Making our world
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MiniGuide

For MIG/MAG welding of stainless steel.

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Stainless steel.

Dependent on the microstructure, stainless steel is divided into various groups.
The most significant groups are:

Ferritic
Martensitic
Duplex (ferrite/austenitic)
Austenitic

Depending on the alloy and its properties, each group is further subdivided. Some of the important stainless steels are listed below.

Ferritic and martensitic stainless steel:

Steel type:	XX:	EN	ASTM:
Ferritic	-	1.4512	409
Ferritic	-	1.4016	430
Martensitic	-	1.4028	420
Martensitic	-	1.4418	-

*XX: former national standard.

Duplex stainless steel (ferrite/austenitic):

Steel type:	XX:	EN	ASTM:
Low alloy duplex "2304"	-	1.4362	S32304
Duplex "2205"	-	1.4462	S31803
Super Duplex "2507"	-	1.4410	S32750

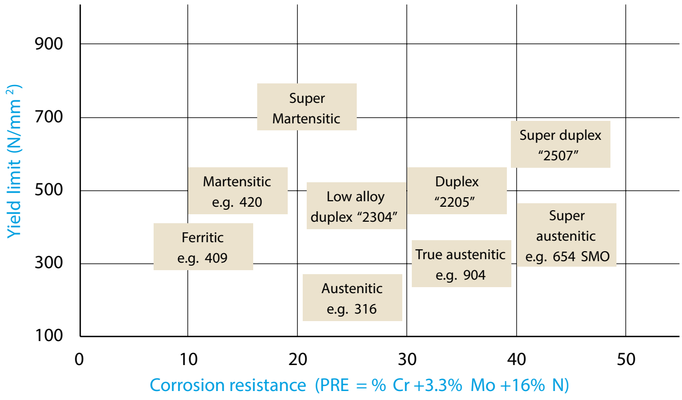
*XX: former national standard.

Austenitic stainless steel:

Steel type:	XX:	EN	ASTM:
Austenitic	-	1.4310	301
Austenitic "18-8"	-	1.4301	304
Austenitic "acid-resistant"	-	1.4436	316
Fully austenitic "254 SMO"	-	1.4547	S31254
Fully austenitic "904 L"	-	1.4539	N08904
Super austenitic "654 SMO"	-	1.4652	S32654

*XX: former national standard.

Strength and corrosion resistance in various types of stainless steel.



Welding stainless steel – practical advice

Welding stainless steel is not normally any different to welding non alloy or low alloy steel. In certain respects, however, the methods do differ. This particularly applies to high alloy steels. Below is a brief overview of considerations.

General considerations

- Higher thermal expansion and lower conductivity leads to a greater risk of deformation (particularly for austenitic steel)
- Due to this, the distance between the tack welds should be shorter than for non alloy steel. It is also important that the tack welds are done in the right order
- Following tack welding, excess weld should be removed before welding
- To avoid unwanted structural elements, e.g. σ phase, the energy per unit length must be limited. It should be between 0.5 - 2.5 kJ/mm
- The maximal interpass temperature for standard material is 250°C

- Limit the size of the melt to avoid heat cracking and avoid end craters by using the right finishing technique. The higher the alloy grade, the more important it is to consider these factors
- It is often important to reach the same chemical composition in the welded items as in the parent metal. Follow the instructions from the filler metal manufacturer
- It is important that the surfaces of both the parent metal and the filler metal are clean and dry
- Always use stainless brushes and clean grinding wheels. Avoid equipment that has been used for low alloy steel

To consider when welding super duplex, fully, and super austenitic stainless steels

- To avoid unwanted structural elements, e.g. σ phase, the heat supply must not be set too high. It should be between 0.2 - 1.5 kJ/mm
- The maximal interpass temperature is 150°C
- A nickel-based filler metal can be necessary for super austenitic and super duplex stainless steel. See the instructions from the filler metal manufacturer

Calculation of energy per unit length (heat input):

$$Q = n \times \frac{U \times I \times 60}{v \times 1000}$$

I = Welding current (A)
U = Arc Voltage (V)
Q = Heat Input (kJ/mm)
n = Efficiency
v = Travel speed (mm/min)

Basic facts on shielding gases

One function of the shielding gases is to protect the hot metal from the surrounding air. Without this protection, the heated or molten metal would oxidise. Pores would also be created.

Other important factors affected by the shielding gas are: the stability of the arc, the welding speed, the welding geometry, resistance to corrosion, mechanical properties and the working environment. The shielding gas therefore has a considerable influence on the weld quality and productivity.

The various elements in the shielding gases have different properties and are closely balanced to provide optimal welding ability.

Argon (Ar)
The main component in the majority of gas mixtures. Argon is an inert* gas.

Helium (He)
An inert gas*. Gives better metal penetration and increases the flow of the melt.

Hydrogen (H_2)
Reduces oxides, improves metal penetration and increases the flow of the melt.

Carbon dioxide (CO_2)
An oxidising gas. Gives arc stability and better weld profiles.

Oxygen (O_2)
An oxidising gas. Gives arc stability, but gives worse metal penetration than CO_2. Can give excessive surface oxidation.

Nitrogen (N_2)
Used as an additive for nitrogen alloy steel. Improves corrosion resistance.

* Does not chemically react with any substance.

MISON® shielding gases

MISON® shielding gases are a group of gases from Linde which give optimal productivity and quality for MIG/MAG, cored wire, TIG and plasma welding. MISON® improves the working environment by reducing the amount of ozone. Adding 300 ppm NO to the shielding gas reacts with any ozone as soon as it is created.

Shielding gases for MIG/MAG welding

MISON® 2, (Ar + 2% CO_2 + 0.03% NO). An all-round shielding gas for all types of stainless steel (ferritic, martensitic, duplex, austenitic).
MISON® 2He, (Ar + +2% CO_2 + 30% He + 0.03% NO). All-round shielding gas for all types of stainless steel. Increased metal enetration and flow of the melt through the addition of helium. Enables a higher welding speed.
MISON® Ar, (Ar + 0.03% NO). Used for super duplex, fully and super austenitic stainless steel. Gives a stable arc and minimises surface oxides.
MISON® N2, (Ar + 1.8% N_2 + 30% He + 0.03% NO). Used for super duplex, fully and super austenitic nitrogen alloy stainless steel. The nitrogen improves corrosion resistance. Better flow of the melt thanks to our addition of helium.

High-speed welding

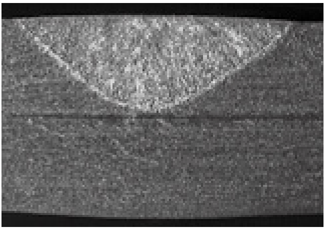
RAPID PROCESSING® is a highly productive MIG/MAG welding method particularly suitable for stainless steel. The weld speed and/or deposition rate can, in many cases, be increased significantly through unconventional parameter settings in combination with an optimal shielding gas composition.

Shielding gases for welding with flux-filled core electrodes

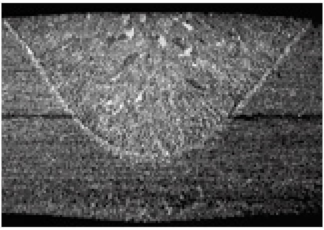
MISON® 18, (Ar + 18% CO_2 + 0.03% NO). The best choice for the majority of flux-filled core electrodes.

Shielding gases for TIG welding

Argon, all-round shielding gas for all types of stainless steel (ferritic, martensitic, duplex, austenitic).
MISON® Ar, (Ar + 0.03% NO). All-round shielding gas for all types of stainless steel. Gives improved working environment and in certain cases, gives better metal penetration compared with argon.
MISON® H2, (Ar + +2% H_2 + 0.03% NO). The addition of hydrogen gives greater welding speed and/or better metal penetration and less surface oxidation. Only suitable for austenitic steel.



Argon.



MISON® H_2

Penetration in a 2.5mm thick piece of steel (ASTM 304) welded without filler metal. MISON® H_2 gives a 60% increased melted cross-section area. Welding current: 80 A. Welding speed: 250 mm/min.

MISON® N_2, (Ar + 1.8% N_2 + 30% He + 0.03% NO). Used for nitrogen alloy steel (duplex, super duplex, fully/super austenitic). The addition of nitrogen improves corrosion properties and the mechanical strength by compensative for nitrogen loss whilst welding. This is particularly important when welding without filler. Helium improves the flow of the melt and gives better metal penetration.

Gases for plasma welding

For plasma welding, the same gas can often be used both as plasma gas and shielding gas. The most common are:
Argon. Can be used for all types of stainless steel. Used mainly as plasma gas (easy to ionise).
Argon/hydrogen mixtures. Used for austenitic stainless steel. Good penetration and flow in the melt. Easy to achieve “key-hole” and oxide- free welds.

Optimising gas shielding for MIG/MAG and TIG welding.

The amount of shielding gas must be sufficient to protect the melt from the surrounding air. A suitable shielding gas flow depends on factors such as: the type of parent material (= stainless steel), type of shielding gas, the size of the gas cup (determined by the strength of the current/the size of the melt), draft and the type of groove/ working position.

Factors to consider when obtaining a good gas shield:

To obtain a laminar gas flow, the flow must be adapted to the size of the gas cup. A flow that is too high or too low risks an insufficient gas shielding. Helium-rich shielding gases require a higher flow than with argon and argon/CO_2 mixtures. The following rule of thumb is applicable to argon and argon/carbon dioxide mixtures:
Flow [l/min] ≈ gas cup's internal diameter [mm]

The flow must be measured at the gas cup outlet. Use a flow meter

Check that the gas shielding is not affected by draft. If the draft cannot be shielded, one of the following can reduce the problem:

- Reduce the distance between the gas cup and the work item
- Increase the gas flow
- Use gas lens (TIG welding)

Remove adhesive spatter from inside of the gas cup (MIG/MAG welding) which can disturb the flow pattern

Avoid having a large distance between the gas cup and the item of work to avoid the risk of insufficient gas shielding

Pre and post-flushing of shielding gases (TIG and MIG/MAG welding)

The aim of pre-flushing is to remove impurities in the gas supply system and force out the air in the joint before welding commences. Post-flushing is used to shield the electrode (TIG welding) and the weld melt/hot metal after welding. In TIG welding, the post-flushing can take up to 10 seconds. If the electrode has a blue or black surface, the post-flushing time must be increased.

Impurities in the gas supply system and how to avoid them

If the shielding gas contains impurities, problems will arise both during and after welding. The impurities seldom arise from the gas cylinder/tank, but occur between the cylinder and the gas cup.

Source of impurities:	Action to take:
Insufficient flushing of the gas system, e.g. after long pauses in work.	Flush through a longer time period.
Diffusion of moisture and air through the hoses.	Use diffusion-secure hoses designed for welding, e.g. in accordance with EN 559.
Leaks in the hoses and connections.	Check regularly. Use leak detection spray on the connections.
Excessively long gas hoses.	Do not use hoses that are longer than necessary.
Leaks in the water-cooled welding equipment.	Check the equipment regularly.

Root protection.

Root protection gases are used to protect the weld's root side from oxidisation during welding. This guarantees good corrosion proper ties on the rear of the weld. Depending on the material, the oxygen concentration on the root side should not exceed 10 - 25 ppm (0.0010 - 0.0025%). The lower value should always be used for duplex and high alloy steel.

The darker the colour of the root run and the surrounding plate, the more serious the oxidation. A good root run should be blank and mostly silver in colour. The root protection gases also contribute in forming the root and give a smoother root with better wetting with the filler metal material. This is beneficial during operation, e.g. in dynamic loading.

Practical advice

- Flush with the amount of root protection gas corresponding to at least 10 times the volume to be shielded before welding begins
- Use a gas flow of around 5-10 l/min during flushing prior to welding
- Reduce the gas flow during welding to avoid an excessively high pressure on the root run. If the pressure is too high, the melt can lift and cause weld defects. Use a gas flow of around 2-3 l/min during welding. Or, as a general rule, a suitable gas flow should barely be noticeable at the outlet
- Let the gas flush after welding until the surface temperature is below 250°C
- Place the chamber's outlet hole high up when using a heavy gas such as argon, and at the bottom when using a lighter gas such as a nitrogen/hydrogen mixture
- Hose diameters under 80mm do not need a chamber -only seal the hose ends (leave an outlet hole in the end). The air is then forced out of the root protection gases (piston effect)

Root protection gases

Argon. The most common root protection gases. Used for all types of stainless steel. The outlet should be at the top.

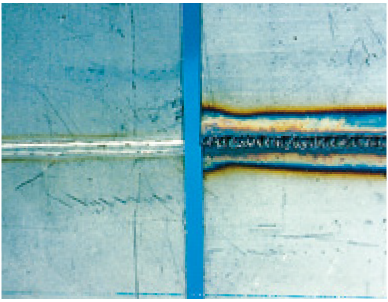
FORMIER® . (N_2 + 10% H_2). Used for nitrogen alloys (duplex, super duplex, fully super austenitic) and austenitic stainless steel. Hydrogen gives a reducing atmosphere which counteracts oxidation. Nitrogen increases corrosion resistance by counteracting the reduction of nitrogen levels in nitrogen alloy steel. Both elements thereby increase the corrosion resistance compared with argon. FORMIER® also gives a smoother and more even root. The outlet should be at the bottom.

Nitrogen. Used for nitrogen alloy stainless steel. Increases corrosion resistance by counteracting the nitrogen reduction in the steel.

MISON® shielding gases are not intended for root protection.

Below: Various gases and gas mixtures - relative density in comparison with air (air = 1)

Gas/Mixture	Density (relative to air)
Air	1
Nitrogen	0.97
N_2 + 10% H_2	0.88
Argon.	1.38
Helium	0.14
Ar + 30% He	1.01
Ar + 70% He	0.51



Root protection gas   Absence of root protection gas

Cutting of stainless steel.

Linde LASERLINE® is a concept for laser cutting and laser welding*.
The laser process is an increasingly popular application for the cutting and welding of stainless steel
Plasma cutting*. normally used for cutting stainless steel. When using non-oxidising gas, this creates good quality oxide-free cross-sections

Post-treatment of stainless steel.

Pickling is the best cleaning method from a corrosion point of view, as the passivising oxide layer is recreated with this method
Smaller objects can be dropped into a bath. For larger constructions which cannot be submerged entirely into a bath can be cleaned with a pickling paste
Blasting and brushing are recommended for mechanical cleaning (certain measures must be taken, however, not to compromise the corrosion resistance)
Grinding with the following fine cleaning and buffing are only used when the surface finish has to be of particularly high quality (e.g. for food or medical applications with high hygiene requirements)
Coarse grinding must never be carried out, as it destroys the corrosion resistance
Flame straightening*. For some constructions, deformations can be corrected after welding by flame straightening

*For further information, contact Linde

AGAs gas guide for stainless steel.

● Recommended shielding gas Can be advantageous in certain cases

	MISON® AR	MISON® N2
MIG/MAG welding (wire electrode)		
Ferritic, martensitic		
Austenitic		
Fully/super austenitic		●
Duplex		
Super duplex		●
Welding with flux-core wire electrode		
Ferritic and martensitic		
Austenitic		
Fully/super austenitic		
Duplex		
Super duplex		
TIG welding (with/without filler metal material.)		
Ferritic and martensitic	●	
Austenitic	●	
Fully/super austenitic		●
Duplex		●
Super duplex		●
Plasma welding		
Ferritic and martensitic		
Austenitic		
Fully/super austenitic		
Duplex		
Super duplex		
Root protection		
Ferritic and martensitic		
Austenitic		
Fully/super austenitic		
Duplex		
Super duplex		

	MISON® H2	MISON® 2HE	MISON® 2	MISON® 18	FORMIER®	VARIGON H5	ARGON	NITROGEN
		●	●					
		●	●					
		●	●					
				●				
				●				
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Getting ahead through innovation.

With its innovative concepts, Linde 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.

Linde 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.

Linde – ideas become solutions.

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