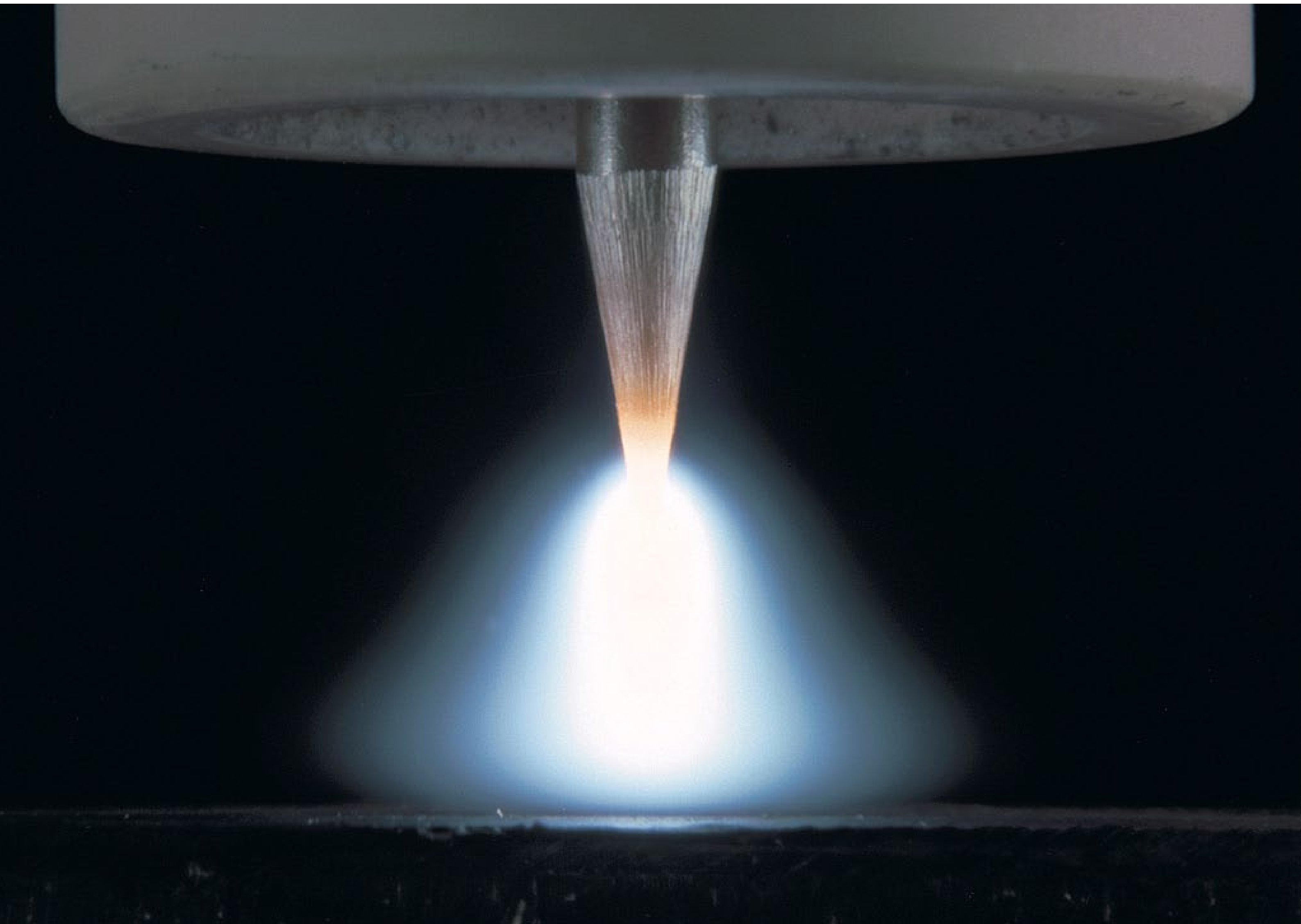
A Member of
The Linde Group

Shielding Gas Handbook.



Contents.

Introduction.

This handbook examines TIG and MIG/MAG welding.
TIG welding uses a non-consumable tungsten electrode and is short for "Tungsten Inert Gas". MIG/MAG welding uses solid or cored wire as the electrode, fed continuously into the arc. MIG is short for "Metal Inert Gas" and MAG is short for "Metal Active Gas".

Introduction
The welding world wants to constantly improve productivity, quality and the work environment.
The construction materials, filler materials and power sources are developing, welding parameters change and new shielding gases are introduced.

The purpose of this handbook is to give a useful overall picture of the shielding gases available for gas arc welding. The handbook describes the significance of shielding gases on the welding process and their effect on productivity, quality and the work environment.
It also gives you guidance in selecting the shielding gas best suited to each welding method and base material from the wide selection of shielding gases, and answers frequently asked questions concerning the purpose, selection and effects of shielding gases.

If you wish to know which shielding gas is best suited to your welding work, you can find the answer in Chapters 7–9. If you wish to find out the base materials for which a specific shielding gas is designed, you can find the answer in Chapter 10, "Applications of Shielding Gases".

If you cannot find answers to all of your questions in this handbook, you can always ask AGA for more information.You can find our contact information from the back cover of this handbook.

Purpose of shielding gas.

Contents

1.1 What are the effects of shielding gas

The basic task of a shielding gas in gas arc welding is to shield the heated and molten metal from the effects of the surrounding air and provide advantageous ignition conditions for the arc.

If the surrounding air gets into contact with the hot metal and the molten pool, the oxygen in the air will oxidise the molten metal and its surroundings, while the nitrogen and humidity in the air cause porosity in the weld.

The composition of the shielding gas affects the way in which material is transferred from the melting filler wire to the molten pool, which in turn affects the number and size of weld spatter.

The shielding gas also affects the appearance and shape of the weld, welding speed, scale loss of alloy materials (which affects the strength of the weld), corrosion properties and the formation of oxides (slag formation) on the surface of the weld bead.

1.2 Effects of the different shielding gas components

1.2.1 Argon

Argon (Ar) is an inert (nonreactive) gas. It does not cause oxidation and has no other effects on the chemical composition of the weld. For this reason, argon is the main component in most shielding gases for TIG and MIG/MAG welding.

1.2.2 Carbon dioxide and oxygen

Pure argon is not suited to MAG welding steel, as the arc becomes too unstable. An oxidising component is required in the shielding gas to increase the stability of the arc and ensure even material transfer during welding. Carbon monoxide (CO_2), oxygen (O_2) or a mixture of them acts as such an oxidiser. The amount of the oxidising component in the shielding gas depends on the steel grade and the welded structure

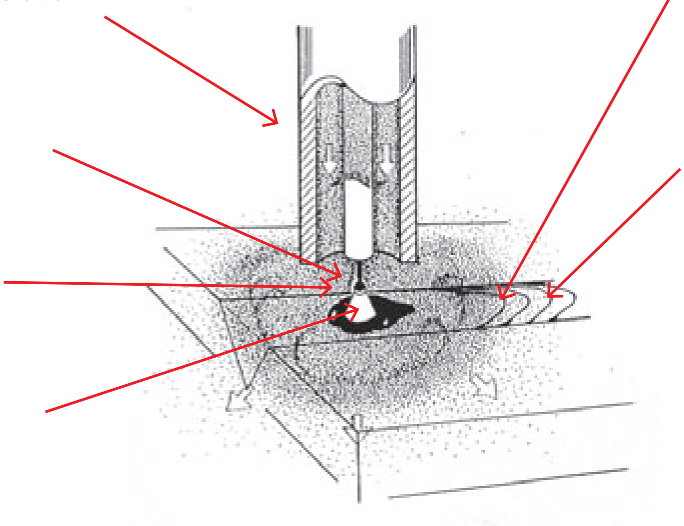
The effect of shielding gas on MIG/MAG welding

Material transfer
The shielding gas has a large effect on material transfer, as well as the size of drops and the forces affecting the drops in the arc.

Shielding effect
The shielding gas shrouds the molten pool and the hot metal from the effects of the surrounding air.

The work environment
The shielding gas affects the formation of fumes and smoke.

Arc stability
The shielding gas affects the stability and ignition of the arc.



Weld appearance
The shielding gas has a significant effect on the amount of spatter and slag.

Metallurgy and mechanical properties
The shielding gas has an effect on the scale loss of alloy materials and the dissolving of oxygen, nitrogen, hydrogen and carbon in the molten pool. This affects the mechanical and corrosion properties of the weld.

Weld profile shape
The shielding gas affects the height of the weld bead, the weld penetration and its fusion with the base material.

Welding speed
The selection of a shielding gas affects the welding speed and through this the overall welding costs.

The arc in gas arc welding can be divided into three parts: the cathode, the anode and the arc plasma region. In MAG welding, where the filler material forms the positive electrode (anode), the cathode region in the work piece is formed of one or several cathode spots. Oxidising gas is required to stabilise these cathode spots, which otherwise tend to wander on the surface of the work piece causing spatter and an uneven weld.

1.2.3 Carbon dioxide or oxygen?

It is most often more economical to use carbon dioxide instead of oxygen as the oxidising component of the shielding gas. One of the benefits is better geometry and appearance of the weld compared to argon-oxygen mixtures. This is caused by the differences in the fluidity of the molten pool due to the surface tension and amount of oxidation. When carbon dioxide is used instead of oxygen, oxidation and slag formation are reduced, which has a beneficial effect on the appearance of the weld and the amount of required post-weld finishing work.

Another benefit of carbon dioxide as the oxidising component is better penetration, in particular side penetration. This is primarily caused by a higher arc voltage and energy transfer and the higher arc pressure caused by carbon dioxide compared to argon-oxygen mixtures.

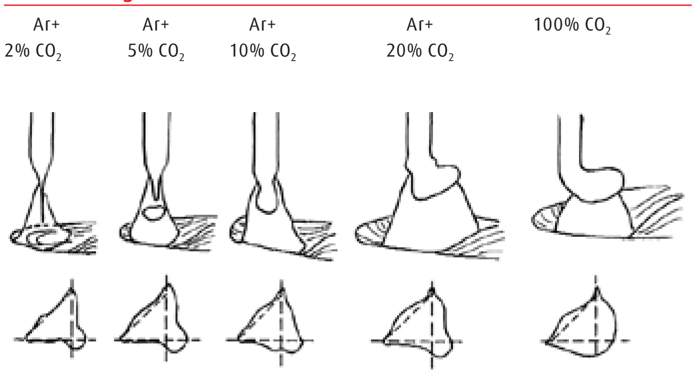
1.2.4 Helium

Helium (He) is an inert gas, as is argon. Helium is used in combination with argon, with an addition of few per cent of carbon dioxide or oxygen, in the shielding gases for MAG welding of stainless steels.

Pure helium or helium-argon mixtures are used as shielding gases in TIG and MIG welding.

Compared to argon, helium provides wider penetration and higher welding speed due to higher arc energy. When helium is used, welding is more sensitive to changes in the arc length, and the arc is more difficult to ignite in TIG welding compared to argon.

The effect of the carbon dioxide content in a shielding gas on MAG welding



The figure illustrates the effect of the carbon dioxide content in a shielding gas on material transfer and typical penetration in welding structural steels in the spray arc region. Increase in the carbon dioxide content of the gas causes high arc pressure, improving the shielding effect of the gas and increasing the side penetration, while also increasing the size of the weld bead and the amount of spatter, surface slag and welding fume.

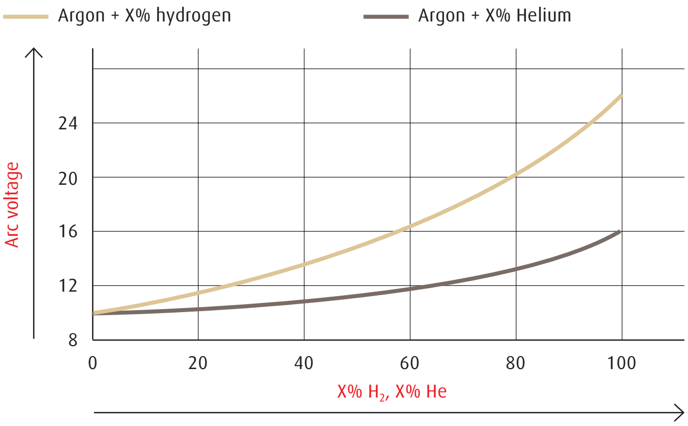
Helium and argon-helium mixtures can be used for root shielding when it is necessary to get the gas to rise up in order to achieve root shielding. As helium is lighter than air, it rises upwards and is safe to use as a non-flammable gas.

1.2.5 Hydrogen

Hydrogen (H_2) can be used as a shielding gas component in the TIG welding of austenitic stainless steels.

Added hydrogen provides a hotter and narrower arc, enabling higher welding speed and better penetration. It also makes the fusion of the weld beam and the base material smoother and reduces the oxidisation of the weld.

The effect of hydrogen and helium added to argon on arc voltage



The higher the helium or hydrogen content in the shielding gas, the higher the arc voltage. Heat transfer to the weld increases, which can be utilised as better penetration and higher welding speed.

In root shielding, added hydrogen is beneficial due to its oxide-reducing effect. FORMIER® 10, 10% of hydrogen in nitrogen, is an often used root shielding gas. However, it is not recommended for use as the root shielding gas for ferritic-austenitic (duplex) steels. Argon or pure nitrogen is better suited to that purpose.

1.2.6 Nitrogen

Nitrogen (N_2) is used as a shielding gas component in the TIG welding of stainless austenitic steels with nitrogen additions and superduplex steels. In these steels, nitrogen is used as an additive with up to 0.5% content to improve the strength of the steel and prevent spot corrosion. Adding a few per cent of nitrogen in the shielding gas helps prevent the nitrogen loss otherwise occurring in the weld during welding.

FORMIER® 10, 10% of hydrogen in nitrogen, is an often used reducing root shielding gas.
It improves the root-side spot corrosion resistance on austenitic steels. The same effect can be achieved in the welding of superduplex steels by using pure nitrogen for root shielding.

1.2.7 Nitrogen monoxide

Nitrogen monoxide (NO) added to MISON® shielding gases reduces the amount of ozone generated during welding. This improves the welder's work environment and reduces the irritation of mucous membranes caused by ozone. Improvements in the work environment also improve the welder's ability to concentrate, productivity and welding quality. The nitrogen monoxide in the MISON® shielding gases also have a stabilising effect on the arc in the MIG welding and soldering of stainless steels and aluminium.

The MISON® shielding gas programme.

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2.1 Background

The importance of shielding gas in the protection of the electrode, molten pool and hot metal during gas arc welding was examined in the previous chapter. The composition of shielding gases is based on wide-scale research and development work, the goal of which is to develop shielding gases for the optimisation of the welding process and meet the development challenges of new materials and techniques.

2.2 Ozone is generated during gas arc welding!

The main focus of the development work has usually been only on the role of the shielding gas in the protection of the weld. AGA has developed a shielding gas programme which also takes into consideration the reduction of problematic air impurities generated during welding.

This programme is called MISON® – the shielding gas product programme for the protection of the welder and the weld.

Welding fumes and gases – are generated in the air as impurities during all welding.

The fumes mainly consist of metal oxides, while the gases consist of ozone, nitrogen oxides and carbon monoxide. The risk of exposure to these impurities is reduced by various means, such as fresh air helmets and respirators, general ventilation, local exhaust, etc. These means, which are naturally always required, share the purpose of protecting the welder from impurities.

However, the most effective protection is achieved when the generation of impurities can be prevented entirely, or the generated amount limited. This is the fundamental idea of the MISON® shielding gases, which effectively reduce the amount of ozone generated during welding.

Ozone is one of the most harmful impurities generated during welding. Its health limit (highest acceptable average concentration during a workday HTP_{8h}, 2009) is only 0.05 ppm, which is 600 times lower than that of carbon monoxide, for example.

A majority of the measures taken to improve the productivity and quality of welding (such as lowering the carbon dioxide content of the shielding gas or changes in welding parameters) have increased the amount of ozone generated. This would appear to be the price we have to pay for development. However, MISON® shielding gases help keep the amount of generated ozone low while allowing the optimisation of the productivity and quality of welding.

During his or her career, a welder is exposed numerous times to ozone concentrations exceeding the HTP limits, unless proper protective measures are taken. When MISON® shielding gases are used, most of the generated ozone is eliminated in the vicinity of the arc without ever getting to the welder's breathing zone.

2.3 Ozone – good and bad

Ozone is a gas appearing naturally in the atmosphere. Most of it is located in the stratosphere, around 25 kilometres above the surface of the Earth. This ozone layer is vital to us, filtering the UV radiation of the Sun and thus forming a protective shield for life on Earth. The depletion of the ozone layer is considered to be the cause of skin cancer becoming more common, a trend which has been established.

Ozone nearer to the ground has become familiar in certain regions due to often repeated ozone warnings. In large urban areas, large amounts of ozone are generated due to the combined effect of the hydrocarbon and nitrogen dioxide emissions and sunlight.

People exposed to ozone experience general symptoms such as a burning sensation in the throat, dry mucous membranes, cough, headaches, chest pains and breathing difficulties. These are the same symptoms that are detected during welding. For persons suffering from asthma, high ozone levels may be fatal. There is currently no solid data on the long-term effects of high ozone levels, but there are clear signs indicating that ozone may cause chronic bronchitis and pulmonary oedemas.

2.4 The MISON® shielding gas programme

In 1976, AGA was granted a patent for a method reducing the amount of ozone generated during gas arc welding with the help of shielding gas.

A revolutionary new shielding gas was brought into the market – MISON®. It had been detected that a small amount of nitrogen monoxide (NO) reacts easily with ozone, forming oxygen (O_2) and nitrogen dioxide (NO_2). The ozone levels in the combustion gases are reduced, resulting in a better work environment for the welder.
MISON® is an entire family of shielding gases, including the right shielding gas for all welding applications. For as long as two decades we have received uniform information from the users of the beneficial effects that MISON® shielding gases have on the work environment, and therefore on productivity and quality.The following chapters include more information on MISON® shielding gases.

2.5 Science in the background

The research performed on the ozone layer in the 1970s (which led to three researchers being awarded with the Nobel Prize in chemistry in 1995) was the starting point for the development of the MISON® gases. This research showed that nitrogen monoxide (NO) is one of the substances easily reacting with ozone.

Based on the research, AGA's team of researchers began investigating how this phenomenon could be utilised in shielding gases. As a result, AGA's MISON® shielding gases were invented. AGA's founder, Gustaf Dalén, has received a Nobel Prize himself in 1912.

The work environment.

Contents

3.1 Background

All welding methods include risk factors endangering the health and safety of the welder. The risk factors include fumes, gases, radiation, heat, noise and heavy lifting.

In recent years, more and more attention has been paid to the creation of healthy and safe working conditions.
Interest has been increased by the general growth in environmental awareness, new regulations and the realisation that a good work environment also improves the productivity of work and therefore the profitability of the entire company.
See below for some reasons on which the increase in productivity through improved work environment is based:

- Poor working conditions will likely lead to several absences due to illness or injury
- The replacement needs training, and the amount of correction work required on the welding is often increased
- poor working conditions also often cause the work performance level to fluctuate during the day, in particular with regard to productivity and quality
- motivation and work satisfaction are increased when the employees notice that the employer actively invests in their well-being

With regard to the work environment, this handbook focuses on air impurities generated during welding, the amount and quality of which we can significantly affect merely by selecting the right shielding gas.

3.2 Air impurities typical to welding environments

Air impurities related to welding comprise dust, fumes and gases generated during welding. The existence of dust and fumes is usually easy to notice by eye.

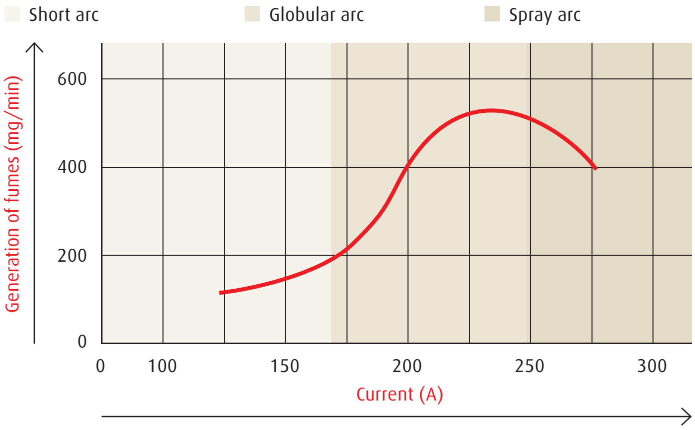
However, the generated hazardous gases are often invisible to the naked eye. The welders must be protected from the generated impurities, for example by arranging sufficient general ventilation and using local extraction or fresh air helmets. It is important to avoid the plume of combustion gas rising from the weld and use welding parameters giving a stable arc. The choice of shielding gas also affects the work environment. For example, by selecting a MISON® shielding gas, you can reduce the probability of exposure to harmful ozone levels during welding.

3.3 Dust and fumes

In a welding context, particles which are larger than 1 µm (0,001 mm) are defined as dust. They fall near the arc and mainly comprise welding spatter. Welding fumes are formed of particles smaller than 1 micrometre. Fumes generally remain floating in the air and can be carried far from the welding location. Fumes mainly consist of metal oxides. They are generated when the molten metal is first vaporised in the arc and is then condensed and oxidised due to the surrounding air. In MIG/MAG welding, fumes are almost entirely generated from the filler material and the substances it contains. The base metal contributes only a minor amount of the total fumes. In cored wire welding, the powder contained in the wire affects the generation and composition of fumes.

Spatter plays an integral role in the generation of fumes – the more spatter, the more fumes. The amount of spatter is affected by the welding parameters and the composition of the shielding gas.

MAG welding, unalloyed steel, wire diameter 1.0 mm



In the short and spray arc regions the arc is stable, resulting in lower fume generation than in the globular arc region. The higher fume generation in the spray arc region compared to short arc is explained by the increased metal vaporisation.

When moving from the globular arc region to a spray arc, fume generation is clearly reduced and is at its lowest when a stable spray arc has been reached. If the current and voltage are further increased, the fume generation rate will also increase.If the carbon dioxide content of the shielding gas exceeds 25–30 per cent, a stable spray arc is no longer pos- sible and there is heavy fume generation.

The effect of different factors on fume generation and the work environment.

Affecting factor	Effect
MMA welding	More fumes than in MIG/MAG and TIG welding
MIG/MAG welding	The amount of fumes depends on the welding parameters and the shielding gas
TIG welding	Low amount of fumes
Filler material	Largest cause of fumes. Affects the amount and composition. Solid wires generate less fumes than cored wires. Most fumes are generated from wire without shielding gas.
Welding parameters	Short arc = low amount of fumes
	Globular arc = more fumes
	Pulse arc = less fumes
	Spray arc = less fumes
Shielding gas	More spatter = more fumes
	Shielding gas has low CO_2 or O_2 content = less fumes
	Shielding gas has high CO_2 or O_2 content = more fumes

3.4 Fume composition

Fume composition depends on, for example, how easily the additives mainly contained in the filler material tend to vaporise and oxidise. The following is a short description of the most typical fume components and their harmful effects.

Chromium, Cr
When chromium alloy steels are welded, chromium III and chromium VI compounds are generated, the latter of which are more harmful as they are water-soluble. The fumes cause irritation of the mucous membranes and metal fume fever, and they also affect the respiratory tract and lungs. Chromium is considered to be carcinogenic.

Copper, Cu
Copper can be contained in the base material or the filler material. Most filler material wires for unalloyed and low-alloy steels are copper-coated. Breathing copper fumes may cause metal fume fever and lung deformation.

Iron, Fe
Ferrous oxides are present in welding fumes when ferrous metals are welded. Long-term of breathing ferrous oxides may cause iron dust lung. It is condition somewhat similar to silicosis but not as dangerous.

Manganese, Mn
Manganese is used as an alloy component in steel and filler materials. Manganese oxide is poisonous in large quantities. The symptoms of a manganese poisoning are irritation of the mucous membranes, tremors, stiffness in the muscles and overall weakness. It can also affect the nervous system and the respiratory tract. Manganese may also cause metal fume fever.

Nickel, Ni
Nickel is a common alloy material in stainless steels together with chromium. The nickel oxides in the welding fumes may cause metal fume fever. Nickel is among the substances suspected to be carcinogenic.

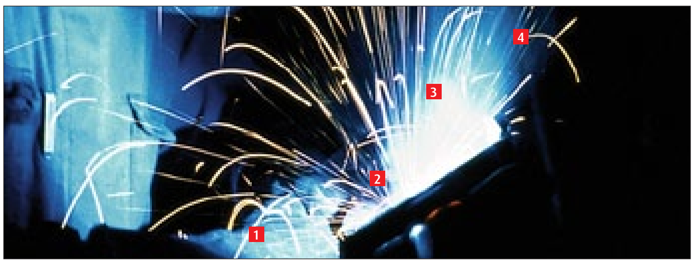
Zinc, Zn
Zinc oxide fumes are generated when galvanised sheet metal is welded. Breathing zinc fumes causes metal fume fever.

3.5 Gases generated during welding

Gases generated during welding have a significant impact on the welder's work environment. The following section contains information on the main gases, their origin and effects. In gas arc welding, the very high temperature and the UV radiation of the arc are the main causes of the generated gases. The gases examined in the following are toxic and/or suffocating.

3.5.1 Ozone, O_3

Ozone is a colourless, highly toxic gas. In particular, ozone affects the mucous membranes in the respiratory tract. Overexposure to ozone causes irritation or a burning feel in the throat, cough, chest pains and wheezing breath.



Ozone's HTP_{8h} value in Finland is only 0.05 ppm O_3 (HTP values, 2009)

1. The welding arc generates UV radiation
2. The UV radiation collides with the oxygen molecules in the air, splitting it and forming two separate oxygen atoms (O_2 -> O+O)
3. An oxygen atom meets a new oxygen molecule, forming an ozone molecule (O+O_2 -> O_3)
4. Most of the ozone is formed at a distance of 10–15 cm of the arc. The ozone rises up with the hot air column and enters the welder's breathing zone

Ozone is formed of the oxygen in the air as the UV radiation generated by the arc collides with an oxygen molecule which is split into oxygen atoms. These will react further with oxygen molecules forming ozone, with the sum reaction being as follows: $3O_2$ -> $2O_3$

UV radiation at wavelengths of 130–175 nm generates the most ozone. A majority of ozone is formed in the immediate vicinity of the arc. Ozone exits the arc region along with the hot plume of smoke rising from the welding spot.

The amount of ozone emissions depend on how much ozone was originally formed and how much of that amount is reduced back into oxygen (O_2) in the surrounding smoke plume.

Ozone is reduced in the smoke plume in the following three ways:

1. Thermal reduction in the zone nearest to the arc, where the temperature is 500°C or higher.

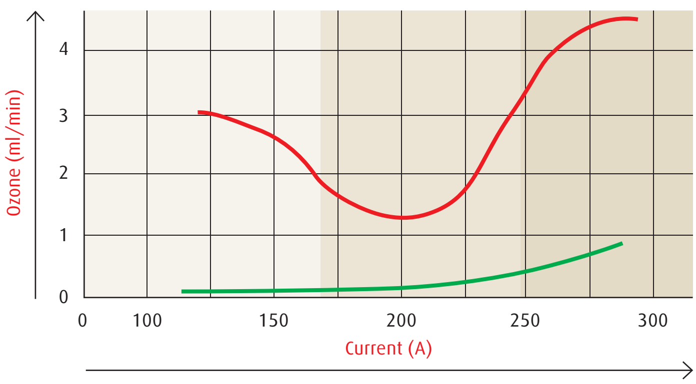
2. Catalytic reduction, where the metal oxide particles in the smoke plume act as the catalyst.

3. Chemical reduction as the ozone reacts with other gases in the smoke plume. The most efficient reaction is between ozone and nitrogen monoxide (NO) as follows: NO + O_3 -> NO_2 + O_2

The 0.03% nitrogen monoxide addition in MISON® shielding gases is sufficient to effectively reduce the amount of ozone generated during welding.

Unalloyed steel, wire diameter 1.0 mm

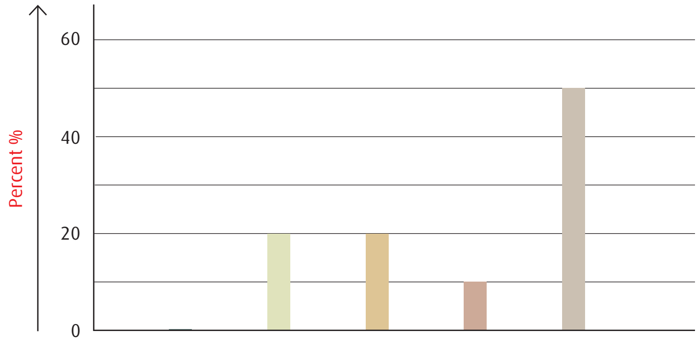
Short arc Globular arc Spray arc
Argon gas mixture MISON® gas mixture



The effect of MISON® shielding gas on MAG welding.
When MISON® shielding gas is used, less ozone is generated.
With standard gas mixtures, ozone emissions are lowest in the globular arc region, where fume emissions are at their maximum.
Cf. the graph in section 3.3.

The probability of exposure of ozone concentrations

MMA welding - Unalloyed steel	0%
MAG welding - Unalloyed steel	20%
TIG/MAG welding - Stainless steel	20%
TIG welding - Aluminium alloys	10%
MIG welding - Aluminium alloys	50%



The probability of exposure to the effects of ozone concentrations of over 0.1 ppm (over two times the HTP_{8h} values) in welding work; the source material is the research of Prof. Ulvarsson in 1978.
Using MISON® shielding gases, the exposure probability is significantly reduced.

Affecting factor	Effect
Welding process	The combined effect of the filler material, shielding gas and welding parameters. More nitrogen oxides are formed during MMA welding, resulting in lower ozone generation than in MIG/MAG or TIG welding.
Filler material	Cored wires generate somewhat more smoke, and ozone generation is lower than when solid wires are used.
Base material	MIG welding of aluminium results in the largest ozone emissions.
Welding parameters	Higher arc energy = more ozone. Pulse welding = less smoke but more ozone.
Shielding gas	More fumes = less ozone. Low O_2 or CO_2 content = lots of ozone.
Spatter	More spatter = more fumes = less ozone.
Other	More nitrogen oxides = less ozone.

The effect of different factors on ozone generation and the work environment.

3.5.2 Nitrogen monoxide, NO

Nitrogen monoxide is formed out of the oxygen and nitrogen in the surrounding air.
A spray arc or hot metal starts the following reaction:
$N_2 + O_2 \rightarrow 2NO$

The HTP_{8h} value for nitrogen monoxide in Finland is 25 ppm (HTP values, 2009).

Air entering the arc space causes the generation of nitrogen monoxide (NO). The more air enters the arc space, the higher the generation of nitrogen monoxide.

3.5.3 Nitrogen dioxide, NO_2

Part of the nitrogen monoxide formed in the vicinity of the arc can change into nitrogen dioxide (NO_2) at lower temperatures as follows:
$2NO + O_2 \rightarrow 2NO_2$

The HTP_{8h} value for nitrogen dioxide in Finland is 3 ppm NO_2 (HTP values, 2009).

Most nitrogen dioxide (NO_2) is formed during MMA welding, then MIG/MAG welding and the least during TIG welding.

If there is ozone in the vicinity, the nitrogen monoxide will primarily react with it forming nitrogen dioxide and oxygen ($NO + O_3 \rightarrow NO_2 + O_2$). This reaction is utilised by the MISON® shielding gases to reduce the ozone concentration in the combustion gases.

The generation of small amounts of nitrogen dioxide as a result of ozone elimination is acceptable, as ozone is considered to be clearly more problematic than nitrogen dioxide in welding.

3.5.4 Ozone (O_3) and nitrogen dioxide (NO_2)

The nitrogen monoxide (NO) added to MISON® shielding gases removes ozone (O_3) but increases the amount of nitrogen dioxide (NO_2). The combined effect of impurities of similar type and classified as harmful occurring simultaneously in the smoke can be evaluated as follows:
$C_1/HTP_1 + C_2/HTP_2 + ... + C_n/HTP_n < 1$

In the formula, C is the measured concentration of the substance in question, and HTP is the concentration of the substance classified as harmful. In the breathing zone, the total must be less than 1. Because the HTP value of ozone is clearly lower than that of nitrogen dioxide, it is beneficial to reduce the amount of ozone generated in the smoke.

The HTP_{8h} value for carbon monoxide in Finland is 30 ppm CO. (HTP values, 2009) Correspondingly, the HTP_{8h} value for carbon dioxide is 5000 ppm CO2 (HTP values, 2009).

Carbon monoxide is an odourless and colourless gas which prevents oxygen from binding with blood.

Carbon monoxide poisoning causes fatigue, headaches, chest pains, trouble concentrating and, finally, unconsciousness. The higher the carbon dioxide content of a shielding gas, the more carbon monoxide is formed.

In normal conditions during MAG welding, the generation of carbon monoxide is not, however, an especially serious problem. However, dangerously high carbon monoxide concentrations may occur in closed, poorly ventilated spaces.

3.5.5 Carbon monoxide, CO

Carbon monoxide is mainly formed as carbon dioxide (CO_2) in the shielding gas is broken up as follows: $2CO_2 \rightarrow 2CO + O_2$

3.6 Other impurities

Other impurities generated during welding originate from the coating of the metal, solvents used in the cleaning of the metal surface or an unclean sheet metal surface as they come into contact with heat and UV radiation.

Cleaning the surfaces to be welded in the vicinity of the arc is an effective way of limiting the generation of such impurities. Solvents containing chlorinated hydrocarbons, for example ethylene trichloride, can form toxic compounds in the air due to the effect of the arc. Such cleaning agents should not be used in the cleaning of welded workpieces.

The effect of shielding gas on productivity.

Contents

4.1 General

The total costs of welding per produced unit comprise several different factors. The chart beside illustrates the factors of which the costs are formed and how they are divided. Shielding gas, filler material, maintenance and electrical power form a relatively small part of the total costs. The majority of costs in both manual and mechanised welding are formed of work and capital costs.

In order to reduce unit costs, the efficient utilisation of production machinery plays a central role. The higher the achieved deposition rate and operating factor, the higher the profitability and the lower these significant cost factors and henceforth the overall costs.

In TIG and MIG/MAG welding, the choice of shielding gas has a significant effect on both the deposition rate and the operating factor.

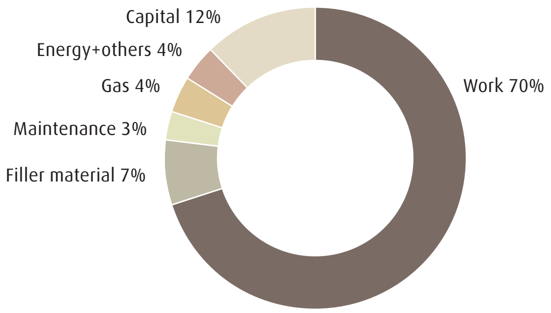
When a shielding gas enabling a high welding speed is used, the deposition rate can be increased, while a shielding gas providing a smooth weld and low-spatter welding improves the operating factor as the amount of post-weld finishing work is reduced.

The shielding gas also affects the attained level of quality, which is naturally one of the basic factors when making choices. Compared to the achievable cost savings, the price differences of different shielding gases are marginal. Investing in the gas that produces the best results with regard to profitability brings savings many times over in the total costs.

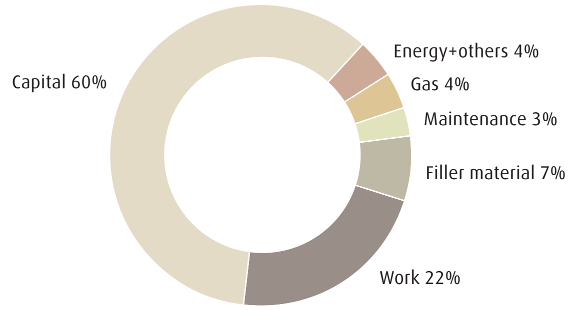
4.2 Welding process

The most common welding process currently used is MIG/MAG welding. The share of MIG/MAG welding has more than doubled since 1975. The growth has been at the expense of MMA welding

Manual welding



Mechanised Welding



An example of the division of welding costs per product unit (unalloyed steel). An efficient method of reducing costs is to select a shielding gas providing a high welding speed and low-spatter welding.

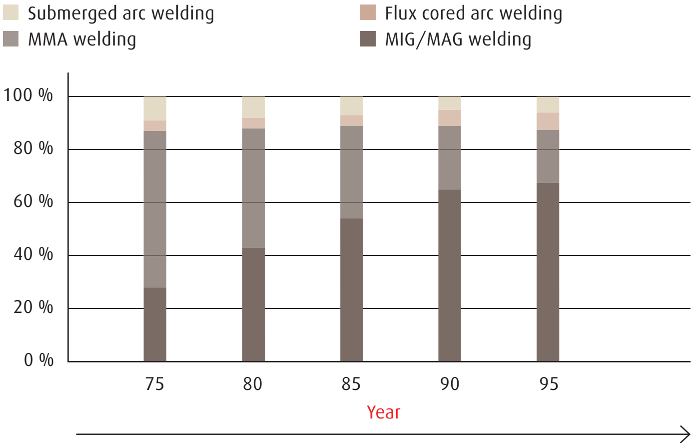
One of the reasons for the popularity of MIG/MAG welding is its high deposition rate, as is evident from the table on the next page.

The deposition rate can be further increased by using cored wire in some applications or by using high-productivity welding (RAPID PROCESSING®), to which we will return in Section 4.5.
The suitability of MIG/MAG welding for mechanised and robot welding has also affected in its growth.

Example

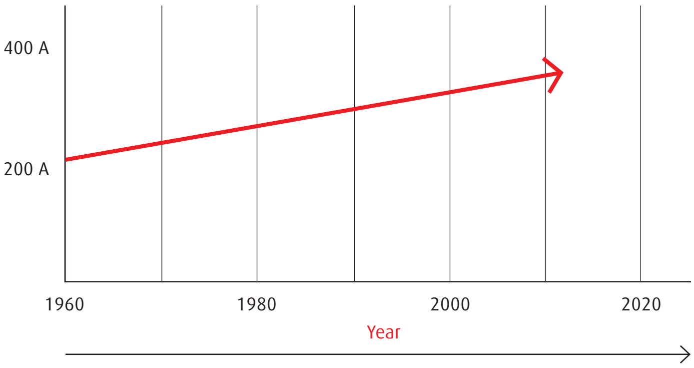
Unalloyed steel Sheet thickness 8 mm Horizontal, PB Design throat thickness 5 mm	Wire diameter (mm)	Deposition rate (kg/h)	Wire feed speed (m/min)	Welding speed (cm/min)
MMA welding, alkaline electrode	5	2,6		22
MMA welding, high-power rutile electrode	5	5,7		49
MAG welding, solid wire, CO_2	1,2	4,2	8	36
MAG welding, solid wire, MISON® 18	1,2	5,8	11	50
Flux cored wire welding, rutile wire MISON® 18	1,6	6	8	55
RAPID PROCESSING®, solid wire, MISON® 8	1,2	9,5	18	81

The popularity of MIG/MAG welding thru the years



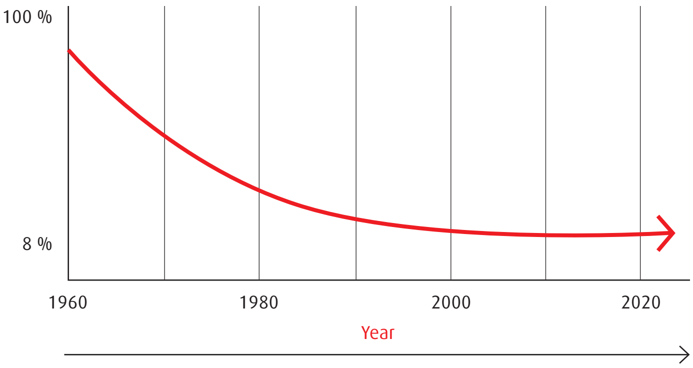
The relative consumption of filler material per process in Western Europe 1975-1995
The growth of MIG/MAG welding has been sped up by the high deposition rate, lower overall costs, better work environment and suitability for mechanisation.

Average welding current



The increased welding parameters and reduced CO_2 content of the shielding gases have increased the rate of deposition and welding speed, with the downside of increased ozone generation.
The direction of development has for years been towards higher productivity. In MIG/MAG welding, productivity has been improved by using

Average CO_2 content



higher welding parameters and reducing the CO_2/O_2 content in shielding gases. However, this has the downside of increased ozone generation during welding. By using MISON® shielding gases, it is possible to improve productivity and reduce ozone generation at the same time.

4.3 Shielding gas

4.3.1 Ar/CO_2 gas mixtures or CO_2?

Carbon dioxide (CO_2) used to be the most used shielding gas in MAG welding, to a large extent due to its better availability and cheaper price compared to gas mixtures. Overall, it is more crucial to examine what benefits a shielding gas can offer for productivity and quality, and what effect it will have on the amount of post-weld finishing work, than only consider this single cost factor. Compared to the achievable cost savings, the price differences of different shielding gases are marginal. Investing in the gas that produces the best results brings savings many times over in the total costs. By using gas mixtures, welding can be optimised for both productivity and quality.
This has also been verified in practical welding work. The use of pure carbon dioxide as shielding gas is almost nonexistent nowadays.

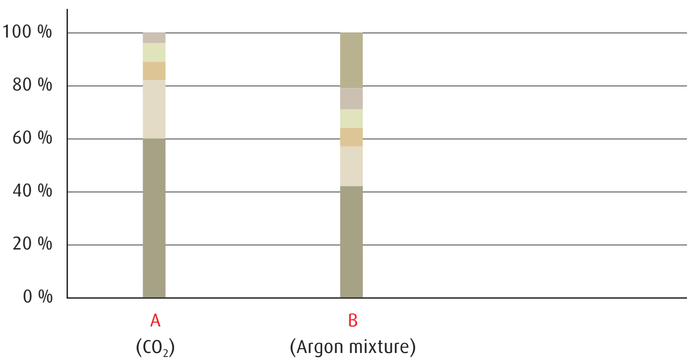
The chart below illustrates the change in total costs when moving from carbon dioxide to a gas mixture. It matches the practical results achieved over the years very well. In many cases, the savings have been even larger.

An example of cost savings achieved by changing the shielding gas: Changing the shielding gas increased welding speed and reduced the amount of post-weld finishing work. The achieved 30% increase in productivity lowered the total costs by 21%.

The higher the carbon dioxide content in the shielding gas, the more spatter is formed and the larger the number of large spatter welding onto the surface. Spatter originates from the filler material. An increase in the amount of spatter reduces the deposition efficiency and increases the amount of post-weld finishing work required.

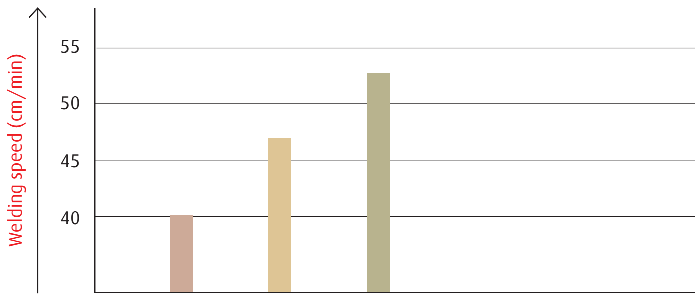
Change in total costs: From carbon dioxide to a gas mixture.

Capital	A: 60%	B: 42%	Work	A: 22%	B: 15%
Filler material	A: 7%	B: 7%	Energy, Maintenance	A: 7%	B: 7%
Shielding gas	A: 4%	B: 8%	Cost savings	A: 0%	B: 21%



The higher the argon content of the gas mixture, the less spatter there is and the less post-weld finishing is required.

The effect of shielding gas in the welding speed.



The effect of shielding gas in the welding speed of a horizontal joint meeting a certain A dimension. Horizontal weld, A dimension 4 mm, sheet thickness 6 mm, solid wire 1.0 mm, wire feeding speed 12 m/min.

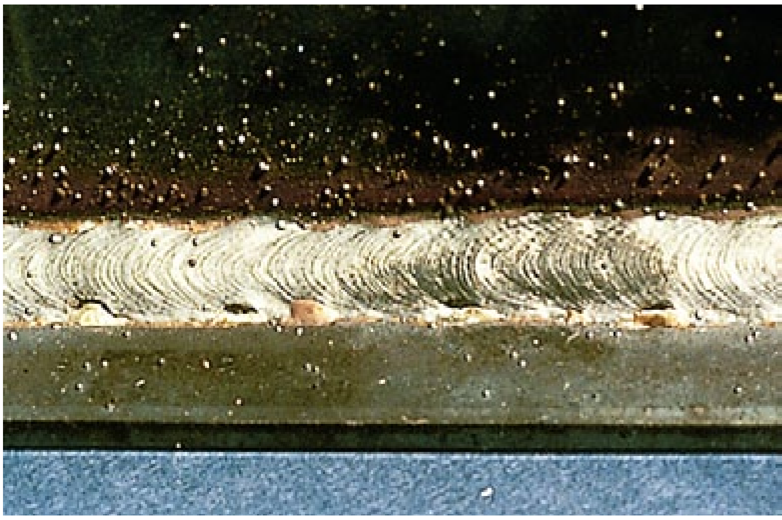
4.3.2 Welding speed and and deposition rate

One reason for the reduction of total welding costs is the increased welding speed achievable with gas mixtures.
Carbon dioxide does not allow as high a welding speed, because the weld bead will become too high and its fusion to the base material will be worsened. The chart beside illustrates the welding speeds achieved with different shielding gases with a constant wire feeding speed.
The lower the CO_2 content of the shielding gas, the higher the welding speed.

4.3.3. Spatter, post-weld finishing

Unalloyed and low-alloy steels

Post-weld finishing work forms a significant cost item. If a lot of spatter is generated during welding, it must be removed by grinding. The larger the spatter is, the more they contain heat and the better they weld onto the surface of the base material.



Mitä argonvaltaisempaa seoskaasu on, sitä vähemmän roiskeita ja jälkityötä.


CAT
1340kg
AGA

Stainless steels

In the MAG welding of stainless steels, a small amount of an oxidising component (1–2% CO_2) must be added to the argon-based shielding gas in order to stabilise the arc and minimise spatter. However, an inert shielding gas should be chosen for the welding of some high-alloy stainless steels, such as super-duplex and austenitic high-alloy stainless steels, if you wish to fully utilise the corrosion resistance characteristics of these steel grades.

We recommend using the MISON® Ar shielding gas instead of pure argon (which causes an unstable arc with a lot of spatter generation). In addition to argon, it contains 0.03% nitrogen monoxide, which is sufficient to stabilise the arc without mentionable oxide formation. The amount of post-weld finishing work is reduced which, in turn, improves the productivity of welding.

4.3.4 MIG soldering

When thin or metal-coated sheet metal is MIG soldered, it is important to achieve an arc generating only a little heat in order not to melt the base material (during soldering, only the filler material should melt). The arc must be stable in order to avoid spatter and porosity. Pure argon as the shielding gas results in an unstable arc. Different argon mixtures do provide a stable arc, but too much heat is generated. The nitrogen monoxide contained in the MISON® Ar shielding gas (Ar+0.03% NO) is enough to stabilise the arc while keeping heat generation low. Experience from the automotive industry shows that the repair costs of solders are reduced by as much as 70% when pure argon is replaced with the MISON® Ar shielding gas. The solder quality is also improved.

The share of large spatter which weld easily onto surfaces of the total amount of spatter as the CO2 content of the shielding gas changes.

4.3.5 Adding helium or hydrogen

By adding helium or hydrogen to a shielding gas, heat transfer to the weld is increased and the welding speed can be increased.

Examples of shielding gases containing helium are MISON® 2He, MISON® N2, MISON® He30, VARIGON® He50 and VARIGON® He70. These shielding gases provide a wider weld, wider penetration and enable a higher welding speed.

When hydrogen is added to a shielding gas, the heat transfer to the weld increases and the arc becomes more focused, providing more penetration. The MISON® H2 shielding gas designed for the TIG welding of austenitic stainless steels contains 2% hydrogen. The result is a higher welding speed, better penetration and a smoother fusion between the weld and the base material.
The weld also becomes less oxidised and productivity is improved due to the reduced post-weld finishing work required.

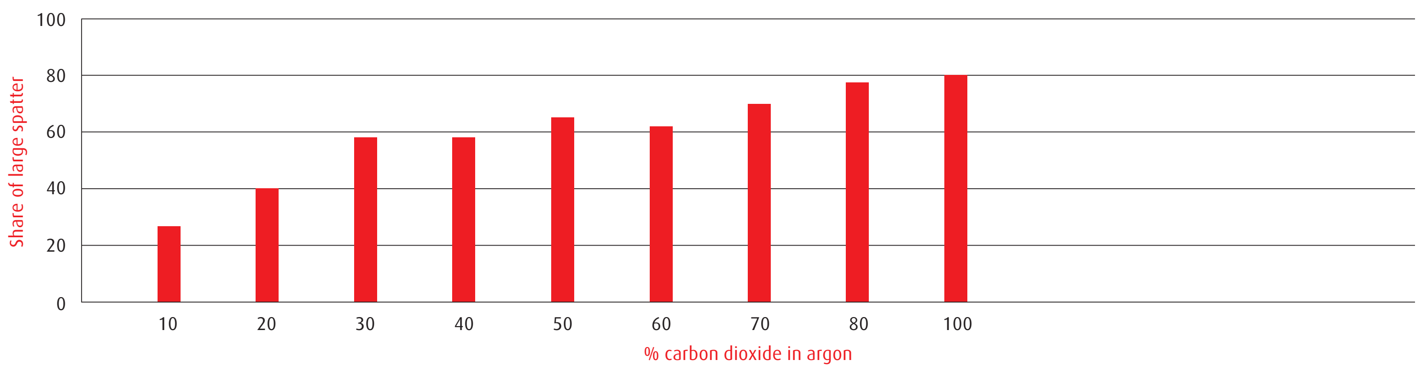
For more information on MISON® shielding gases, see Chapter 10. The effects of the different shielding gas components are described in more detail in Chapter 1.

4.4 Filler material and shielding gas

The general starting point of choosing the filler material is to use a filler material with the same chemical composition and strength as the base material. There are, naturally, numerous exceptions to this. The guidebooks of the material and filler material suppliers contain information on which filler materials are suited to different base materials. The wire type can usually be chosen from either solid wire or cored wire (flux or metal cored). Solid wires are used the most. Using cored wire is beneficial in some applications.

By choosing the right combination of filler material and shielding gas, the productivity of welding can be increased as a result of the higher welding speed and/or higher deposition rate. The appearance of the weld is also improved due to less spatter and surface oxides, and the smoother fusion of the weld and the base material. This reduces the amount of post-weld finishing work needed and increases productivity.

The share of large spatter which weld easily onto surfaces of the total amount of spatter as the CO2 content of the shielding gas changes



4.5. High-productivity MIG/MAG welding

The single most important factor increasing productivity is the deposition rate.

In MIG/MAG welding, it is 3–5 kg per hour on the average. However, it is often possible to increase the deposition rate up to 7–10 kg per hour without investing in new equipment.

By using unconventional welding parameters, you can widen the welding operating range, which is directly correlated with productivity as evident from the chart above. Based on the above, AGA has been developing a high-productivity welding method, RAPID PROCESSING®. The developed techniques are forced short arc, which aims at increasing welding speed, and rotating spray arc which increases the deposition rate in the welding of thick materials (e.g. 15–20 mm).

Depending on the case, a welding speed of more than double that of regular MAG welding can be achieved with the forced short arc. This technique can be utilised using the current equipment in both mechanised and manual welding.

4.5.1 Example of a rotating spray arc application

Welding application: Robot welding of a bus chassis component, PA (flat)

A very high deposition rate can be achieved with rotating spray arc, up to 20 kg per hour. This requires that the wire feeding speed can reach a maximum of 35–40 metres per minute. A new, reliable wire feeder and a high-power power source must often be acquired. In practice, this almost always requires mechanised welding.

MISON® 8 is the best shielding gas for both techniques; its low carbon dioxide content provides a stable arc, only a little spatter welding itself onto surfaces, a low-bead weld with a smooth fusion with the base material and low surface oxidation.

When the high-productivity RAPID PROCESSING® techniques are used, more ozone is generated. For this reason, it is important to use a shielding gas which limits the generation of ozone for the sake of the welder's work environment.

4.5.2 Example of a forced short arc application

During the manufacturing of a semi-trailer, some of the exterior joints were welded as intermittent welds. In practice, it rather quickly became evident that during rain, rusty dirt flowed over painted surfaces from the unwelded segments of the joint in question.

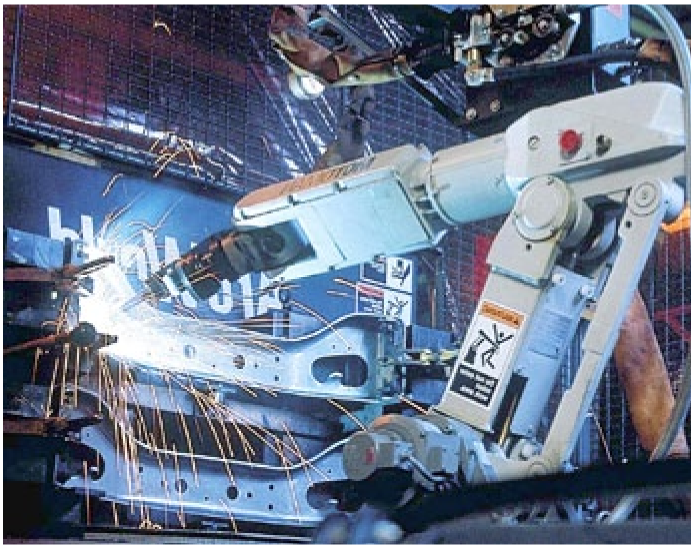
Due to this, it was decided to weld the entire joint, which increased the length of the weld from 11 metres to 16 metres.

Through the implementation of the RAPID PROCESSING® technique, welding speed could be increased by so much that despite the increased weld length, the welding time was reduced from 29 minutes to 20 minutes.

Lower welding costs and better quality with the RAPID PROCESSING® technique

	Previous process	RAPID PROCESSING®
Weld length	2 x 400 cm	1 x 400 cm
Air gap	6 mm	5 mm
Sheet thickness	10 mm	10 mm
Filler material	Cored wire	Solid wire
Root gap area	60 mm²	50 mm²
Welded filler material	2.0 kg	1.6 kg
Total welding time	Cored wire	Solid wire
Root gap area	40 min	10 mm

The RAPID PROCESSING® technique allowed the increase of welding speed, reduction of filler material consumption and reduction of product welding costs.
At the same time, side penetration was improved and deformations were reduced.



Shorter welding time despite longer weld length by using the RAPID PROCESSING® technique

	Weld length/product (cm)	Welding speed (cm/min)	Welding time (min)
Intermittent weld, MAG	1100	40	29
Continuous weld, MAG	1600	40	42
Continuous weld, RAPID ROCESSING®	1600	90	20

Shielding gas and quality.

Contents

5.1 General

5.1.1 Weld quality

The quality of welding work is the sum of several different factors. If the welded structure is correctly designed, the manufacturing implementation, including the welding process, gap preparation, welding parameters, filler material and shielding gas, has an essential effect on the quality level reached. For example, mistakes in shielding gas selection may impair the achieved end result with regard to mechanical characteristics, corrosion resistance or weld appearance.

Changes in the mechanical characteristics of a weld may be caused by changes in the metal's microstructure, poor fusion between the weld and the base material, or disadvantageous penetration profile causing lacks of fusion.

Corrosion resistance may be reduced, for example, as a result of microstructure changes and surface oxidation. Surface slag and spatter affect the appearance of the weld and often cause problems for the further processing of the workpiece.

5.2 Unalloyed and low-alloy steels

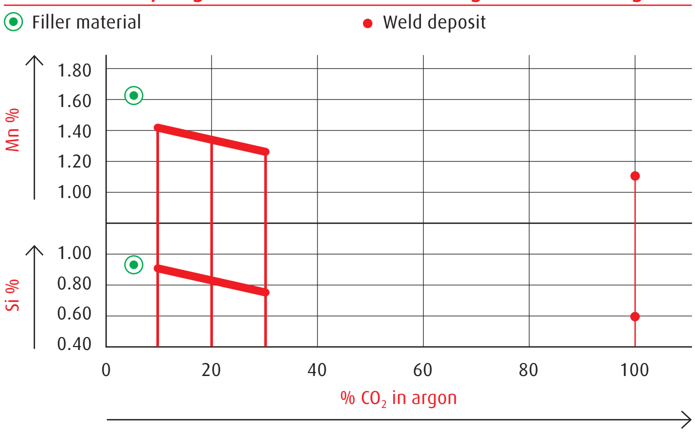
In the MAG welding of unalloyed and low-alloy steels, argon-based shielding gases with 5–25% carbon dioxide or 5–10% oxygen are used. In TIG welding, inert shielding gases are used.

In both TIG and MAG welding, the welder's work environment can be improved by using MISON® shielding gases, which contain a small amount of nitrogen monoxide (NO) that reduces the generation of harmful ozone.Nitrogen monoxide also stabilises the arc in the TIG welding of these steels.

5.2.1 Mechanical characteristics

The shielding gas used affects the mechanical characteristics of the weld. The lower the carbon dioxide or oxygen content in the shielding gas, the purer (fewer oxide inclusions) the achieved welding material. The granularity of the microstructure also becomes finer, which is beneficial for the impact ductility.

The effect of hydrogen and helium added to argon on arc voltage



The effect of the shielding gas on the weld deposit's manganese and silicon content. A higher CO_2 content in a shielding gas increases the burning loss of alloy materials, which reduces the yield strength and tensile strength of the weld.

By reducing the CO_2 or O_2 content of the shielding gas, the burning loss of alloy materials in the filler material is reduced, increasing the yield strength and tensile strength. The differences between mechanical characteristics in argon-carbon dioxide mixtures in the range of 8–25% are so small that they usually do not have a practical significance. However, when pure carbon dioxide is used, the difference may be significant compared to the above.

Extensive research has shown that the small NO addition in the MISON® shielding gases does not affect the mechanical characteristics of the weld.

Weld toughness with different shielding gases and filler materials

PZ 6103	metal-cored wire	(AWS A5.20: E71T-G)
PZ 6104	nickel-alloy metal-cored wire	(AWS A5.29 : E71TG-Ni1)
PZ 6111	rutile cored wire	(AWS A5.20: E71T-1)

The fatigue resistance of the welded joint strongly depends on the geometry of the welded joint. In MIG/MAG welding, the weld shape ´can be affected by the selection of a shielding gas. With gas mixtures, a smoother fusion between the weld and the base material is achieved than with carbon dioxide. The peak stresses in the structure (notch effect) are smaller and the fatigue resistance of the welded structure is better.

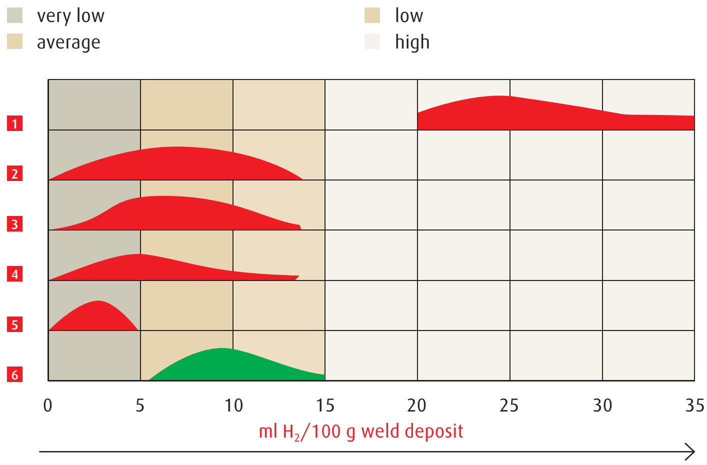
In structures with fatigue-inducing loads, certain requirements are set for the fatigue resistance and the weld fusion with the base material. If the fusion is poor, grinding or TIG treatment is required on the welded joint, increasing costs. Oxide inclusions in the weld affect the fatigue resistance even if the weld is grinded or polished. Oxide inclusions can act as the nucleation of the crack.

The higher the carbon dioxide or oxygen content of the shielding gas, the larger the number of oxide inclusions in the weld deposit.

The large amount of hydrogen dissolved into the weld can cause brittleness and porosity, in particular with unalloyed, low-alloy and non-austenitic high-alloy steels.

In certain conditions, adding hydrogen to the shielding gas is beneficial. In the TIG welding of unalloyed and low-alloy steels, productivity can be improved and surface oxidation reduced by using the MISON® H2 shielding gas, which contains 2% hydrogen. This requires that the base material is not very thick and the internal stresses do not rise very high.

Hydrogen content of weld

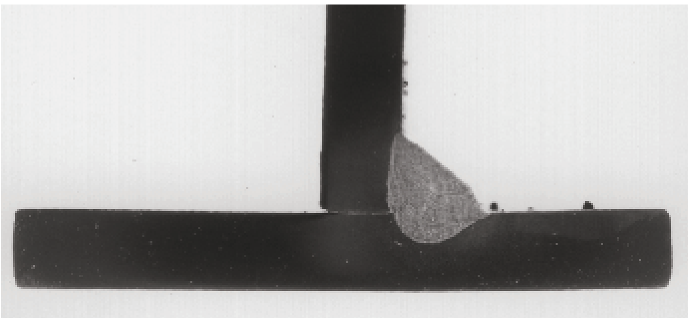


1 Rutile electrodes
2 Cored wires
3 Submerged arc
4 Alkaline electrodes
5 Solid wires
6 TIG welding with MISON® H2 as shielding gas

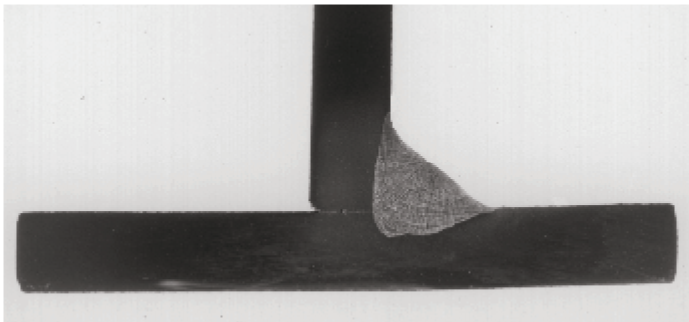
When unalloyed and low-alloy steels are TIG welded with MISON® H2 used as the shielding gas, the hydrogen content of the weld is comparable with rutile cored wire welding.

Better fatigue resistance with argon mixtures

By using argon mixtures, a better fusion between the weld and the base material can be achieved, while also improving the fatigue resistance of the weld.



CO_2 Welding speed 40 cm/min



Ar + 20% CO_2 Welding speed 47 cm/min

5.2.2 Visual quality

Spatter

Spatter welded onto the base material during welding must usually be removed before painting or other surface treatment.In addition to welding parameters, shielding gas is another important factor in spatter formation.

The lower the carbon dioxide content of the shielding gas, the less spatter is formed.

The best result with regard to spatter formation is achieved with the MISON® 8 shielding gas (8% CO_2). Welding is relatively spatter-free also with the MISON® 18 shielding gas (18% CO_2).

Surface oxides

Surface slag is formed of oxides, appearing as brown, glassy areas on the surface of the weld. The slag must be removed before painting or other surface treatment. The more oxidising the shielding gas is (the more it contains carbon dioxide or oxygen), the larger the amount of oxides generated.
The least surface slag is formed with the MISON® 8 shielding gas.

Weld shape

Different shielding gases provide a different weld shape. The lower the carbon dioxide content of the shielding gas, the better the melt's flow and spread. The weld bead becomes low with a good fusion with the base material. Pure carbon dioxide gives a rather high weld bead with a more abrupt fusion with the base material.

When stainless steels are welded, both the type of the welded steel and the filler material must be taken into consideration when choosing the shielding gas.

5.3 Stainless steels

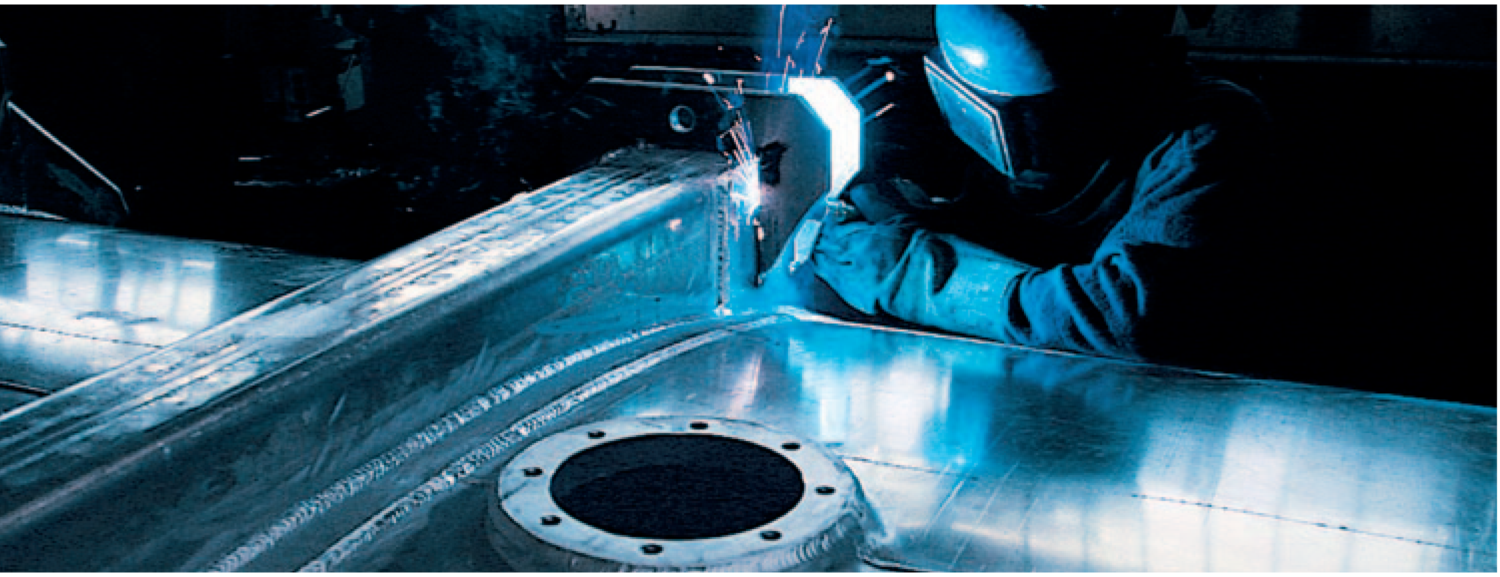
Stainless steels are divided into different types based on their microstructure (depends on the steel alloys and their quantities).
The types are ferritic, martensitic, austenitic, high-alloy austenitic and ferritic-austenitic (duplex and superduplex) stainless steels.
When choosing the shielding gas, you must take the type of the welded stainless steel into consideration (see also Chapter 7).
In the TIG welding of stainless steels, argon or argon mixtures with nitrogen or hydrogen are used.
In the MAG welding of stainless steels with solid and metal-cored wires, shielding gases containing 2–3% carbon dioxide or 1–2% oxygen are used.

Higher oxygen and carbon dioxide content causes excessive surface oxidation. High-alloy stainless steels are often MIG-welded using an inert shielding gas to prevent excessive surface oxidation.
When rutile cored wires are used, a more oxidising shielding gas is required.

Most cored wires designed for welding with shielding gas have been designed for shielding gases containing 15–25% or as much as 100% carbon dioxide.

The resulting slag protects the molten metal, so the weld is not carbonised regardless of the high CO_2 content of the shielding gas.
The weld surface oxidation is also minor due to the slag protecting the surface.

In both TIG and MIG/MAG welding, the amount of ozone can be reduced by using MISON® shielding gases, which contain a small amount of nitrogen monoxide (NO) and improve the welder's work environment. Nitrogen monoxide also stabilises the arc in TIG and MIG welding.



5.3.1 Mechanical characteristics

With the condition that the shielding gas is suited to the welded steel and the filler material type used, it does not affect the mechanical characteristics of the weld.

5.3.2. Corrosion resistance

One of the basic issues with stainless steels is to understand the effect of the welding process on corrosion resistance.
If the carbon dioxide content of the shielding gas in MAG welding with solid and metal-cored wires exceeds 3%, the result may be the harmful carbonisation of the weld deposit.
Carbon reacts with the chromium in the steel, forming chromium carbides at grain boundaries. Correspondingly, the chromium content in areas near the grain boundaries decreases and corrosion resistance is reduced (grain boundary corrosion).

However, most stainless steel today have very low carbon content or they are stabilised, so the above will not usually be a problem when stainless steels are welded.
Nitrogen is added as an alloy in some stainless steels to improve corrosion resistance but also to increase their strength.
Examples of this are high-alloy austenitic and superduplex steels.
Nitrogen loss occurring during the welding of these steels can impair their corrosion properties.

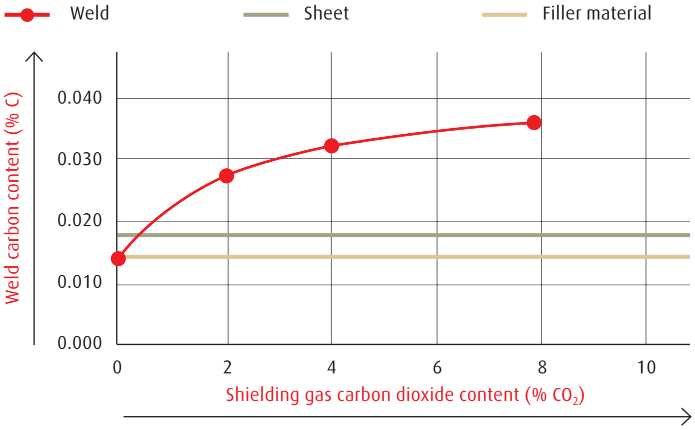
In MAG welding, and to some extent, in TIG welding with filler material, this can be rather easily compensated using a filler material with a suitable composition. In TIG welding without filler material, the nitrogen loss must be compensated by using a shielding gas containing nitrogen (MISON® N2).

The nitrogen monoxide (NO) added into MISON® shielding gases does not affect the corrosion resistance of stainless steels.

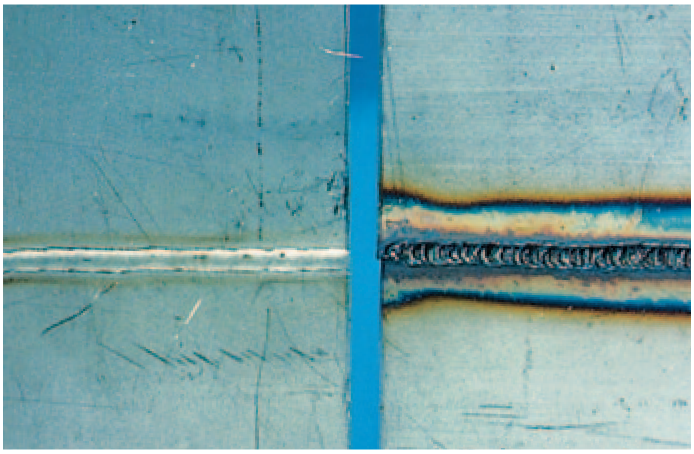
5.3.3 Root protection

In some applications, the root side of the weld must be protected. Otherwise, an oxide layer is formed, containing chromium originating from the metal underneath the layer.
The chromium content near the root surface is reduced, increasing the risk of corrosion. Argon, nitrogen-hydrogen mixtures and argon-hydrogen mixtures are used for root protection.

MAG spray arc welding, solid wire



On the left, a root surface protected with the FORMIER® 10 root shielding gas.
On the right, a root surface unprotected during welding.



The effect of the carbon dioxide content in a shielding gas on the carbonisation of austenitic stainless steel.
When the carbon dioxide content rises above three per cent, weld carbon content of 0.03% is approached, above which the danger of grain boundary corrosion is considered to increase.

Argon and FORMIER® 10 (N_2 + 10% H_2) are the most common root shielding gases for austenitic stainless steels.
Due to the hydrogen added to the root shielding gas the gas is reducing, which reduces the oxidation of the root surface and improves its fusion. Root shielding gases with hydrogen content are not recommended for the root protection of ferritic, martensitic or ferritic-austenitic (duplex, superduplex) steels.
High-purity nitrogen can be used as root protection in the welding of duplex steels.

Nitrogen improves spot corrosion resistance by forming a thin austenitic layer on the root surface.
MISON® shielding gases are not recommended to be used for root protection of stainless steels, as they tend to cause discolouration in the root surface.

5.3.4 Visual quality

The oxidation of the weld can be reduced in the TIG welding of austenitic (not ferritic or martensitic) stainless steels by using a shielding gas containing hydrogen, such as MISON® H2, which contains 2% hydrogen. The result is not only reduced weld oxidation, but also higher penetration and a more even fusion between the weld and the base material.

5.4 Aluminium and aluminium alloys

Only inert gases are used in the gas arc welding of aluminium and aluminium alloys. MISON® Ar is recommended due to its ozone-reducing and work environment improving effect.
The nitrogen monoxide (NO) added into MISON® shielding gases does not affect the mechanical characteristics or corrosion resistance of the weld.

Penetration can be improved by adding helium into the shielding gas (MISON® He30, VARIGON® He50, VARIGON® He70).
Helium enables better penetration and reduces the danger of lack of fusion. This is especially important when welding thick materials, reducing the need for preheating.

The higher heat transfer can also be utilised by increasing welding speed. Aluminium and its alloys react easily with hydrogen and moisture, forming pores. For this reason, it is essential that the purity of the shielding gas is retained all the way to the arc when welding aluminium. Some necessary measures for guaranteeing the purity from the cylinder to the gun are presented in Chapter 11.

5.5 Other metals

Only inert shielding gases are used in the gas arc welding of copper and its alloys. When thick materials are welded, argon-helium mixtures provide more heat and increased penetration. The need for preheating is also reduced (preheating is often required due to copper's high thermal conductivity.

The nitrogen monoxide (NO) added into MISON® shielding gases (MISON® Ar, MISON® He30) does not affect the mechanical characteristics or corrosion resistance of the weld. Titanium and its alloys react easily with hydrogen, oxygen and nitrogen, which results in brittleness.

High hydrogen concentrations also cause porosity.
Only inert gases should be used in the welding of these metals.
The nitrogen monoxide (NO) added into the MISON® Ar shielding gas does not affect the mechanical characteristics or corrosion resistance of the weld. However, there may be some discolouration in the weld.

Because titanium and titanium alloys react easily with hydrogen, oxygen and nitrogen, it is important that the purity of the shielding gas is retained all the way to the arc.

For demanding applications, we recommend using high-purity argon (over 99.996%), Argon 4.6.

Shielding gases for unalloyed and low-alloy steels.

Contents

6.1 General

Unalloyed and low-alloy steels can be divided into types based on their properties, purpose of use and heat treatment according to the following table.
With regard to the selection of the shielding gas, they all belong to the same group.
When a shielding gas is selected for unalloyed and low-alloy steels, the following factors are more important than the type of the base material:
- Welding process: TIG or MIG/MAG welding
- Manual or mechanical welding
- Type of filler material: solid wire, flux-cored wire or metal-cored wire
- Short arc, spray arc, pulse or high-productivity welding (RAPID PROCESSING®)

MISON® Ar shielding gas is recommended for the TIG welding of unalloyed and low-alloy steels.

If the goal is higher productivity, the MISON® H2 shielding gas can be used in the TIG welding of unalloyed steels, when welding thin materials with low internal stresses.

Steels	Discription
Regular steels For example EN 10025-2: S235 JR DIN 17100: RSt 37-2 RAEX Laser 250 C	Hot rolled or normalised/normalisation rolled carbon and carbon-manganese steels. Yield strength up to around 300 MPa.
High-strength steels For example EN 10025-2: S 355 J0 DIN 17100: St 52-3 U RAEX Multisteel	Thermomechanically rolled or normalised/ normalisation rolled. Yield strength around 300–400 MPa. Can be welded as regular steels. Preheating may be required with thicker sheets. More information is available from the steel manufacturer.
Ultra-high-strength steels For example EN 10149-2: S 500 MC DIN SEW 092: QStE 500 TM RAEX Optim 500 MC	Thermomechanically rolled or normalised/ normalisation rolled Yield strength around 400 MPa and above. Can be welded as regular steels. Preheating may be required with thicker sheets. More information is available from the steel manufacturer.

High quality and economical benefits can be achieved through the utilisation of the different properties.
Solid wire or cored wire can be used in the MAG welding of unalloyed and low-alloy steels.

The cored wire can be either metal-cored or powder-cored.
Most filler materials are designed and approved for welding with specific shielding gases, or more commonly, specific type of shielding gas.
The selection of possible shielding gases is usually large, allowing the utilisation of the differences in the properties of the different shielding gases on a case-by-case basis.
For example, solid wires for unalloyed and low-alloy steels allow a greater freedom with regard to the carbon dioxide content of the shielding gas compared to, let's say, flux-cored wires designed for high-alloy steels.
Flux-cored wires are returned to later in this handbook.

MISON® 8 shielding gas is especially recommended for robot welding and mechanised welding, and high-productivity welding (RAPID PROCESSING®).
With it, a high welding speed and low-spatter welding can be achieved.
The weld bead is low and there is very little surface slag.
The shielding gas is suited to short arc, spray arc and pulse welding.
It is also suited to manual welding where a spatter-free and low-slag weld is desirable.

MISON® 18 shielding gas can be considered as a general gas which is suited to both mechanised and manual welding.
The shielding gas has good short and spray arc properties, and it can also be used as the shielding gas for pulse welding.
The shielding gas provides low-spatter welding producing a low weld bead. MISON® 25 provides a fluid and highly manageable molten pool when short arc is used.

The shielding gas has an excellent tolerance to impurities in spray arc welding, and it produces a tight weld even in unfavourable conditions.
Compared to carbon dioxide, spatter formation is reduced and the weld fusion with the base material and welding speed are significantly better.
It is the most oxidising of the gas mixtures, due to which slag formation is also highest.

MISON® 25 is the most used shielding gas, which is especially recommended for short arc welding (small machines) and spray arc welding when the weld has tightness requirements or the welding conditions are unfavourable.

The MISON® 8, MISON® 18 and MISON® 25 shielding gases have significant welding-technical differences.

Shielding gases for unalloyed and low-alloy steels

Process	Filler material	Shielding gas	Properties
MIG	Solid wire	MISON® 8 Short arc Spray arc Pulse welding	The best choice for robot, mechanical and high-productivity welding, but also suited to manual welding. High welding speed, low amount of slag and spatter. Even weld, good deposition efficiency and a stable arc.
		MISON® 18 Short arc Spray arc Pulse welding	General gas with a wide operating range. Good short arc and spray arc properties. Can also be used for pulse welding. Adjusting welding parameters is easy and spatter formation is minor.
		MISON® 25 Short arc Spray arc	As the amount of helium increases, heat transfer to the weld also increases.
		CO_2 Short arc Globular arc	Unstable and high-spatter welding. Weld has high bead with a lot of surface slag. Good tolerance for impurities. Strong smoke formation.
	Powder-cored wire	MISON® 18	General gas with a wide operating range. Adjusting welding parameters is easy and spatter formation is minor.
		MISON® 25	The best choice for robot, mechanical and high-productivity welding. High welding speed, low amount of slag and spatter. Even weld, good deposition efficiency and a stable arc.
	Metal-cored wire	MISON® 8	The best choice for robot, mechanical and high-productivity welding. High welding speed, low amount of slag and spatter. Even weld, good deposition efficiency and a stable arc.
		MISON® 18 Spray arc Pulse welding	General gas with a wide operating range. Good short arc and spray arc properties. Adjusting welding parameters is easy and spatter formation is minor.
		MISON® 25 Spray arc	Produces a tight weld even in unfavourable conditions. Good tolerance for impurities. Best choice for applications with high tightness requirements.
TIG	With or without filler material	MISON® Ar	Stable and easily ignitable arc.
		MISON® H2	Increases welding speed. Only for the welding of thin materials.
MIG soldering	Solid wire (silicon-bronze, aluminium bronze)	MISON® Ar	Stable and easily ignitable arc. Low formation of oxides. Less pores than with argon. Less deformation than with argon-carbon dioxide mixtures.
		MISON® 2He	Stable arc. Better fluidity of molten pool when soldering thicker workpieces.

All MISON® shielding gases remove ozone generated during welding and improve the welder's work environment.

Shielding gases for stainless steels.

Contents

7.1 General

Stainless steels are high-alloy steels which can be divided into different types based on their microstructures.
The most common steel types are listed in the table below.

Ferritic and martensitic stainless steels have strength properties which are similar to unalloyed and low-alloy steels.
They are excellently suited to use as structural steel and have a high heat resistance.

However, these steels are not as corrosion-resistant as austenitic stainless steels,which are used most out of all stainless steels.
Their typical properties include good corrosion resistance and good impact ductility even at low temperatures.

High-alloy austenitic stainless steels contain more chromium, nickel, molybdenum and nitrogen, which makes them more corrosion resistant than regular austenitic grades.

Unlike regular austenitic stainless steels, the ferrite content of the weld is around 5% after welding, the weld is fully austenitic after welding with high-alloy austenitic grades.

Steels type	Application examples
Ferritic For example AISI 430 Ti, X 3 CrTi 17, W.nr 1.4510 X 2 CrMoTi 18 2, W.nr 1.4521, SS 2326	Chemical industry, household appliances, boilers, exhaust pipes.
Martensitic For example AISI 410, X 12 Cr 13, W.nr 1.4006, SS 2302	Mechanical engineering, water turbines, steam pipelines, ship propellers.
Austenitic For example AISI 304, X 5 CrNi 18 10, W.nr 1.4301, SS 2333 AISI 316, X 3 CrNiMo 17 13 3, W.nr 1.4436, SS 2343	Oil and gas industry, chemi cal industry, paper and pulp industry, food industry, household items, mechanical engineering, vehicles, medical instruments.
High-alloy austenitic For example AISI 317 L, X 2 CrNiMo 18 15 4, W.nr 1.4438, SS 2367	Oil and gas industry, chemical industry, paper and pulp industry, flue gas washers.
Duplex (ferritic-austenitic) For example AISI 329, X 3 CrNiMoN 27 5 2, W.nr 1.4460, SS 2324	Oil and gas industry, chemical industry, seawater technology.
Superduplex For example X 2 CrNiMoCuN 25 6 3, W.nr 1.4507	Oil and gas industry, chemical industry, paper and pulp industry, seawater technology.

Ferritic-austenitic stainless steels are known as duplex steels.
Their benefits include high yield strength and good resistance to stress corrosion, as well as good resistance to general corrosion and spot corrosion.Superduplex steels were developed from duplex steels.
In superduplex grades, the corrosion resistance of the steel has been further improved by adding alloy materials such as nitrogen.

7.2 Which shielding gases are suited to different steel grades

Because the microstructures of different steel grades are different, their sensitivities to the different components of shielding gases are also different.
For more information on this subject, see Chapter 5.

7.2.1 MIG/MAG welding

The carbon dioxide and oxygen content of the shielding gas must not be too high in order not to oxidise the weld surface too much.
However, a certain amount of oxygen or carbon dioxide is required in the MAG welding of steel to stabilise the arc.
MISON® 2 and MISON® 2He are shielding gases containing 2% carbon dioxide.
They are recommended for regular-grade stainless steels (ferritic, austenitic and duplex).

The helium added to the MISON® 2He shielding gas improves penetration and provides a more fluid, well spreading molten pool.
When high-alloy austenitic and superduplex steels are welded, we primarily recommend using the inert shielding gas MISON® Ar.

The small amount of nitrogen monoxide added to the shielding gas provides a more stable arc, less spatter and better penetration than argon.
MISON® 2He is also a suitable shielding gas for these steel grades.
It has the downside of a clearly more oxidised weld surface.
Rutile cored wires require a shielding gas with a higher carbon dioxide content than the abovementioned gases.
Recommended gases are MISON® 18 (18% CO_2) and MISON® 25 (25% CO_2).
The use of carbon dioxide is also possible with some wire types.
However, this will result in more spatter and welding smoke, both of which are less than desirable with stainless steels.

7.2.2 TIG welding

The most multi-purpose shielding gas for the TIG welding of stainless steels is MISON® Ar.
Due to the nitrogen monoxide added to the shielding gas, the arc is more stable than with argon.

The MISON® H2 shielding gas containing 2% hydrogen can also be used for the TIG welding of austenitic stainless steels contains.
MISON® H2 provides a less oxidised weld, higher welding speed and better penetration and fusion between the weld and the base material.
However, it is not suitable for ferritic and ferritic-austenitic steels such as duplex and superduplex.
Nitrogen is used as an alloy material in high-alloy austenitic and superduplex steels.

When these steels are welded, nitrogen loss occurs in the weld, reducing the weld's spot corrosion resistance. This can be taken into consideration in TIG and MAG welding with filler material by using a filler material with a suitable composition.

In TIG welding without filler material, the nitrogen losses can be compensated by using the MISON® N2 shielding gas, which contains 1.8% nitrogen in addition to argon and helium.

7.2.3. Root protection

Argon can be used as the root shielding gas of all stainless steels. Argon is also used for root protection in the welding of unalloyed and low-alloy steels, aluminium, copper and titanium.
High-purity nitrogen can also be used for root protection in the welding of austenitic stainless steels.

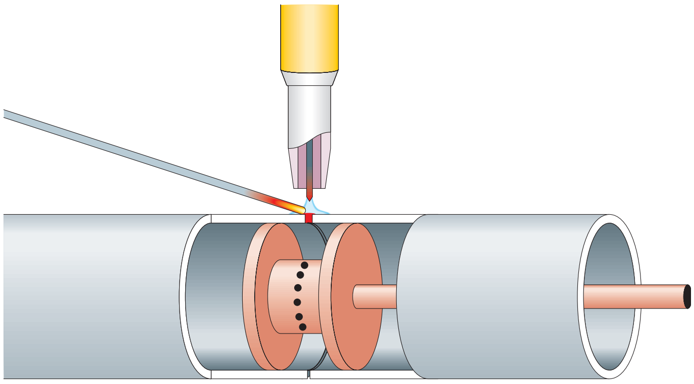
It can also provide benefits when welding high-alloy austenitic and duplex and superduplex steels, because it prevents nitrogen loss in the weld deposit and helps retain a good resistance to spot corrosion. Nitrogen can also be used as the root shielding gas for unalloyed and low-alloy steels. The requirements for the purity of the nitrogen are not as high in this application, however. Hydrogen reduces oxide formation on the root side.

Shielding gases containing hydrogen, FORMIER® 10 (10% hydrogen in nitrogen) and VARIGON® H5 (5% hydrogen in argon) can be used for the root protection of austenitic and high-alloy austenitic steels.

However, with titanium-stabilised stainless steels, a shielding gas containing nitrogen tends to form titanium nitrides which are visible on the root surface of the weld as yellow areas.FORMIER® 10 is a flammable gas mixture, and special care should be taken in its use.

It should not be used for the root protection of tanks due to the danger of explosion. MISON® Ar shielding gas is not recommended for use as the root shielding gas for stainless steels, as it tends to cause discolouration of the root.

Efficient root protection



The root surface of stainless steels must be protected with a root shielding gas.
By limiting the protected volume to the immediate vicinity of the root, the flushing time can be kept short.
This reduces gas consumption and often also guarantees the best end result.

Shielding gases for stainless steels

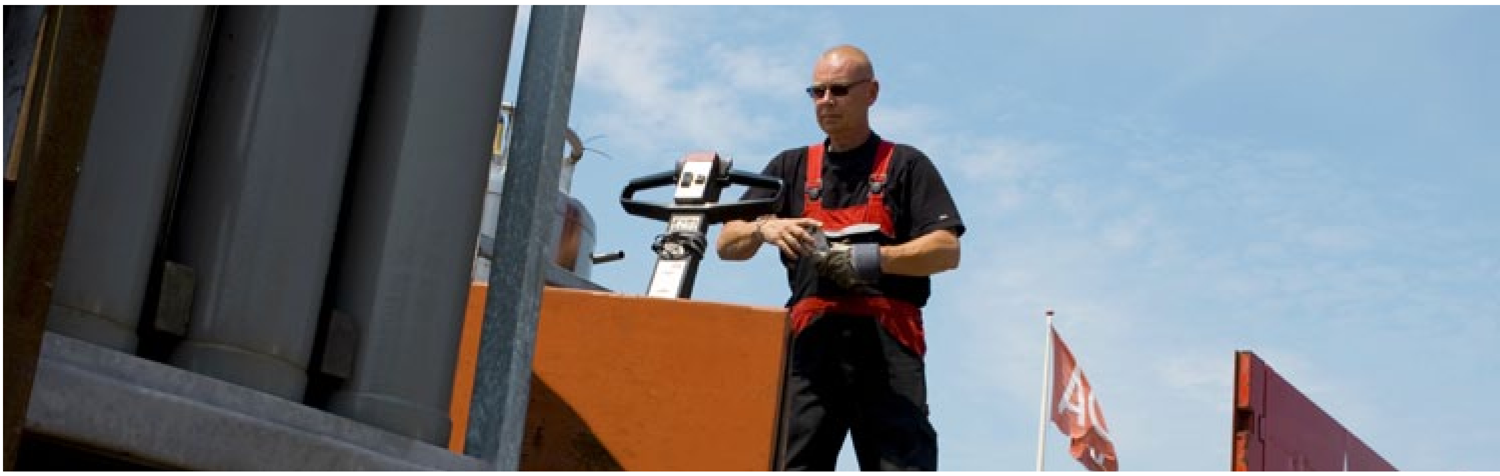
Stainless steel type	Process	Filler material	Shielding gas	Properties
Ferritic For example AISI 430 Ti, X 3 CrTi 17 AISI 409, X 2 CrTi 12 Martensitic For example AISI 410, X 12 Cr 13 AISI 420, X 20 Cr 13 AISI 420, X 20 Cr 13	MIG/MAG	Solid wire	MISON® 2 Short arc Spray arc Pulse welding	Good short and spray arc properties. Low spatter and surface slag. Smooth weld with a good fusion. Especially for small sheet thicknesses.
			MISON® 2He Short arc Spray arc Pulse welding	General gas with a wide operating range. Low spatter and surface slag. Better penetration and fluidity of molten pool than with shielding gas with no added helium. Smooth weld with a good fusion. Enables a high welding speed. Especially for larger sheet thicknesses.
			CRONIGON® He Short arc Spray arc Pulse welding	General gas with a wide operating range. Low spatter and surface slag. Better penetration and fluidity of molten pool than with shielding gas with no added helium. Even weld bead with a good fusion. Enables a high welding speed. Does not carbonise the molten pool. No ozone-eliminating properties.
		Rutile cored wire	MISON® 18	General gas with a wide operating range. Adjusting welding parameters is easy and spatter formation is minor.
			MISON® 25	Recommended alternative in addition to the previous. Especially for cored wires designed for welding with a more oxidising gas than the MISON® 18 shielding gas.
	TIG	With or without filler material.	MISON® Ar	Provides a stable arc which is easy to ignite.
	Root protection		Argon	Inert shielding gas

All MISON® shielding gases remove ozone generated during welding and improve the welder's work environment.

Shielding gases for stainless steels

Stainless steel type	Process	Filler material	Shielding gas	Properties
Austenitic **For example** **AISI 304, X 5 CrNi 18 10** **AISI 316, X 3 CrNiMo 17 13 3** **AISI 321, X 6 CrNiTi 18 10**	MIG/MAG	Solid wire	MISON® 2 Short arc Spray arc Pulse welding	Good short and spray arc properties. Low spatter and surface slag. Smooth weld with a good fusion. Especially for small sheet thicknesses.
			MISON® 2He Short arc Spray arc Pulse welding	General gas with a wide operating range. Low spatter and surface slag. Better penetration and fluidity of molten pool than with shielding gas with no added helium. Smooth weld with a good fusion. Enables a high welding speed. Especially for larger sheet thicknesses.
			CRONIGON® He Short arc Spray arc Pulse welding	General gas with a wide operating range. Low spatter and surface slag. Better penetration and fluidity of molten pool than with shielding gas with no added helium. Even weld bead with a good fusion. Enables a high welding speed. Does not carbonise the molten pool. No ozone-eliminating properties.
		Rutile cored wire	MISON® 18	General gas with a wide operating range. Adjusting welding parameters is easy and spatter formation is minor.
			MISON® 25	Recommended alternative in addition to the previous. Especially for cored wires designed for welding with a more oxidising gas than the MISON® 18 shielding gas.
	TIG	With or without filler material.	MISON® Ar	Provides a stable arc which is easy to ignite.
			MISON® H2	The added hydrogen provides higher welding speed, better penetration and lower weld oxidation.
			VARIGON® H5	Especially for mechanised welding. Provides a high welding speed and low weld oxidation.
	Root protection		Argon	Inert
			FORMIER® 10	Reducing. Flammable gas mixture
			VARIGON® H5	Reducing

All MISON® shielding gases remove ozone generated during welding and improve the welder's work environment.



Shielding gases for stainless steels

Stainless steel type	Process	Filler material	Shielding gas	Properties
High-alloy austenitic For example SS 2562, X 1 NiCrMoCu 25 20 5 254 SMO 654 SMO	MIG/MAG	Solid wire	MISON® Ar (Short arc) Spray arc Pulse welding	Provides a stable arc which is easy to ignite.. Very little weld oxidation.
			MISON® 2He (Short arc) Spray arc Pulse welding	General gas with a wide operating range. Low spatter and surface slag. Better penetration and fluidity of molten pool than with shielding gas with no added helium. Smooth weld with a good fusion. Enables a high welding speed. Especially for larger sheet thicknesses.
			MISON® N2 (Short arc) Spray arc Pulse welding	The nitrogen mixture reduces nitrogen loss in the . weld deposit. Very little weld oxidation. The added helium improves the fluidity and penetration of the weld and enables a higher welding speed.
	TIG	With or without	MISON® N2	Nitrogen addition reduces nitrogen loss in the weld deposit. The added helium improves the fluidity and penetration of the weld and enables a higher welding speed.
			MISON® H2	The added hydrogen provides a higher welding speed and better penetration and reduces weld oxidation.
			MISON® Ar	Provides a stable arc which is easy to ignite.
	Root protection		Argon	Inert
			FORMIER® 10	Reducing. Flammable gas mixture
			Nitrogen	Unreactive (nitrogenising)
			VARIGON® H5	Reducing

All MISON® shielding gases remove ozone generated during welding and improve the welder's work environment.

Shielding gases for stainless steels

Stainless steel type	Process	Filler material	Shielding gas	Properties
Duplex For example AISI 329, X 3 CrNiMoN 27 5 2 2205, X 2 CrNiMoN 22 5 3	MIG/MAG	Solid wire	MISON® 2He Short arc Spray arc Pulse welding	General gas with a wide operating range. Low spatter and surface slag. Better penetration and fluidity of molten pool than with shielding gas with no added helium. Smooth weld with a good fusion. Enables a high welding speed. Especially for larger sheet thicknesses.
			CRONIGON® He Short arc Spray arc Pulse welding	General gas with a wide operating range. Low spatter and surface slag. Better penetration and fluidity of molten pool than with shielding gas with no added helium. Smooth weld with a good fusion. Enables a high welding speed. Does not carbonise the molten pool. No ozone-eliminating properties. Rutile cored wire
	Rutile cored wire		MISON® 18	General gas with a wide operating range. Adjusting welding parameters is easy and spatter formation is minor.
			MISON® 25	Recommended alternative in addition to the previous. Especially for cored wires designed for welding with a more oxidising gas than the MISON® 18 shielding gas.
	TIG	With or without filler material.	MISON® N2	The nitrogen mixture reduces nitrogen loss in the weld. deposit. The added helium improves the fluidity and penetration of the weld and enables a higher welding speed.
			MISON® Ar	Provides a stable arc which is easy to ignite.
	Root protection		Argon	Inert
			Nitrogen	Unreactive (nitrogenising)
Superduplex For example X 2 CrNiMoCuN 25 6 2 SAF 2507, X 2 CrNiMoN 25 7 4 Zeron 100	MIG/MAG	Solid wire	MISON® Ar (Short arc) Spray arc Pulse welding	Provides a stable arc which is easy to ignite. Very little weld oxidation.
			MISON® 2He (Short arc) Spray arc Pulse welding	General gas with a wide operating range. Low spatter and surface slag. Better penetration and fluidity of molten pool than with shielding gas with no added helium. Smooth weld with a good fusion. Enables a high welding speed. Especially for larger sheet thicknesses.
			MISON® N2 (Short arc) Spray arc Pulse welding	Nitrogen addition reduces nitrogen loss in the weld deposit. Very little weld oxidation. The added helium improves the fluidity and penetration of the weld and enables a higher welding speed.
	TIG	With or without filler material.	MISON® N2	The nitrogen mixture reduces nitrogen loss in the weld deposit. The added helium improves the fluidity and penetration of the weld and enables a higher welding speed.
			MISON® Ar	Provides a stable arc which is easy to ignite.
	Root protection		Argon	Inert
			Nitrogen	Unreactive (nitrogenising)

All MISON® shielding gases remove ozone generated during welding and improve the welder's work environment.

Aluminium shielding gases.

eral
8.2 Choosing the shielding gas for aluminium
Selection table

8.1 General

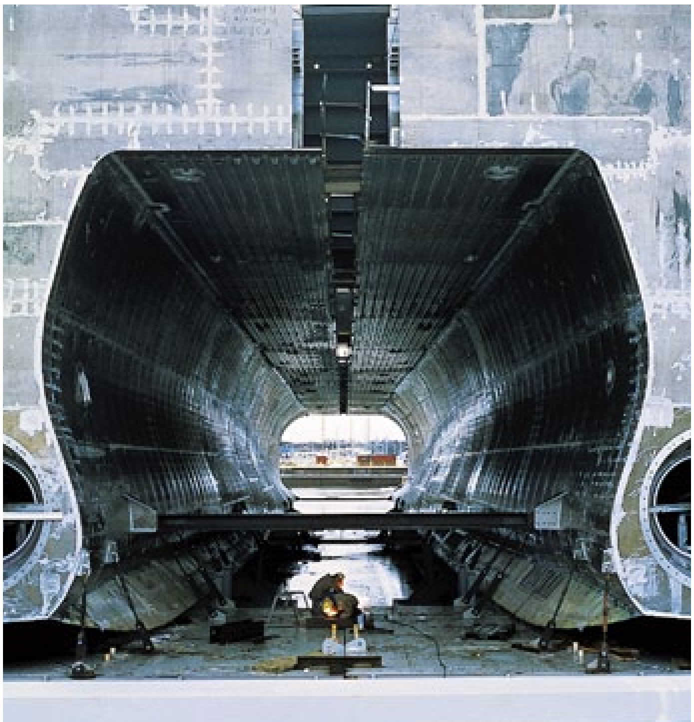
Aluminium and aluminium alloys are structural materials with many good properties, for example lightness, low sensitivity to corrosion, good machinability, good thermal and electrical conductivity and good low-temperature properties.
Due to this, aluminium is used more and more in welded structures and new applications are found all the time.
Pure aluminium has relatively meagre mechanical characteristics, and it is hardly used at all in load-bearing structures.
Its strength is improved through alloying and various heat treatments.
The most common aluminium alloys are:
Al-Cu, Al-Mn, Al-Si, Al-Mg, Al-Si-Mg and Al-Zn.
There are several classification systems for aluminium; probably the most well known is the numerical classification of the Aluminium Association (AA).

In Finland, wrought aluminium alloys are classified according to the four-digit designation system specified in the standard, SFS-EN 573-1.

The standard is identical to the international designation system recommendation published by the Aluminium Association, USA.
See the table below for some common applications and the weldability of different aluminium alloys with gas arc methods.
The weldability of pure aluminium is very good.
However, there are large differences in the weldability of different aluminium alloys, which must be taken into consideration when selecting the materials for a designed structure.

With regard to choosing the shielding gas, there are no differences between the classifications.

With aluminium in particular, retaining the purity of the shielding gas all the way to the welding spot is emphasised.
Even a small amount of moisture entering the molten pool causes porosity in the weld.



Structures welded from aluminium may be very large.
Pictured: the world’s largest aluminium catamaran being built at the dockyard of Finnyards Oy (currently STX Europe).

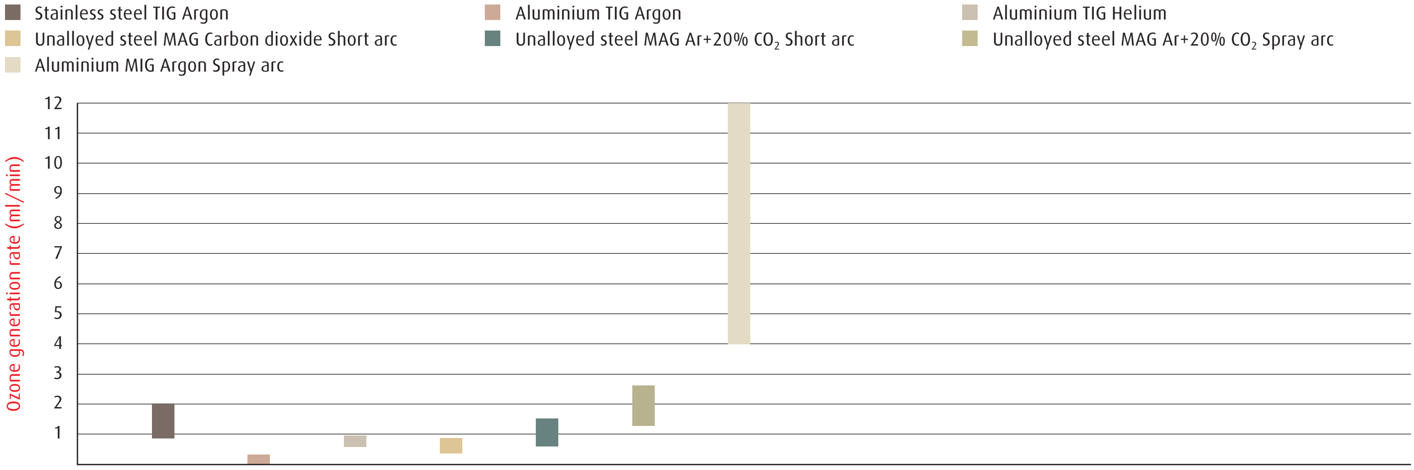
SFS-EN 573-1	Main alloys	Example SFS-EN 573-1	Weldability	Typical Applications
1XXX	Unalloyed (Al ≥ 99.0%)	EN AW-1200	Very good	Bus bars, decorative trims, kettles
2XXX	Copper	EN AW-2011	Possible, not recommended	Aircraft industry
3XXX	Manganese	EN AW-3003	Good	General applications, trims
4XXX	Silicon	EN AW-4045	Good	Welding filler materials
5XXX	Magnesium	EN AW-5005	Good	Boats, ships, tank structures, rolling stock
6XXX	Magnesium and silicon	EN AW-6060	Good	Decorative and flashing strips, doors, windows
7XXX	Zinc	EN AW-7020	Possible, not recommended	Aircraft industry, rolling stock
8XXX	Other alloys			

8.2 Choosing the shielding gas for aluminium

Inert gases are used in the gas arc welding of aluminium.
The most used shielding gas is MISON® Ar, which also reduces the amount of ozone generated during welding.
Ozone is a large problem in the MIG welding of aluminium, during which very large amounts of ozone is generated.
For this reason, all available means of reducing ozone exposure are necessary.

The standard gas for welding thin materials is MISON® Ar.
If you wish to increase penetration or welding speed with thicker materials, you can use shielding gases with a helium content (MISON® He30, VARIGON® He50, VARIGON® He70).

Ozone generation rates when welding different base materials.



Aluminium shielding gases

Process	Filler material	Shielding gas	Properties
MIG	Solid wire	MISON® Ar Spray arc Pulse welding	Provides a more stable arc than argon or argon-helium mixtures
		MISON® He30 Spray arc Pulse welding	General gas for welding thicker materials. Better side penetration and higher welding speed due to the helium mixture.
		VARIGON® He50 VARIGON® He70 Spray arc Pulse welding	As the amount of helium increases, heat transfer to the weld also in creases. Better penetration and higher welding speed. For welding thick materials. No ozone-eliminating properties.
TIG	With or without filler material.	MISON® Ar	Provides a more stable arc than argon or argon-helium mixtures. Arc is easy to ignite. Better penetration than with argon.
		MISON® He30	General gas for welding thicker materials. Better side penetration and higher welding speed due to the helium mixture.
		VARIGON® He50 VARIGON® He70	As the amount of helium increases, heat transfer to the weld also increases. Better penetration and higher welding speed. For welding thick materials. No ozone-eliminating properties

All MISON® shielding gases remove ozone generated during welding and improve the welder's work environment.

Shielding gases for other metals.

Contents

9.1 Shielding gases for copper and copper alloys

Copper is very ductile.
It also has a good corrosion resistance against many substances.
The electrical and thermal conductivity of unalloyed copper is good, but with copper alloys these properties are poorer.

Weldability varies greatly from one copper alloy to another.
Copper and copper alloys are used extensively in electrical equipment, water pipelines, valves, heat exchangers and chemical equipment.
MISON® Ar shielding gas is recommended for the MIG and TIG welding of copper and copper alloys.

When thicker pieces are welded, argon-helium mixtures (MISON® He30, VARIGON® He50, VARIGON® He70) or pure helium can be used.
The helium added to the shielding gas improves penetration and reduces the need for preheating.

9.2 Shielding gases for titanium and titanium alloys

Titanium is often used due to its corrosion resistance or its good weight-strength ratio. In particular, the tensile strength and yield strength of titanium alloys are high.

Titanium and titanium alloys can be divided into different classes.
The American ASTM classification system is the most commonly used.
The most common unalloyed class is Grade 2, which is intended for general applications.

Aluminium and zinc are used as alloys in so-called alpha alloys to improve strength. The most commonly used alpha alloy is Grade 6, which is used in the space industry. Beta alloys include, for example, vanadium, molybdenum and/or chromium. These alloys have the best strength properties.

Grades 19 and 21 are used extensively in the off-shore industry.
High strength and corrosion resistance are typical for these classes, but they are difficult to weld.

Inert shielding gases must be used when welding titanium and titanium alloys. Titanium reacts very easily with hydrogen, oxygen and nitrogen. For demanding applications, we recommend high-purity argon (over 99.996%), Argon 4.6.

Shielding gases for copper and copper alloys

Process	Filler	Shielding gas	Properties
MIG	Solid wire	MISON® Ar Short arc Spray arc Pulse welding	Provides a more stable arc than argon or argon-helium mixtures.
		MISON® He30 Spray arc Pulse welding	General gas for welding thicker materials. Better side penetration and higher welding speed due to the General gas for welding thicker materials. Better side penetration and higher welding speed due to the helium mixture.
		VARIGON® He50 VARIGON® He50 Helium Spray arc Pulse welding	As the amount of helium increases, heat transfer to the weld also increases. Better penetration and higher welding speed. For welding thick materials. No ozone-eliminating properties.
TIG	With or without filler material.	MISON® Ar	Provides a more stable arc than argon or argon-helium mixtures. Arc is easy to ignite.
		MISON® He30	General gas for welding thicker materials. Better side penetration and higher welding speed due to the helium mixture.
		VARIGON® He50 VARIGON® He70 Helium	As the amount of helium increases, heat transfer to the weld also increases. Better penetration and higher welding speed. For welding thick materials. No ozone-eliminating properties.

All MISON® shielding gases remove ozone generated during welding and improve the welder's work environment.

9.3 Shielding gases for nickel-based alloys

The corrosion resistance of stainless steels is insufficient for many applications. The corrosion resistance properties of stainless steel can be further improved by adding alloys (e.g. nickel, chromium and molybdenum).

If the total share of alloys exceeds 50%, the metal is no longer referred to as steel; it is now a nickel-based alloy. Some of these alloys do not contain iron at all. Nickel-based alloys are used when excellent corrosion resistance is required of the material.

We recommend MISON® Ar or MISON® H2 shielding gas for the TIG welding of nickel-based alloys. The hydrogen added to the shielding gas reduces the amount of surface oxides and increases the welding speed. Inert shielding gases must be used in MIG welding, too.

The most recommended alternative is MISON® Ar. The small amount of nitrogen monoxide (NO) added to it makes the arc more stable, resulting in only minor surface oxidation and spatter-free welding.
The use of argon-helium mixtures is also possible, when you wish to improve the fluidity of the molten pool.

Process	Filler	Shielding gas	Properties
Argon	With or without filler material.	Argon 4.6	For demanding applications. Provides a clean, metallic weld surface. A welding shoe is often necessary.
		MISON® Ar	For less demanding applications. Provides a more stable arc than argon. Arc is easy to ignite.
Root protection		Argon 4.6	Inert

All MISON® shielding gases remove ozone generated during welding and improve the welder's work environment.

Process	Filler	Shielding gas	Properties
MIG	Solid wire	MISON® Ar	For less demanding applications. Provides a more stable arc than argon or argon-helium mixtures. Arc is easy to ignite.
TIG	With or without filler material	MISON® Ar	For less demanding applications. Provides a more stable arc than argon or argon-helium mixtures. Arc is easy to ignite.
		MISON® H2	The added hydrogen provides a higher welding speed, better penetration and reduced oxidation.
Root protection		FORMIER® 10	Reducing. Flammable gas mixture
		Argon	Inert

All MISON® shielding gases remove ozone generated during welding and improve the welder's work environment.

Shielding gas applications.

Contents

10.1 Selection table

Shielding gas applications

	MAG			MIG	TIG	MIG soldering	Root protection
	Solid wire	Flux-cored wire	Metal-cored wire	Solid wire			
Structural steels	MISON® 8 MISON® 18 MISON® 25 CO_2	MISON® 18 MISON® 25 CO_2	MISON® 8 MISON® 18 MISON® 25			MISON® Ar	MISON® Ar MISON® 2He
Stainless steels	MISON® 2 MISON® 2He	MISON® 18 MISON® 25 CRONIGON® He	MISON® 2 MISON® 2He CRONIGON® He	MISON® Ar			FORMIER® 10* Argon* VARIGON® H5*
Aluminium				MISON® Ar MISON® He30 VARIGON® He50 VARIGON® He70	MISON® Ar MISON® He30 VARIGON® He50 VARIGON® He70		
Copper				MISON® Ar MISON® He30 VARIGON® He50 VARIGON® He70	MISON® Ar MISON® He30 VARIGON® He50 VARIGON® He70		
Titanium					Argon 4.6 MISON® Ar		Argon 4.6
Nickel alloys				MISON® Ar	MISON® Ar MISON® H2		FORMIER® 10 Argon

*See the tables on previous pages

MISON® 8

(Ar + 8% CO_2 + 0.03% NO)
MISON® 8 shielding gas is recommended for the MAG welding of unalloyed and low-alloy steels with solid wire and metal-cored wire.
This shielding gas is especially designed for spray arc and pulse welding.

MISON® 8 provides a high welding speed and low spatter and surface slag.

The weld bead or reinforcement is low, the arc is stable and the deposition efficiency is high.
MISON® 8 is the best choice when trying to achieve the highest productivity in robot or mechanised welding.

Reduces the amount of harmful ozone generated more than usual during high-productivity welding.
Classification: ISO 14175-Z

MISON® 18

(Ar + 18% CO_2 + 0.03% NO)
MISON® 18 shielding gas is suited to the MAG welding of unalloyed and low-alloy steels with solid wire and metal-cored wire.
It is also suited to pulse welding with certain limitations, and it can also be used as the shielding gas for the rutile cored wire welding of stainless steels.

MISON® 18 provides a low weld bead and low-spatter welding in all arc regions.

Well suited to be used as a general gas.

Reduces the amount of harmful ozone generated during welding.
Classification: ISO 14175-Z

MISON® 25

(Ar + 25% CO_2 + 0.03% NO)
MISON 25 shielding gas is suited to the MAG welding of unalloyed and low-alloy steels with solid wire and metal-cored wire.

MISON® 25 provides a fluid and highly manageable molten pool when short arc is used.

The shielding gas has an excellent tolerance to impurities in spray arc welding, and it produces a tight weld even in unfavourable conditions.

Spatter formation is lower, the weld fusion with the base material better and the welding speed higher compared to carbon dioxide.
It is the most oxidising of the gas mixtures, due to which slag formation is also the highest.

The gas is especially recommended for short arc welding (small machines) and spray arc welding when the weld has tightness requirements or the welding conditions are unfavourable.

Reduces the amount of harmful ozone generated during welding.
Classification: ISO 14175-Z

MISON® Ar

(Ar + 0.03% NO)
MISON® Ar is suited to the TIG welding of most metals, and provides and easily igniting arc which is more stable than with argon.

MISON® Ar is also suited to the MIG welding of aluminium and its alloys, high-alloy stainless steels (duplex and superduplex), copper and nickel alloys.

Provides a stable and spatter-free welding.

Also recommended for the MIG soldering of coated steels.

This shielding gas is not recommended for root protection.
Reduces the amount of harmful ozone generated during welding.
Classification: ISO 14175-Z

MISON® 2

(Ar + 2% CO_2 + 0.03% NO)
MISON® 2 is suited to the MAG welding of stainless steels, such as standard austenitic grades (e.g. AISI 304 and 316), ferritic and standard-grade duplex steels.

MISON® 2 is suited to short arc, spray arc and pulse welding.

Low spatter and surface slag, good penetration and low weld bead.

Reduces the amount of harmful ozone generated during welding.
Classification: ISO 14175-Z

MISON® 2He

(Ar + 2% CO_2 + 30% He + 0.03% NO)
MISON® 2He is suited to the MAG welding of stainless steels, such as most austenitic (e.g. AISI 304 and 316), ferritic and standard-grade duplex steels.

The shielding gas is suited to short arc, spray arc and pulse welding.

Low spatter and surface slag, good penetration and low weld bead.

Especially recommended for the welding of thicker materials.

Also suited to the MIG soldering of coated steels when material thickness is over 1.5 mm. Reduces the amount of harmful ozone generated during welding.
Classification: ISO 14175-Z

MISON® N2

(Ar + 1.8% N_2 + 30% He + 0.03% NO)
MISON® N2 is suited to the TIG welding of stainless duplex steels and nitrogen-alloyed austenitic steels.

The nitrogen in the gas reduces the nitrogen loss in the weld, providing better corrosion resistance and good mechanical characteristics.

Can also be used in the MIG welding of high-alloy austenitic and superduplex steels.

Reduces the amount of harmful ozone generated during welding.
Classification: ISO 14175-Z

MISON® H2

(Ar + 2% H_2 + 0.03% NO)
MISON® H2 is suited to the TIG welding of austenitic stainless steels and nickel-based alloys.

The hydrogen enables a hotter and more focused arc, a deeper welding speed, better penetration and a smooth fusion between the weld and the base material.

The hydrogen also prevents weld oxidation.

Reduces the amount of harmful ozone generated during welding.
Classification: ISO 14174-Z

CRONIGON® He

(Ar + 1% O_2 + 30% He)
CRONIGON® He is a multi-purpose gas for the MAG welding of stainless steels.

Low spatter and surface slag.

Helium addition provides better fluidity of the molten pool and deeper penetration.

Especially for situations where you wish to ensure that the weld has a very low carbon content (<0.030%) in spray arc welding.

No ozone-reducing effect.
Classification: ISO 17175-M13

MISON® He30

(Ar + 30% He + 0.03% NO)
MISON® He30 is suited to TIG welding and the MIG welding of certain high-alloy stainless steels, nickel-based alloys, aluminium and copper and their alloys.

MISON® He30 provides a very fluid molten pool, better side penetration, higher welding speed and it also reduces the need for preheating. Reduces the amount of harmful ozone generated during welding.
Classification: ISO 14175-Z

VARIGON® He50 - VARIGON® He70

(Ar + 50% He) - (Ar + 70% He)
VARIGON® shielding gases are suited to TIG welding and the MIG welding of certain high-alloy stainless steels, nickel-based alloys, aluminium and copper and their alloys.

By varying the helium content of the shielding gas, you can achieve the desired properties for the optimisation of heat transfer, molten pool management, penetration and welding speed.

Especially suited to the welding of thick aluminium and copper.
Classification: ISO 14175-I3

VARIGON® H5

(Ar + 5% H_2)
VARIGON® H5 is especially suited to the mechanised TIG welding of austenitic materials.

Provides a high welding speed and oxidation-free weld.

Can also be used as the root shielding gas for austenitic stainless steels.
Classification: ISO 14175-R1

FORMIER® 10

(N_2 + 10% H_2)
FORMIER® 10 is suitable for use as the root shielding gas primarily of austenitic materials.

Also used for the root protection of unalloyed and low-alloy steels. FORMIER® 10 is a reducing root shielding gas which provides a well-formed, oxide-free root surface.

The gas is flammable, so it should not be used for root protection in tank welding.
Classification: ISO 14175-N5

Delivery forms of shielding gases.

Contents

11.1 Delivery forms

Shielding gases can be delivered in different forms.
AGA delivers shielding gases mainly in the following ways:

1. In gaseous form (carbon dioxide in liquid form) in cylinders.
   The most common cylinder sizes are 50 l/200 bar and 20 l/200 bar. Smaller cylinder sizes are also included in AGA's rental system. The selection of cylinder sizes depends on the type of the shielding gas.

2. In gaseous form (carbon dioxide in liquid form) in cylinder bundles, Maxi cylinders or SuperMaxi cylinders. A cylinder bundle comprises 12 cylinders with a fixed connection to gas output, while Maxi and SuperMaxi cylinders are round tanks (450 and 800 l). The availability of Maxi and SuperMaxi cylinders depends on the gas type.
   Bundles, Maxi cylinders and SuperMaxi cylinders can be transported with a forklift. This delivery form is suited to medium-large customers with a gas delivery network.

3. In liquid form to tanks on the customer's premises.
   Liquid argon (LAR), liquid MISON® (LAR + 0.03 NO) or liquid carbon dioxide (LIC) is transported in a tanker truck to the customer's tank, from which it is conducted to the gas network via an evaporator.

This delivery form is suited to customers with very high gas consumption.

11.1.1 AGAs gas distription systems

Many of our customers currently use a gas distribution system comprising a gas manifold (reduces the cylinder pressure to network pressure), cylinders or cylinder bundles connected to it, a gas network and the required number of tapping points.

Several different types of gas manifolds are available depending on the gas, gas requirement and the desired level of automation.

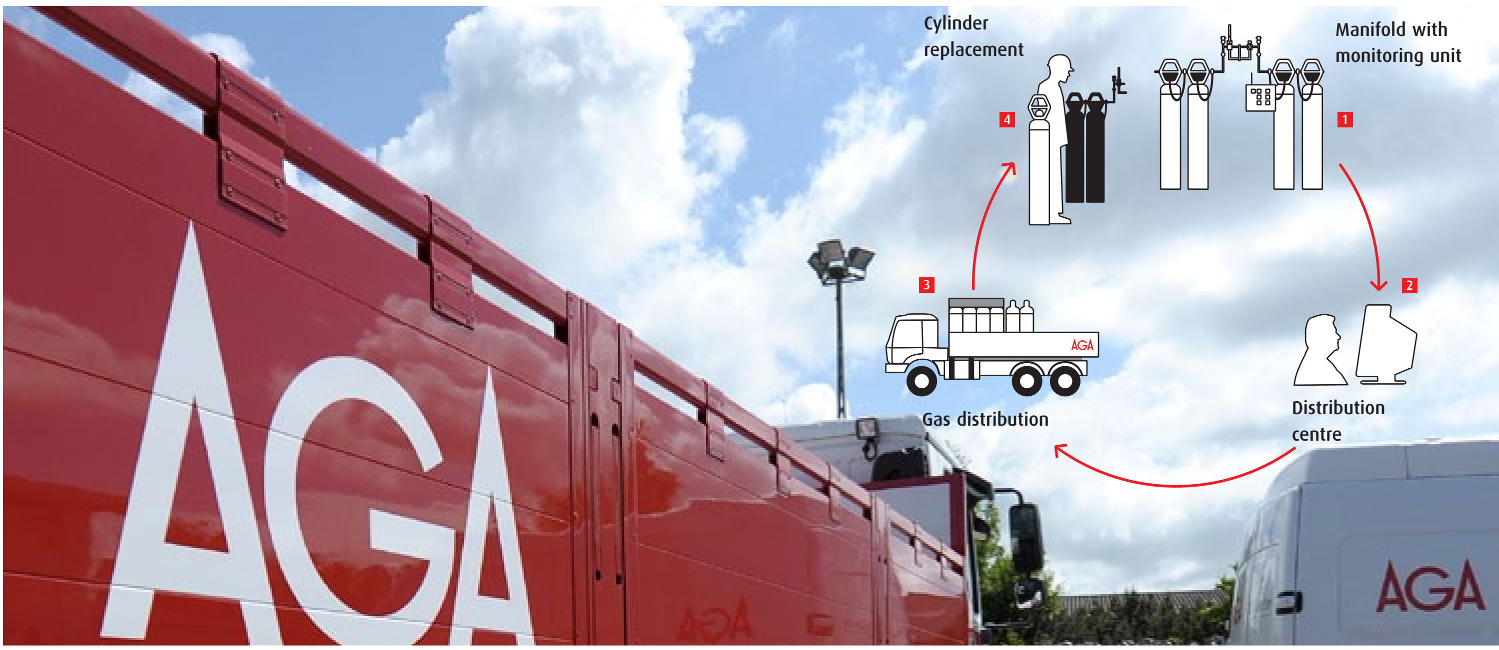
If the gas consumption is very high, the gas can be delivered in liquid form.

The gas will then be fed from the liquid gas tank to the gas network via an evaporator, and further to the point of use from the tapping points. The delivered gases can also be mixed into the desired mixture using a mixer before it is conducted to the gas network.

A gas distribution system guarantees a reliable and continuous gas supply to different points of use.

Gas cylinders do not need to be moved at the worksite, which saves time and work, and improves safety.

A gas distribution system also reduces the amount of cylinders needed and lowers rental and transportation costs.
In order to ensure correct operation, the design and implementation of the gas distribution system should be commissioned from a company specialising in the installation of gas networks.
AGA has long experience in the design and implementation of functional gas systems with specialty, pharmaceutical and industrial gases.



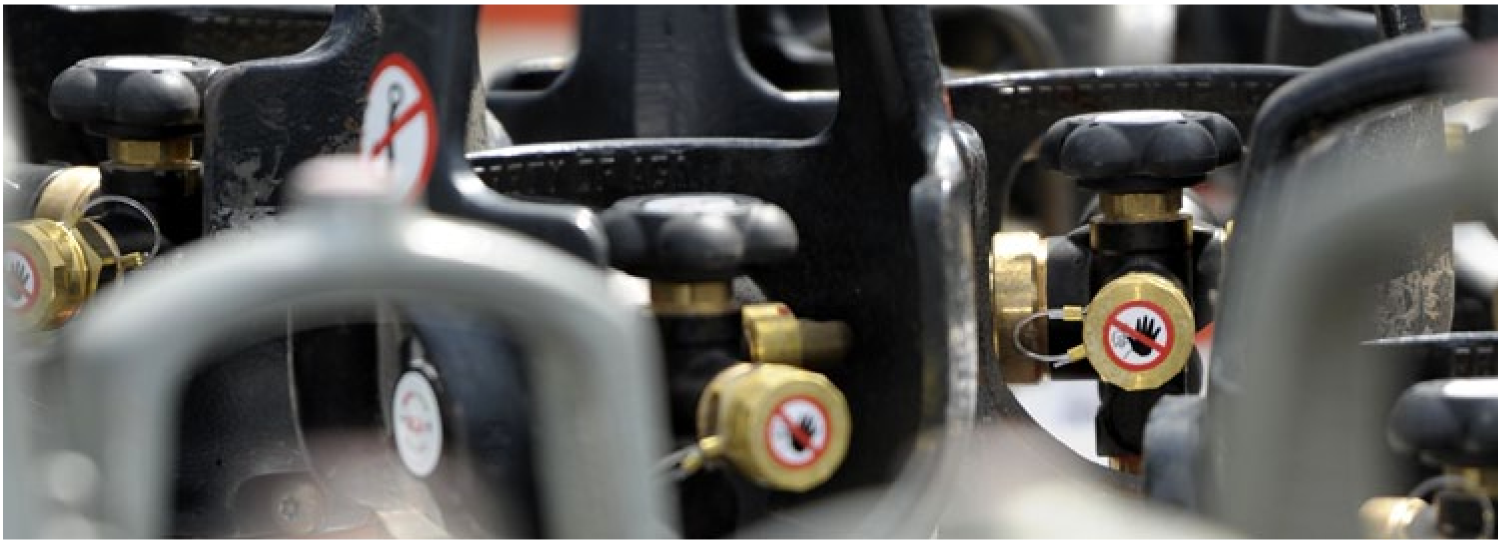
11.2 Cylinders and cylinder bundles

See the table below for information on typical gas cylinders and cylinder bundles.
The values given are suggestive.
The gas cylinders are equipped with a fixed LC cap with a barcode attached.
Each cylinder has its own barcode, which contains information on, for example, the cylinder's technical specifications, the cylinder's current location, refilling history and gas composition.
The gas cylinders are also marked in other ways.

- Industrial gas cylinders are painted black
- The colours of the cylinder shoulder are determined by the cylinder colour standard
- The colour indicates the hazardous property of the gas or gas mixture
- As an exception to this, individual identifying colours have been specified for some gases
- Gases with their own colours are acetylene, oxygen, nitrous oxide, argon, nitrogen, carbon dioxide and helium
- During the transition period, cylinders painted according to the old standard will be in circulation
- Information is stamped on the cylinder shoulder, including the cylinder's manufacturing information, maximum allowed filling pressure, cylinder weight and time of last inspection
- The cylinder is a pressure vessel which must be inspected at regular intervals
- A white label indicates the product's name and composition.
  It also shows the ADR/VAK transportation class, the UN number and instructions related to the safe use of the gas

Cylinder type (m^3, 200 bar)	Gas volume* (m^3, 200 bar)	Empty cylinder weight incl valve and protective cap (around) (kg)	Height including valve and protective cap (mm)	External diameter (mm)
OTC-5	1,0	8,8	555	140
OTM-5	1,0	7,0	600	152
OTC-20	4,0	36,5	1065	204
OTC-50	10,0	70,0	1775	230
Cylinder bundles and balls			Width x depth x height (mm)	
12 x OTC-50	120	1050	1100 x 850 x 1840 1020 x 780 x 1930	
Maxi cylinder	90	600, 850	1050 x 1050 x 1150	
SuperMaxi cylinder	160	1450	1220 x 1220 x 1530	

* Approximate amount (varies according to gas/gas mixture)



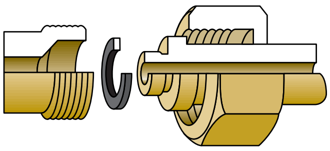
11.3 Cylinder valve threads

In order to increase safety and prevent incorrect connections, the cylinders and cylinder bundles have different threads depending on the gas or gas mixture. See below for the cylinder threads of the most common gases.

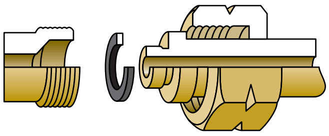
A regulator designed for the gas and cylinder pressure in question must be used on the cylinders. Using an adapter between the pressure regulator and the cylinder valve is not allowed.

Valve threads

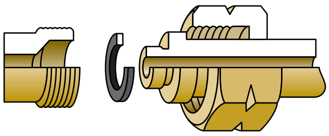
24.32 x 1.814 SFS 2292
MISON® Ar, MISON® 2, MISON® 2He, MISON® N2, MISON® H2, MISON® 8, MISON® 18, MISON® 25, MISON® He30, VARIGON® He50, VARIGON® He70, VARIGON® H5, Argon, Nitrogen, Helium, Ar/CO_2 mixtures.



21.80 x 1.814 SFS 2292 ODOROX®, Oxygen, Carbon dioxide.



left-handed 21.80 x 1.814 SFS 2292 FORMIER® 10, Hydrogen.



11.4. Gas purity

The purity of the shielding gas is very significant in welding. Gas purity affects the weld quality and welding speed, and the operating life of the electrode in TIG welding.
AGA guarantees the purity of gas all the way to the delivery point, e.g. a cylinder valve. From there onwards, it is the customer's responsibility to ensure the purity of the gas on the way to the point of use.

If the shielding gas is conducted to the point of use through a gas distribution network, you should invest in the design, construction and maintenance (tightness) of the network.

Here are a few tips for ensuring the purity of the gas from the cylinder valve or tapping point onwards.

- Do not let gas out of the cylinder valve before connecting the pressure regulator
- Flush the pressure regulator and the hoses for a while before starting the actual work
- Use only gas hoses intended for the shielding gas
- Avoid unnecessarily long and large-diameter hoses
- Ensure that the hoses are undamaged and that all connections are tight
- If the welding gun is water-cooled, ensure that it has no leaks
- Use the recommended gas flow and check it with a rotameter from the end of the nozzle

If the flow is too high, the gas shielding is unstable, and if it is too low, it is insufficient to shield the arc and the molten pool. Also remember that in gas arc welding, the gas shielding is reduced by draught, spatter accumulation in the gas nozzle and an unstable arc.

11.5. Safe handling of gas

Using gases in welding is risk-free when the gases and gas equipment are handled correctly. For this reason, the user must have sufficient information on the following issues:
- Gas properties and safe handling
- Correct handling of the equipment
- Protective measures required before work, during work and after work
- Currently valid regulations

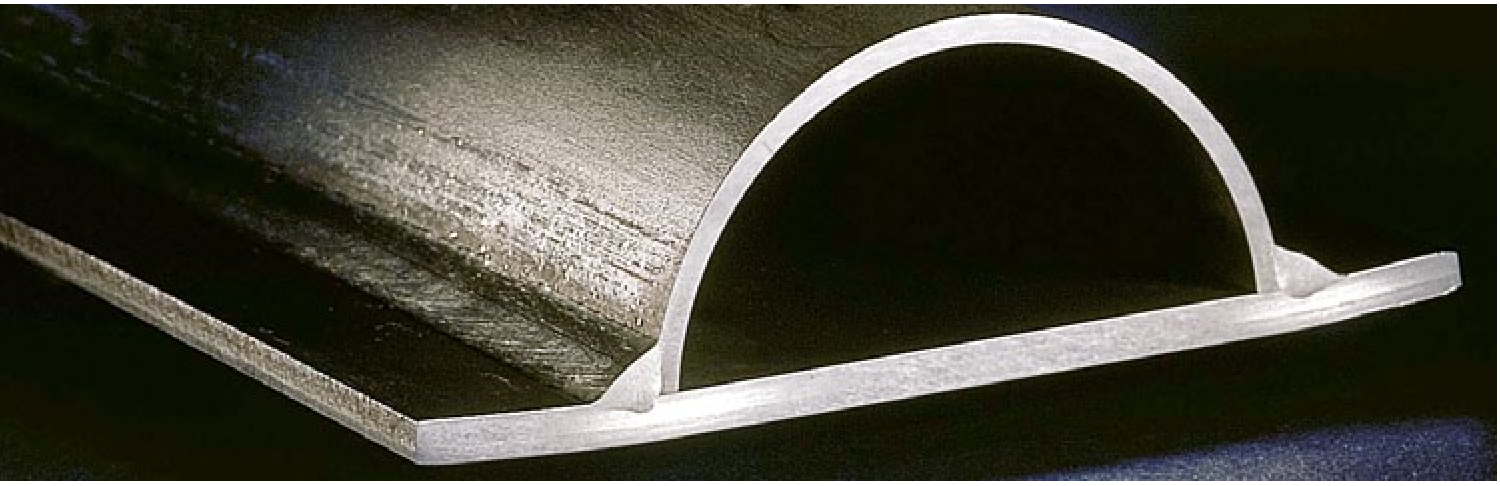
11.6 Laws and regulations

There are a number of regulations concerning the transportation, storage and use of gases. The storage and use of flammable and oxidising gases in particular is strictly regulated. In addition to these regulations applying to everyone, there are often company-specific regulations which the user must also follow.

AGA also arranges training on gas safety. We can also supply all necessary information on the safe use of our products.

Terminology.

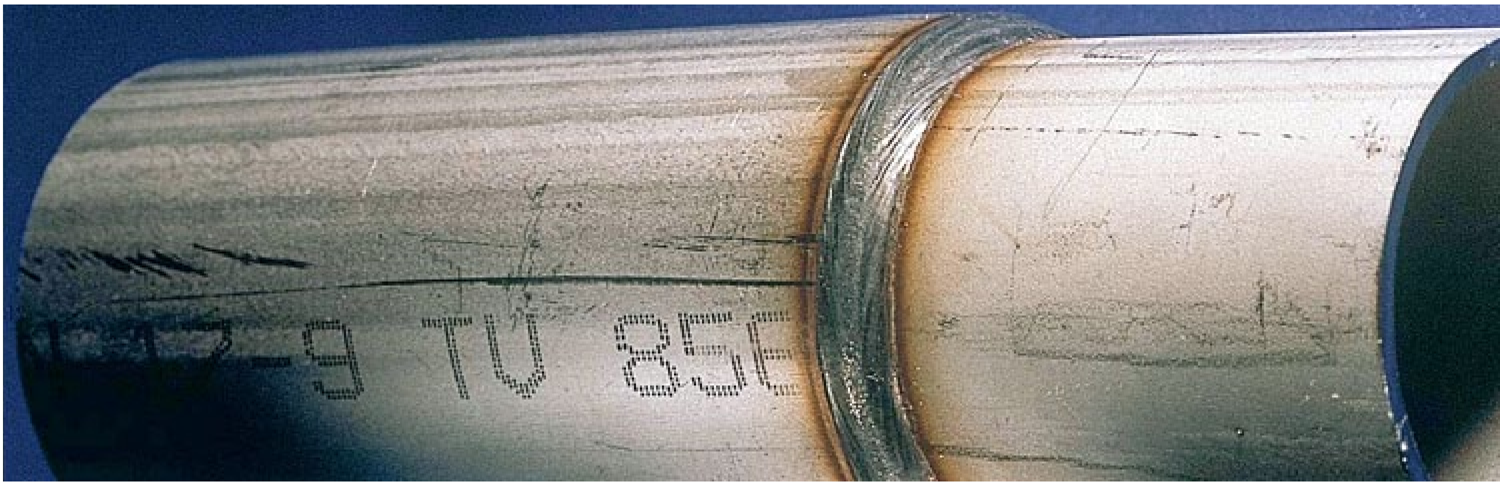
- **Anode:** Positive electrode
- **Austenitic stainless steel:** A steel with a microstructure that is austenitic at room temperature (the most common stainless steels, for example AISI 304, AISI 316)
- **Duplex steel:** A steel with a microstructure that is half ferritic and half austenitic at room temperature
- **Ferritic stainless steel:** A steel with a microstructure that is mainly ferritic at room temperature
- **HTP:** The Finnish Threshold Limit Value. Exposure limits defined by the Ministry of Labour which should not be exceeded at workplaces. HTP_{8h} and HTP_{15min} are the values of average harmful concentrations over 8 hours and 15 minutes, respectively
- **Cathode:** Negative electrode
- **MAG welding:** Gas arc welding in which the arc burns between the fed filler material wire and the base material. A reactive gas is used as the shielding gas (MAG = Metal Active Gas)
- **Metal fume fever:** A condition resembling flu caused by the breathing of metal oxides. Its symptoms include fever, tremors, sweating an nausea
- **MIG welding:** Gas arc welding in which the arc burns between the fed filler material wire and the base material. An inert gas is used as the shielding gas (MIG = Metal Inert Gas)
- **MIG soldering:** MIG welding using a filler material wire with a low melting point (aluminium bronze, silicon bronze) without melting the base material
- **Micrometre µm:** One millionth of a metre = 0.001 mm
- **Ozone (O_3):** A colourless, highly toxic gas. When oxygen molecules (O_2) are subjected to UV radiation, for example from a welding arc, ozone is generated
- **Spot corrosion:** Localised spot-like corrosion
- **MMA welding:** Arc welding where the arc burns between the elec trode and base material (MMA = Manual Metal Arc)
- **Ppm:** One millionth (ppm = Parts Per Million)
- **Iron dust lung:** Lung inflammation caused by breathing iron dust
- **High-alloy austenitic steel:** Stainless austenitic steel, the corrosion resistance of which has been improved by alloying
- **Superduplex:** High-alloy duplex steel
- **TIG welding:** Gas arc welding in which the arc burns between a non-consumable electrode (tungsten) and the base material. Welding is performed with or without filler material. Inert shielding gas is used (TIG = Tungsten Inert Gas)
- **Cored wire welding:** MIG welding using a metal powder, rutile or alkaline-cored wire instead of solid wire



The shielding gas classifications and designations according to the EN ISO 14175:2008 standard.

Name	Composition	Classification	Designation
MISON® Ar	Ar + 0,03% NO	Z	EN ISO 14175-Z-Ar+NO-0,03
MISON® H2	Ar + 2% H_2 + 0,03% NO	Z	EN ISO 14175-Z-ArH+NO-2/0,03
MISON® N2	Ar + 30% He + 1,8% N_2 + 0,03% NO	Z	EN ISO 14175-Z-ArHeN+NO-30/1,8/0,03
MISON® 2	Ar + 2% CO_2 + 0,03% NO	Z	EN ISO 14175-Z-ArC+NO-2/0,03
MISON® 2He	Ar + 30% He + 2% CO_2 + 0,03% NO	Z	EN ISO 14175-Z-ArHeC+NO-30/2/0,03
MISON® 8	Ar + 8% CO_2 + 0,03% NO	Z	EN ISO 14175-Z-ArC+NO-8/0,03
MISON® 18	Ar + 18% CO_2 + 0,03% NO	Z	EN ISO 14175-Z-ArC+NO-18/0,03
MISON® 25	Ar + 25% CO_2 + 0,03% NO	Z	EEN ISO 14175-Z-ArC+NO-25/0,03
MISON® He30	Ar + 30% He + 0,03% NO	Z	EN ISO 14175-Z-ArHe+NO-30/0,03
Argon	Ar 4.0 (99,990% Ar)	I1	EN ISO 14175-I1-Ar
Argon 4.6	Ar 4.6 (99,996% Ar)	I1	EN ISO 14175-I1-Ar
CORGON® 8	Ar + 8% CO_2	M20	EN ISO 14175-M20-ArC-8
CORGON® 18	Ar + 18% CO_2	M21	EN ISO 14175-M21-ArC-18
CORGON® 25	Ar + 25% CO_2	M21	EN ISO 14175-M21-ArC-25
CORGON® 3	Ar + 5% CO_2 + 5% O_2	M23	EN ISO 14175-M23-ArCO-5/5
CRONIGON® He	Ar + 30% He + 1% O_2	M13	EN ISO 14175-M13-ArHeO-30/1
CRONIGON® S2	Ar + 2% O_2	M13	EN ISO 14175-M13-ArO-2
VARIGON® He50	Ar + 50% He	I3	EN ISO 14175-I3-ArHe-50
VARIGON® He70	Ar + 70% He	I3	EN ISO 14175-I3-ArHe-70
VARIGON® H5	Ar + 5% H_2	R1	EN ISO 14175-R1-ArH-5
VARIGON® H35	Ar + 35% H_2	R2	EN ISO 14175-R2-ArH-35
Helium	He 4.6 (99,996% He)	I2	EN ISO 14175-I2-He
FORMIER® 10	N_2 + 10% H_2	N5	EN ISO 14175-N5-NH-10
Carbon dioxide	CO_2 2.8 (99,8% CO_2)	C1	EN ISO 14175-C1- C

MISON® shielding gases remove ozone generated during welding and improve the welder's work environment.



Gas selection table.

The shielding gas product programme will be complemented as new weldable materials and methods are developed.

The shielding gases included in the table are part of AGAs warehouse programme.
We will deliver other mixtures and specialty gases on order.

Select the right gas for your process.

● Recommended ▲ Alternativ ■ Can give further benefits

Process	Material	MISON® AR	HE30	H2	2	2HE	8	18	25	ARGON® –	4.6	VARIGON® H5	HE50
TIG	Unaloyed/low alloyed steels	●	■							▲			■
	Stainless steels, austenitic	●	■	■						▲		■	■
	Stainless steels, duplex	●	■		■					▲			■
	Aluminium and its alloys	●	■							▲			■
	Copper and its alloys	●	■							▲			■
	Titanium									▲	●		■
MIG/MAG	Unaloyed/low alloyed steels						■	●	▲				
	Stainless steels, austenitic				●	■							
	Stainless steels, duplex					●							
	Aluminium and its alloys	●	■							▲			■
	Copper and its alloys	●	■							▲			■
PLASMA	Unaloyed/low alloyed steels									●	■		
	Stainless steels, austenitic									▲		●	
	Stainless steels, duplex									●			
	Aluminium and its alloys									●			
	Copper and its alloys									●			
	Titanium									▲	●		
ROOT PROTECTION	Unaloyed/low alloyed steels									▲			
	Stainless steels, austenitic									▲		▲	
	Stainless steels, duplex									▲			
	Aluminium and its alloys									●			
	Copper and its alloys									●			
	Titanium									▲	●		

MIG/MAG: It is anticipated that welding is done with solid wire electrodes. Other gas selections can be made when welding is done with cored wire electrodes. See also www.aga.com.

Select the right gas for your process.

● Recommended ▲ Alternativ ■ Can give further benefits

Process	Material	VARIGON® HE70	CRONIGON® S2	CRONIGON® HE	CORGON® 3	CORGON® 8	CORGON® 18	CORGON® 25	FORMIER® 10	Nitrogen –	Carbon dioxide
TIG	Unaloyed/low alloyed steels										
TIG	Stainless steels, austenitic										
TIG	Stainless steels, duplex										
TIG	Aluminium and its alloys	■									
TIG	Copper and its alloys	■									
TIG	Titanium										
MIG/MAG	Unaloyed/low alloyed steels				▲	▲	▲	▲			▲
MIG/MAG	Stainless steels, austenitic		▲	■							
MIG/MAG	Stainless steels, duplex		▲	■							
MIG/MAG	Aluminium and its alloys	■									
MIG/MAG	Copper and its alloys	■									
PLASMA	Unaloyed/low alloyed steels										
PLASMA	Stainless steels, austenitic										
PLASMA	Stainless steels, duplex										
PLASMA	Aluminium and its alloys										
PLASMA	Copper and its alloys										
PLASMA	Titanium										
ROOT PROTECTION	Unaloyed/low alloyed steels								●	▲	
ROOT PROTECTION	Stainless steels, austenitic								●	▲	
ROOT PROTECTION	Stainless steels, duplex								●	▲	
ROOT PROTECTION	Aluminium and its alloys									▲	
ROOT PROTECTION	Copper and its alloys									▲	
ROOT PROTECTION	Titanium										

MIG/MAG: It is anticipated that welding is done with solid wire electrodes. Other gas selections can be made when welding is done with cored wire electrodes. See also www.aga.com.

Getting ahead through innovation.

With its innovative concepts, AGA is playing a pioneering role in the global market. As a technology leader, our task is to constantly raise the bar. Traditionally driven by entrepreneurship, we are working steadily on new high-quality products and innovative processes.

AGA offers more. We create added value, clearly discernible competitive advantages and greater profitability. Each concept is tailored specifically to meet our customers' requirements – offering standardized as well as customised solutions. This applies to all industries and all companies regardless of their size.

AGA – ideas become solutions.

Sweden
AGA Gas AB
www.aga.se

Norway
AGA AS
www.aga.no

Iceland
ISAGA ehf
www.aga.is

Latvia
AGA SIA
www.aga.lv

Finland
Oy AGA Ab
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Denmark
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