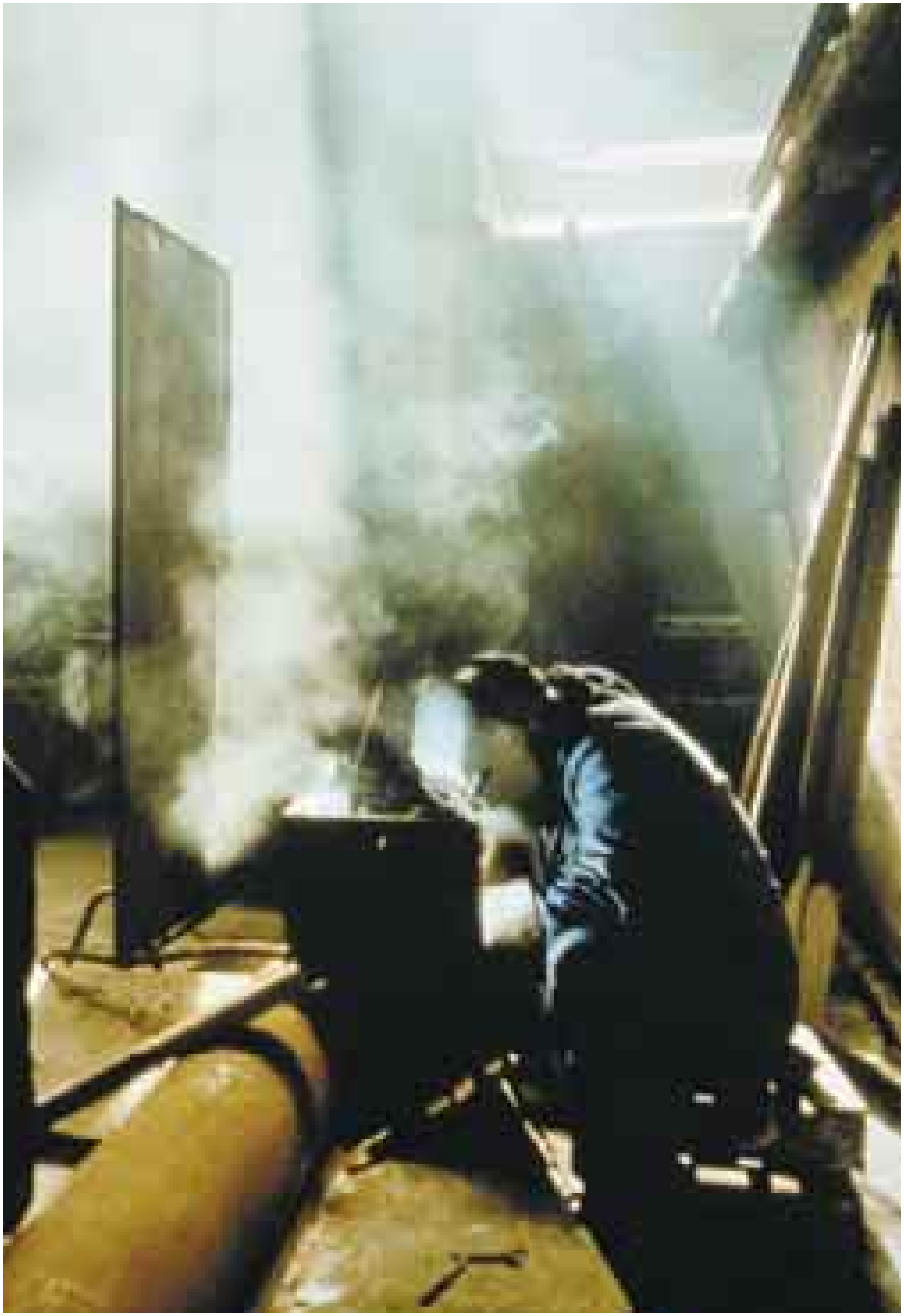
Always use adequate safety equipment and a shielding gas that minimizes the effect of air pollutants.

6.8 Oil

Oil is not necessary to remove from health aspects but rather for quality reasons. If the oil is removed with the help of chlorinated hydrocarbon, this cleaning agent 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.

Localized extractor fans to help improve the working environment



Fume - an inescapable part of welding

7 Shielding gases for unalloyed and low-alloy steels

CONTENTS

7.1 General

With regard to weldability, unalloyed and low-alloy steels can be divided into the following classes according to their composition, strength and how they have been heat treated. When it comes to selection of shielding gas, all these steels can be grouped together.

Carbon steels and carbon-manganese steels	(C-steel and CMn-steels)
Micro-alloyed steels High strength low-alloy steels (HSLA)	C- or CMn-steels fine-grained treated by small additions of aluminium, niobium, vanadium or titanium to increase strength without loss of ductility. Thermo-mechanical controlled process (TMCP).
Extra High Strength steels	Fine-grain-treated (as above) and quenched-and-tempered after hot rolling. Can be welded in the same way as ordinary structural steels. Some require pre-heating where the material is thick, to reduce the risk of cold cracking. Contact the steel manufacturer for further information.
Low-alloy steels	These steels are alloyed with up to a few percent of alloying elements such as chromium, nickel and molybdenum in order to increase the mechanical properties. The alloying elements have a pronounced influence on the weldability of the metal, and therefore the different steels within this group vary widely in their suitability for welding. The steel manufacturer can give further information.

When selecting shielding gases for unalloyed and low-alloy steels, it is more important to consider the following factors than the type of base metal.

- Welding method: GMAW or GTAW?
- Manually welding or mechanized welding?
- Type of filler metal: solid wire, flux-cored wires or metal-cored wires?
- Short-arc, spray-arc, pulsed arc or high productivity welding (RAPID PROCESSING)?

For GTA welding of unalloyed and low-alloy steel we recommend MISON Ar. If higher productivity is called for, MISON H2 can be used for GTA welding of unalloyed steels of thinner sections.

Filler metals for GMA welding of unalloyed and low-alloy steels can take the form of solid wires, flux-cored wires or metal-cored wires. Most filler metals have been designed and tested for a certain shielding gas. Different shielding gases can normally be used and you should contact your AGA representative for the correct recommendation. Solid wires for unalloyed and low alloyed steels allow for a wider flexibility regarding, e.g. CO_2 content than do high alloy steels and certain flux cored wires.

For robot welding and other mechanized GMA welding, and for high-productivity welding such as RAPID PROCESSING, MISON 8 is the best choice. It gives a high welding speed and very little spatter and surface slag and is intended for both short-arc, spray-arc and pulsed arc welding.

For manual welding MISON 18 is recommended. MISON 18 is the most versatile gas for both short arc and spray arc welding. It can be used for both mechanized and manual welding. It is therefore the best choice for welding shops with mixed production where only one gas is preferred. For manual short arc welding, MISON 25 is an alternative that gives good weld metal fluidity and wettability to the base metal.

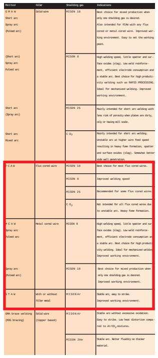
Selection chart for unalloyed and low-alloy steel

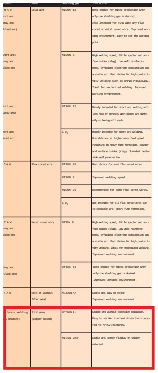
Method	Filler	Shielding gas	Indications
G M A W Short arc Spray arc (Pulsed arc)	Solid wire	MISON 18	Best choice for mixed production when only one shielding gas is desired. Also intended for FCAW with any flux cored or metal cored wire. Improved working environment. Easy to set the working point.
(Short arc) Spray arc Pulsed arc		MISON 8	High welding speed, little spatter and surface oxides (slag). Low weld reinforcement, efficient electrode consumption and a stable arc. Best choice for high productivity welding such as RAPID PROCESSING. Ideal for mechanized welding. Improved working environment.
Short arc (Spray arc)		MISON 25	Mainly intended for short arc welding with less risk of porosity when plates are dirty, oily or having mill scale.
Short arc Mixed arc		CO_2	Mainly intended for short arc welding. Unstable arc at higher wire feed speed resulting in heavy fume formation, spatter and surface oxides (slag). Somewhat better side wall penetration.

Local variations in the shielding gas programme may exist.

Method	Filler	Shielding gas	Indications
F C A W	Flux cored wire	MISON 18	Best choice for most flux cored wires.
		MISON 8	Improved welding speed.
		MISON 25	Recommended for some flux cored wires.
		C O_2	Not intended for all flux cored wires due to unstable arc. Heavy fume formation.
M C A W Spray arc Pulsed arc	Metal cored wire	MISON 8	High welding speed, little spatter and surface oxides (slag). Low weld reinforcement, efficient electrode consumption and a stable arc. Best choice for high productivity welding. Ideal for mechanized welding. Improved working environment.
Spray arc (Pulsed arc)		MISON 18	Best choice for mixed production when only one shielding gas is desired. Improved working environment.
G T A W	With or without filler metal	M I S O N Ar	Stable arc, easy to strike. Improved working environment.

Local variations in the shielding gas programme may exist.





Method	Filler	Shielding gas	Indications
GMA braze welding (MIG brazing)	Solid wire (Copper based)	MISON Ar	Stable arc without excessive oxidation. Easy to strike. Low heat distortion compared to Ar/CO_2 mixtures.
		MISON 2He	Stable arc. Better fluidity on thicker material.

Local variations in the shielding gas programme may exist.

8 Shielding gases for stainless steels

CONTENTS

8.1 General

Stainless steels are divided into different types depending of the micro structure of the steels. The most commonly used types are shown in the table below.

Type of stainless steel:	Typical applications:
Ferritic	Structural components
Martensitic	Structural components
Austenitic (AISI 304, 316)	Hygienic products, white goods, cryogenics, chemicals
Super-austenitic	Chemicals, pulp and paper
Duplex (ferrite-austenitic)	Offshore, chemicals
Super-duplex	Offshore, chemicals, pulp and paper

Ferritic and martensitic stainless steels have roughly the same strength properties as unalloyed and low-alloyed steels. They are excellent as structural steels and they feature good heat resistance, but are not as corrosion-resistant as austenitic stainless steels.

The most commonly used of the stainless steels are the austenitic stainless steels. These have good corrosion resistance and the impact strength is good even at low temperatures.

In super-austenitic stainless steels a high content of chromium, nickel, molybdenum and nitrogen provides good corrosion resistance. Unlike ordinary austenitic stainless steels, which show a few percent of ferrite after welding, the superaustenitic grades remain fully austenitic after welding.

Ferrite-austenitic stainless steels are known as duplex steels. The advantages of duplex steels are high yield strength and good resistance to stress corrosion, but also to general corrosion and pitting.

Super-duplex stainless steel is a later generation of duplex stainless steels. Their resistance to corrosion has been improved still further by an increased alloy content, e.g. nitrogen.

8.2 Why different shielding gases suit different stainless grades

As different stainless steels have different micro structure they may be more or less sensitive to different components in the shielding gas. For more information, see section 5, Quality.

8.2.1 GMA welding The CO_2 or the O_2 content of the shielding gas should not be too high in order to prevent oxidation of the weld surface. A certain amount of O_2 or CO_2 is nonetheless required to stabilize the arc when GMA welding steels. MISON 2 with 2% CO_2 from the MISON® range of shielding gases is recommended for standard types of stainless steels (ferritic, austenitic and duplex stainless steels).

The addition of helium to the shielding gas as in MISON 2He will increase penetration. Fluidity also increases, giving a flatter weld bead.

When welding super-austenitic and super-duplex stainless steel, the use of shielding gases with oxidising components like MISON 2 or MISON 2He is not recommended, as for these steels the surface will become too oxidized. If pure argon is used the arc will be unstable resulting in spatter and, usually, poor penetration. We recommend MISON Ar, an inert gas. The small NO addition is sufficient to stabilise the arc, which means no spatter and good penetration.

For flux-cored arc welding, shielding gases containing higher CO_2 concentrations are usually recommended by the filler metal producer. We recommend MISON 18 which contains 18% CO_2 .

8.2.2 GTA welding The most versatile gas for GTA welding of stainless steel is MISON Ar. MISON H2, with a 2% hydrogen content, has a reducing effect on the oxides. It is intended for GTA welding of austenitic and super-austenitic stainless steels. Besides oxide-free weld surfaces, it also gives a higher welding speed, better penetration and smoother transition between weld and base metal. MISON H2 should not be used for ferritic and ferrite-austenitic steels like duplex and super-duplex stainless steels.

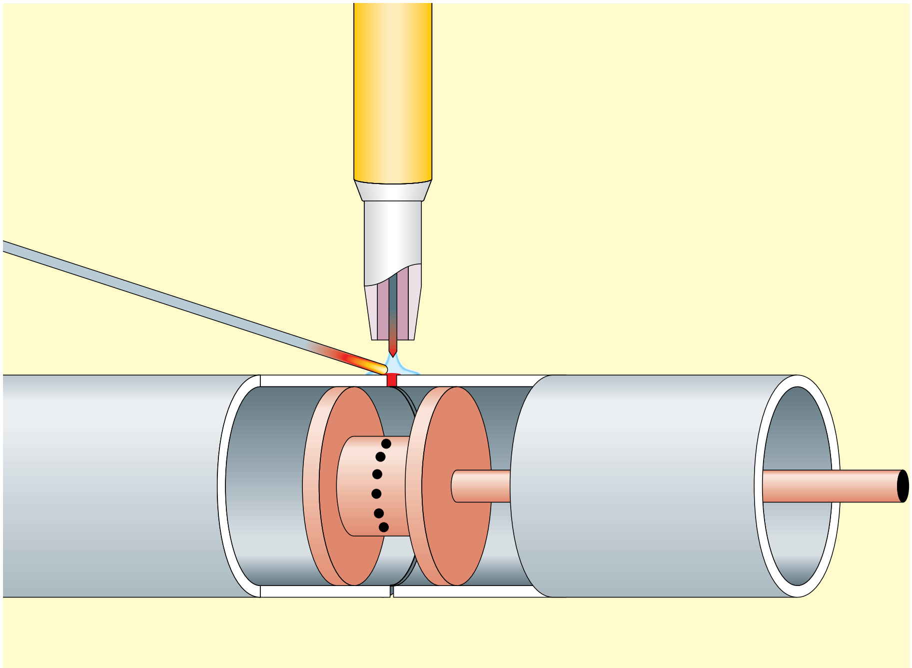
Super-austenitic and the super-duplex stainless steels are alloyed with nitrogen and other alloying components. When welding these steels a loss of nitrogen in the weld metal decreases the pitting resistance. This can be compensated for in GTA and GMA welding by a proper alloying of the filler metal. In GTA welding without filler metal the loss of nitrogen has to be compensated for by using MISON N2, a shielding gas which, besides argon and helium, also contains 1.8% nitrogen.

8.2.3 Root protection For root protection purposes, argon can be used for all types of stainless steels. Argon is also used as rooot protection for unalloyed and low-alloy steels as well as for aluminium, copper and titanium.

Also high purity nitrogen can be used for root protection of austenitic stainless steels and unalloyed or low-alloy steels. It can even prove beneficial when welding super-austenitic, duplex and super-duplex stainless steels since it will prevent nitrogen loss from the weld metal, thus preserving the good pitting resistance of this type of stainless steels.

Hydrogen has a reducing effect on the oxides on the root side. Shielding gases containing hydrogen like (N_2 + 10% H_2) and (Ar+5% H_2) can be used for austenitic and super-austenitic steels.

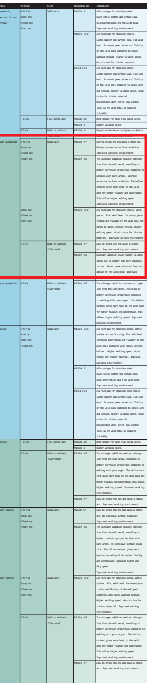
MISON shielding gases are not recommended as root shielding gases since they could give raise to a slightly oxidation.



Selection chart for stainless steel

Metal	Method	Filler	Shielding gas	Indications
Austenitic, martensitic and ferritic	GMAW Spray arc Pulsed arc Short arc	Solid wire	MISON 2	All-round gas for stainless steel. Gives little spatter and surface slag. Good penetration and flat weld bead. Improved working environment.
			MISON 2He	All-round gas for stainless steels. Little spatter and surface slag. Flat weld bead. Increased penetration and fluidity of the weld pool compared to gases without helium. Higher welding speed. Good choice for thicker material.
			ROBINON	All-round gas for stainless steels. Little spatter and surface slag. Flat weld bead. Increased penetration and fluidity of the weld pool compared to gases without helium. Higher welding speed. Good choice for thicker material. Recomended when extra low carbon level in the weld metal is required (<0,030%).
	FCAW	Flux cored wire	MISON 18	Best choice for most flux cored wires.
			MISON 8	Higher welding speed.
	GTAW	With or without filler metal	MISON Ar	Easy to strike the arc and gives a stable arc. Improved working environment.

Local variations in the shielding gas programme may exist.

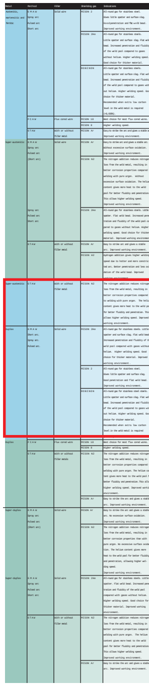


Metal	Method	Filler	Shielding gas	Indications
Super-austenitic	G M A W Spray arc Pulsed arc (Short arc)	Solid wire	MISON Ar	Easy to strike arc and gives a stable arc. Without excessive surface oxidation. Improved working environment.
			MISON N2	The nitrogen addition reduces nitrogen loss from the weld metal, resulting in better corrosion properties compared to welding with pure argon. Without excessive surface oxidation. The helium content gives more heat to the weld pool for better fluidity and penetration. This allows higher welding speed. Improved working environment.
	Spray arc Pulsed arc Short arc		MISON 2He	All-round gas for stainless steels. Little spatter. Flat weld bead. Increased penetration and fluidity of the weld pool compared to gases without helium. Higher welding speed. Good choice for thicker material. Improved working environment.
	G T A W	With or without filler metal	MISON Ar	Easy to strike arc and gives a stable arc. Improved working environment.
			MISON H2	Hydrogen addition gives higher welding speed due to hotter and more constricted arc. Better penetration and less oxidation of the weld bead. Improved working environment.

(Continued on next page)

Local variations in the shielding gas programme may exist.

Metal	Method	Filler	Shielding gas	Indications
Super-austenitic	GTAW	With or without filler metal	MISON N2	The nitrogen addition reduces nitrogen loss from the weld metal, resulting in better corrosion properties compared to welding with pure argon. The helium content gives more heat to the weld pool for better fluidity and penetration. This allows higher welding speed. Improved working environment.
Duplex	G M A W Short arc. Spray arc. Pulsed arc.	Solid wire	MISON 2He	All-round gas for stainless steels. Little spatter and surface slag. Flat weld bead. Increased penetration and fluidity of the weld pool compared with gases without helium. Higher welding speed. Good choice for thicker material. Improved working environment .
			MISON 2	All-round gas for stainless steel. Gives little spatter and surface slag. Good penetration and flat weld bead. Improved working environment.
(Continued on next page)			ROBINON	All-round gas for stainless steel steels. Little spatter and surface slag. Flat weld bead. Increased penetration and fluidity of the weld pool compared to gases with out helium. Higher welding speed. Good choice for thicker material. Recomended when extra low carbon level in the weld metal is required (<0.030%).



Local variations in the shielding gas programme may exist.

Metal	Method	Filler	Shielding gas	Indications
Duplex	F C A W	Flux cored wire	MISON 18	Best choice for most flux cored wires.
			MISON 8	Higher welding speed.
	G T A W	With or without filler metals	MISON N2	The nitrogen addition reduces nitrogen loss from the weld metal, resulting in better corrosion properties compared to welding with pure argon. The helium content gives more heat to the weld pool for better fluidity and penetration. This allows higher welding speed. Improved working environment.
			MISON Ar	Easy to strike the arc and gives a stable arc. Improved working environment.
Super-duplex	G M A W Spray arc Pulsed arc (Short arc)	Solid wire	MISON Ar	Easy to strike the arc and gives a stable arc. No excessive surface oxidation. Improved working environment.
			MISON N2	The nitrogen addition reduces nitrogen loss from the weld metal, resulting in better corrosion properties than with pure argon. No excessive surface oxidation. The helium content gives more heat to the weld pool for better fluidity and penetration, allowing higher welding speed. Improved working environment.

(Continued on next page)

Local variations in the shielding gas programme may exist.

Metal	Method	Filler	Shielding gas	Indications
Super-duplex	G M A W Spray arc Pulsed arc Short arc	Solid wire	MISON 2He	All-round gas for stainless steels. Little spatter. Flat weld bead. Increased penetration and fluidity of the weld pool compared with gases without helium. Higher welding speed. Good choice for thicker material. Improved working environment.
	G T A W	With or without filler metal	MISON N2	The nitrogen addition reduces nitrogen loss from the weld metal, resulting in better corrosion properties compared to welding with pure argon. The helium content gives more heat to the weld pool for better fluidity and penetration. This allows higher welding speed. Improved working environment.
			MISON Ar	Easy to strike the arc and gives a stable arc. Improved working environment.

Local variations in the shielding gas programme may exist.

9 Shielding gases for aluminium

CONTENTS

9.1 General

Aluminium and aluminium alloys are structural materials with many good and useful properties such as low weight, low susceptibility to corrosion, good processing properties, high heat- and electrical- conductivity as well as good low temperature properties. As a result, aluminium is becoming a growth area with many new applications as an engineering material.

Pure aluminium has poor mechanical properties and is therefore not used in load bearing constructions. To obtain the right properties it is therefore usually alloyed and heat treated or hardened.

The main groups of aluminium alloys are: Al-Cu, Al-Mn, Al-Si, Al-Mg, Al-Si-Mg, Al-Zn. In Europe, the most common type of classification for base metals is the AA classification. The different types and typical applications are shown in the table on the next page.

The world's largest catamaran, manufactured in aluminium at Finnyard Oy.

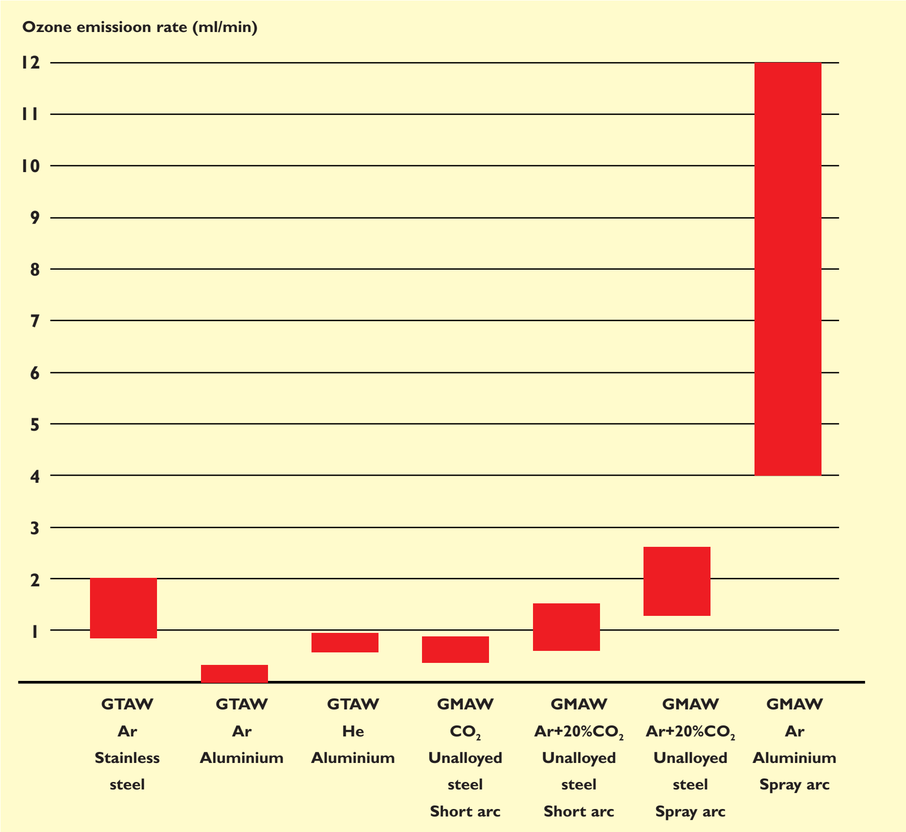
AA terminology	Alloy type	Weldability	Typical applications
1XXX	Non-alloyed	Good	Packings, decorative applications
2XXX	Copper	Reduced	Aircraft sheet construction
3XXX	Manganese	Good	General purpose applications, strip.
4XXX	Silicon	Good	Filler metal
5XXX	Magnesium	Good/reduced	Marine components, pressure vessels, railroad cars
6XXX	Silicon+Magnesium	Good	Automotive frames
7XXX	Zinc	Reduced	High strength aircraft applications
8XXX	Other alloying elements		

Pure aluminium has good weldability. The weldability of the different aluminium alloys varies and care must be taken when choosing base metal for a construction which is going to be welded.

9.2 Shielding gases for aluminium

For aluminium welding (GMAW and GTAW), inert gases are used. MISON Ar, an inert gas, effectively reduces the amount of ozone formed during welding. This is especially important when MIG welding aluminium, as higher amounts of ozone are formed than with other welding methods and base metals, as shown in the figure below.

Emissions of ozone measured during welding trials in a laboratory.



Mixtures of argon and helium can also be used in order to increase the penetration when welding thicker material or to achieve higher welding speed when welding thinner material.

Selection chart for aluminium

Method	Filler	Shielding gas	Indications
GMAW Spray arc Pulsed arc	Solid wire	MISON Ar	Easy to strike the arc. Improved arc stability vs. argon or argon-helium mixtures. Improved working environment.
		Ar+30%He	Improved sidewall penetration. High welding speed. Suitable for thicker materials.
		Ar+60%He	Further improved sidewall penetration. High welding speed. Suitable for the most heavy plates.
GTAW Spray arc Pulsed arc	With or without filler metal	MISON Ar	Easy to strike the arc. Improved arc stability vs. argon or argon-helium mixtures. Improved working environment.
		Ar+30%He	Improved sidewall penetration. High welding speed. Suitable for thicker materials.
		Ar+60%He	Further improved sidewall penetration. High welding speed. Suitable for the most heavy plates.

Local variations in the shielding gas programme may exist.

CONTENTS

Selection chart for copper and its alloys

Method	Filler	Shielding gas	Indications
GMAW Spray arc Pulsed arc (Short arc)	Solid wire	MISON Ar	Easy to strike the arc. Improved arc stability vs. argon or argon-helium mixtures.
		Ar+30%He	Improved sidewall penetration. High welding speed. Suitable for thicker materials.
		Ar+60%He	Further improved sidewall penetration. High welding speed. Suitable for the most heavy plates.
GTAW Spray arc Pulsed arc (Short arc)	With or without filler metal	MISON Ar	Easy to strike the arc. Improved arc stability vs. argon or argon-helium mixtures.
		Ar+30%He	Improved sidewall penetration. High welding speed. Suitable for thicker materials.
		Ar+60%He	Further improved sidewall penetration. High welding speed. Suitable for the most heavy plates.

Local variations in the shielding gas programme may exist.

10.1 Shielding gases for copper and its alloys

Copper has good formability, malleability and corrosion resistance to many substances. The electrical and heat conductivity of pure copper is high, though it is lower for copper alloys. The weldability varies a lot between the different copper alloys.

Copper and its alloys is widely used for electrical conductors, water tubing, valves and fittings, heat exchangers and chemical equipment.

For MIG welding and GTA welding of copper and copper alloys we recommend the MISON®Ar. When welding thicker sections mixtures of argon and helium can be used. The addition of helium gives better penetration and lowers the need for pre-heating.

10.2 Shielding gases for titanium and its alloys

Titanium is often used for its good non-corrosive properties and its low weight. The yield and tensile strength is high, especially for titanium alloys. Its stiffness, however, is low.

Titanium is available in many grades, both unalloyed and alloyed. The American ASTM grading system is the most widely used system in the West.

The most common unalloyed grade is ASTM Grade 2, picked for general purposes. So called alpha-alloys are alloyed with aluminium and tin in order to give better strength. Grade 6, the most common alpha-alloy, is mainly used in aerospace applications.

Beta-alloys are alloyed with vanadium, molybdenum and/or chromium. These alloys demonstrate the highest strength. Grades 19 and 21 are widely used in the off-shore industry. These grades combine high strength with very good resistance, but are difficult to weld.

When welding titanium and titanium alloys, inert shielding gases should be used. MISON Ar can be used . Titanium is extremely sensitive to hydrogen, oxygen and nitrogen and for demanding applications, argon of very high purity (better than 99.995%) is recommended.

Selection chart for titanium and its alloys

Method	Filler	Shielding gas	Indications
GTAW	With or without filler metal	High purity argon (99,995%)	Clean metal surface. Trailing shield may be necessary
		MISON Ar	For less demanding applications. Easy to strike the arc. Better arc stability

10.3 Shielding gases for nickel base alloys

For some purposes the corrosion resistance of stainless steel is not sufficient. Increasing the quantity of the alloying elements (nickel, chromium and molybdenum, for example) helps improve the corrosion properties. However, if the total volume of alloying elements exceeds 50 %, the metal may not be called stainless steel, but are known as nickel based alloys. Some of these alloys do not contain iron at all.

Nickel-based alloys are used where extremely good corrosion resistance is required.

For GTA welding of nickel based alloys we recommend MISON Ar or MISON H2. The addition of hydrogen helps reduce oxides and increase welding speed. For MIG welding of nickel based alloys, inert shielding gases should be used. We recommend MISON Ar. The small NO addition stabilizes the arc without giving excessive surface oxidation and provides a spatter-free weld.

Selection chart for nickel base alloys

Method	Filler	Shielding gas	Indications
GMAW Spray arc Pulsed arc	Solid wire	MISON Ar	Easy to strike the arc. Good arc stability without excessive surface oxidation. Improved working environment.
GTAW	With or without filler metal	MISON Ar	Easy to strike the arc. Stable arc. Improved working environment.
		MISON H2	Hydrogen addition gives higher welding speed. Better penetration and less oxidation of the weld bead. Improved working enviroment.

Local variations in the shielding gas programme may exist.

11 The MISON® range of shielding gases

CONTENTS

11.1 Selection chart

	GMAW (MIG/MAG)	FCAW	MCAW	GMA(MIG brazing	GTAW (TIG)
Mild steel	MISON 18 MISON 8 MISON 25 CO_2	MISON 18 MISON 8 MISON 25 CO_2	MISON 8 MISON 18	MISON Ar MISON 2He	MISON Ar
Stainless steel	MISON 2 MISON 2He MISON Ar MISON N2 ROBINON	MISON 18 MISON 8			MISON Ar MISON N2 MISON H2
Aluminium	MISON Ar Ar+30% He Ar+60% He				MISON Ar Ar+30% He Ar+60% He
Copper, Titanium and Nickel base alloys	MISON Ar Ar+30% He Ar+60% He				MISON Ar Ar+30% He Ar+60% He

Local variations in the shielding gas programme may exist. Contact your AGA representative for further information.

MISON 8

(Ar + 8%CO_2 + 0.03% NO)

Used for GMA welding of all unalloyed and low alloy steels. Also used with metal cored wires (MCAW). It is intended mainly for spray and pulsed arc.

Gives high welding speed, little spatter and surface slag, low weld reinforcement, efficient electrode consumption and a stable arc. Perfect for high output welding. Used with RAPID PROCESSING. Good for robot welding and other mechanized welding. Better working environment with low fume and ozone. EN 439 group = M21

MISON 18

(Ar + 18%CO_2 + 0.03% NO)

For GMA welding of all unalloyed and low alloy steels. For short arc, spray arc and pulsed arc welding. Also for FCAW with any flux cored wire. Best choice for mixed production welding shops. EN 439 group = M21

MISON 25

(Ar + 25%CO2 + 0.03%NO)

For GMA welding and FCAW of all unalloyed and low-alloy steels. MISON 25 has been developed to have good properties in short arc welding and it is not intended for pulsed arc welding. It is less sensitive to surface contamination and coatings and gives good protection against porosity. (EN 439 group = M21).

MISON Ar

(Ar + 0.03%NO)

Used as for pure argon but has excellent ozone reduction properties which significantly enhance the working environment Used for GTA welding of mild steels, stainless steels, aluminium and its alloys etc. Gives a stable arc which is easy to strike. Also for GMA welding of aluminium and high alloyed stainless steels such as super duplex and super austenitic steels. Give stable arc. Can also be used with copper and nickel-based alloys. Not for root protection. Also recommended for GMA braze welding of galvanized steel. EN 439 group = I1

MISON 2

(Ar + 2%CO_2 + 0.03%NO)

Allround choice for GMA welding of stainless steels and especially for the common austenitic grades (such as AISI 304 and 316) as well as for standard duplex steels. For short arc and spray arc as well as for pulsed arc in manual and mechanized applications.

Low spatter and surface slag, good penetration and flat weld beads.
EN 439 group = M12

N.B. All MISON shielding gases contain a small addition of NO which significantly enhances the working environment.

MISON 2He

(Ar + 2%CO_2 + 30%He + 0.03%NO)

Allround shielding gas for GMA welding of stainless steels and most austenitic grades (such as AISI 304 and 316) as well as ferritic and standard duplex steels. For short arc and spray arc as well as pulsed arc, manual and mechanized. Gives little spatter and surface slag, good penetration and flat weld beads. Good for welding thicker materials. It is also suitable for GMA braze welding (MIG brazing) of galvanized steel in thicknesses above 1.5 mm. EN 439 group = M12

MISON N2

(Ar + 1.8%N_2 + 30%He + 0.03%NO)

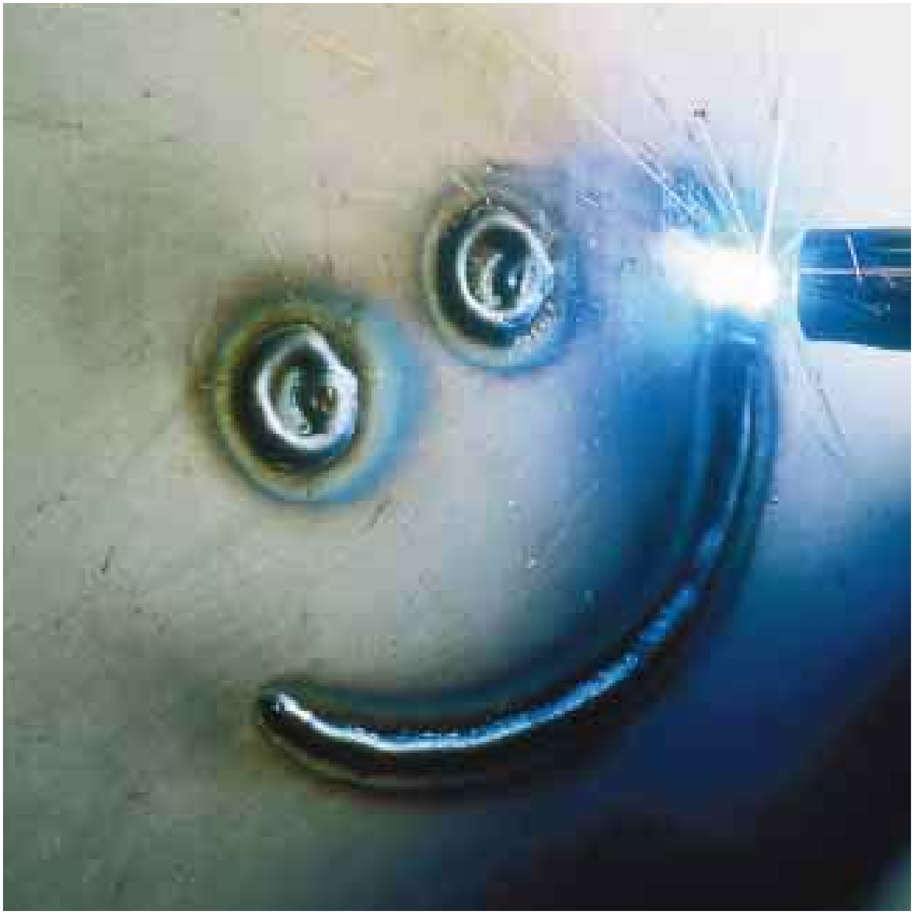
For GTA welding of duplex stainless steels and other austenitic stainless steels alloyed with nitrogen. Nitrogen in the gas limits nitrogen loss from the weld giving better corrosion resistance and good mechanical properties. Also for GTA welding of super-austenitic steels that are nitrogen alloyed. It can also be used for GMA welding of super-anstenitic and super-duplex steels.

Gives hotter weld pool for better fluidity and penetration bringing better speed and productivity. EN 439 group = I3

MISON H2

(Ar + 2%H2 + 0.03%NO)

For GTA welding of austenitic and super-austenitic stainless steels and nickel base alloys. Hydrogen gives a hotter, more constricted arc for better welding speed, better penetration and smoother transition between weld and base metal. Hydrogen also reduces oxidation in the weld bead. EN 439 group = R1



MISON shielding gas shield the weld and the welder.

12 Supply of shielding gases

CONTENTS

12.1 Forms of supply

The MISON® range of shielding gases can be stored and transported in a variety of different states to suit the customer. AGA mainly supplies gases in the following forms:

1. In liquid state in tanks. This is the most economic alternative for high gas consumption.
2. In a gaseous state, in cylinder bundles. Suitable for the medium-sized consumer. A bundle can contain 10 or 12 cylinders with one common gas outlet. The bundle can be handled by a truck.
3. In a gaseous state, in separate cylinders. This is the most common form of supply.

Many welding and cutting companies choose to install a central gas supply. The central supply consists of a gas manifold with cylinders or bundles, a pipe system and a number of outlets suitably placed round the workshop. For very large gas consumption, the alternative is a vaporization plant consisting of a storage tank for liquefied MISON® Ar, connection pipes, a vaporizer and a mixer.

Central supply systems guarantee continuity of supply, save time and space and reduce transportation costs.

12.2 Cylinders and bundles

AGA gases and gas mixtures are supplied in standard cylinders fitted with either a protective cap which is screwed off before use, or with a fixed valve protector. All cylinders are clearly marked for ease of recognition.

12.3 Threads

In order to increase safety and avoid incorrect connection, the cylinder valves have different outlet threads, depending on the type of gas or gas mixture. If you are unsure, please contact your local AGA representative.

12.4 Gas purity

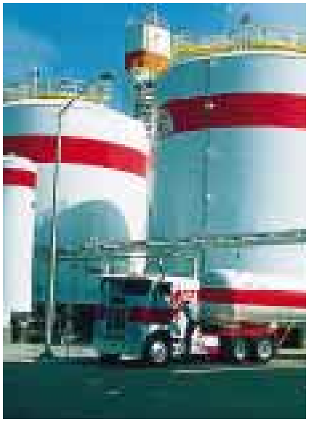
Gas purity has a great influence on welding . It affects factors like weld quality and welding speed. It also affects electrode life in GTA welding. AGA guarantees purity at a certain stage of delivery: at the gas cylinder valve or at an agreed valve in a gas supply system. After that it is the user who is responsible for maintaining purity all the way to the gas nozzle.

TO OPTIMIZE GAS PURITY:

- blow the cylinder valve clean before fitting the regulator.
- allow gas to flow through regulator and hoses a few seconds before using.
- avoid unnecessarily long and wide gas hoses.
- use undamaged gas hoses and see that all couplings are tight.
- if the welding equipment is water-cooled, see that no water is leaking.
- use the correct gas flow. Too high flow creates an unstable gas shield, and too low flow is insufficient to protect both arc and weld pool.

Also, remember that in gas arc welding the gas shield can be disturbed, and thus contaminated, by cross drafts, spatter in the gas nozzle and unstable arc.

12.5 Safe handling of gases



Use of gases for welding involves no risks, if the gases and equipment are handled correctly. Therefore the following things have to be known:

- properties of the gases, and any potential hazards
- how the equipment should be handled
- what protective measures have to be taken before, during and after the work
- what official regulations must be followed

12.6 Laws and regulations

The laws affecting the use of gas embrace building, fire prevention, work environment and flammable goods. National bodies issue regulations, and there are often also local rules.

If you require further information, contact AGA. We can provide all necessary information needed for the safe handling of our products. We can provide training in safety, and we have a number of publications on this subject.

13 Glossary of terms

Anode positive elecrode or terminal

Austenitic steel a steel that mainly has an austenitic structure at room temperature.

Bronchitis an inflammatory condition in the respiratory passages

Carcinogenic producing cancer, cancerous

Cathode negative electrode or terminal

Copperosis changes in the lungs caused by inhaling dust containing copper.

Duplex a steel that has a mixed, austenitic-ferritic structure at room temperature

Emphysema condition where the alveoli of the lungs break down, reducing oxygen level in the blood and making it hard to breathe

FCAW (Flux Cored Arc Welding) a cored wire comprising a metal tube filled with flux is used with the same basic equipment as for GMA welding (MIG/MAG) with solid metal wires

Ferrite-austenitic (duplex) a steel that has a mixed, austenitic-ferritic structure at room temperature

Ferritic of steel that has a mainly ferritic structure at room temperature

GMAW (Gas Metal Arc Welding) also known as MIG/MAG. A small diameter electrode wire is fed continuously into the arc. The arc is struck from the electrode to the workpiece and metal is melted from the electrode, transferred across the arc gap and finally incorporated into the molten pool.

GTAW (Gas Tungsten Arc Welding) also known as TIG. The process employs an electrode made from metal with a high melting point, usually tungsten, which is not melted. The primary function of the arc is to supply heat to melt the parent metal. The welding can be done with or without any filler metal that must be added separately.

MAG (Metal Active Gas) is part of GMAW when an active (oxidizing) component such as CO_2 or oxygen is used in the shielding gas.

Martensitic a steel that can be given a martensitic structure through hardening.

MCAW (Metal Cored Arc Welding) a cored wire comprising a metal tube filled with metal powder is used with the same basic equipment as for GMA welding (MIG/MAG) with solid metal wires

Metal fume fever a condition similar to the flu. Symtoms are fever, shivers, sweating and sickness. Caused by inhalation of various metal oxides.

Micron 0.001 mm.

MIG (Metal Inert Gas) is part of GMAW when an inert (not reacting) shielding gas is used such as argon or helium.

MIG brazing the GMAW process is used but without melting the parent metal, only the filler wire is melted.

MMA (Manual Metal Arc) also known as SMAW. A welding process that uses a flux covered electrode.

Ozone (O_3) a colourless, highly toxic gas. When exposed to ultraviolet light from, for example, a welding arc, oxygen atoms in the air rearrange themselves into ozone.

Pitting small local corrosion attacks resulting in pits.

ppm parts per million.

Pulmonary oedema collection of fluid in the lungs.

Siderosis inflammation of the lungs caused by inhaling dust containing iron.

Silicosis disease of the lungs caused by inhaling silica.

SMAW (Shielded Metal Arc Welding) also known as MMA. A welding process that uses a flux covered electrode.

Super duplex highly alloyed duplex steel.

Super-austenitic highly alloyed austenitic steel.

TIG (Tungsten Inert Gas) also known as GTAW. The process employs an electrode made from metal with a high melting point, usually tungsten, which is not melted. The primary function of the arc is to supply heat to melt the parent metal. The welding can be done with or without any filler metal that must be added separately.

TWA (Time Weighted Average) a measure of recommended maximum exposure to a substance over a specific working time period.

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A natural partner

In collaboration with the customer, we develop total solutions covering gases, process know-how, equipment and services. With new gas technology, we make it possible for the customer to increase profitability, safety and quality, and at the same time protect the environment.

Our major gas markets are Europe, the USA and Latin America. We meet the requirements of more than 1,000,000 customers in manufacturing industries and also in the fields of chemistry, food processing, medicine, metallurgy and specialty gases.

AGA's gas experience has been gathered over almost a century. Our application know-how and knowledge of gas production, delivery and use can be invaluable. When new, advanced gas technology is to be introduced, we are a natural partner.

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