

BACK SHIELDING OF VESSELS – A PRACTICAL BASED SIMULATION

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Key words: *back shielding, efficient back shielding of vessels, turbulent streaming, laminar streaming, sinter metal, simulation of the process, shielding gases, residual oxygen*

Abstract:

Back shielding is very important part of welding production, especially when welding vessels. To guaranty for example the corrosion resistance of stainless steel, it is important to prevent the material of annealing colours. So it's necessary to separate air from the root side. The root pass and the heat affected zone of vessel get protected against oxidation the chemical reaction with nitrogen and the dilution of humidity and this way the dilution of hydrogen.

All metals are sensitive to one or more components of the air. Even if the contact of the root side to the atmosphere is not as intensive as at the top layer chemical reaction will happen. These reactions lead to oxidation, loss of corrosion resistance, hydrogen cracks, embrittlement by dilution of and reactions with nitrogen and many more damages.

Back shielding of big vessel or vessels with a complex design might take a lot of time if not done in the wright way. Laminar streaming is the main keyword. A practical based computer simulation will show the meaning of a controlled filling of vessels regarding the density of the shielding gas and the kind of streaming inside the vessel.

1. INTRODUCTION

For more than 40 years, back shielding and forming has proven their value in welding technology. They permit an increase in weld seam quality and contribute to a reduction of follow-up costs. These costs are reworking, pickling, the associated transport costs and the not inconsiderable loss of time.

Correct back shielding leads to weld seams and roots which needs no reworking. Back shielding got one of the most important applications when welding stainless steel. It prevents the material and the heat effected zone against oxidation. This is necessary to guaranty the corrosion resistance to the steel.

In the case of vessels the whole space has to be filled with shielding gas. We are talking about forming. Although forming is a well-known method, serious mistakes are just still made in the area of vessel production. The most common mistakes occur when the gas gets filled into the vessel. Here, the density of the gas and its fluidic behaviour are usually not taken into account.

2. COMPONENTS OF THE AIR AND THEIR INFLUENCE

The air mainly consists of nitrogen, oxygen, argon and humidity. As stainless steel is sensitive to oxygen, other metals are sensitive to other components of the air. Aluminium for example is sensitive to oxygen and humidity, mild steel to humidity and nitrogen, and also when brazing copper oxidation may happen to the material and to the flux. The welding of gas sensitive materials such as titanium, zirconium, molybdenum or magnesium is not possible without forming or back shielding.

Components of air:

- Nitrogen 78%
- Oxygen 21%
- Argon 1%
- Humidity

3. CHEMICHAC COMPONENTS

3.1 Oxygen

Many Metals and their alloying elements are sensitive to Oxygen. At high temperatures and in contact with Oxygen they form oxides. They can be visible as a layer (annealing colours), as slag or they can be integrated into the micro structure of the material. These elements are e.g. Iron, Chromium, Nickel, Niobium, Titanium, Copper, Aluminium, Silicon and some more (figure 1).

They follow chemical reactions like:

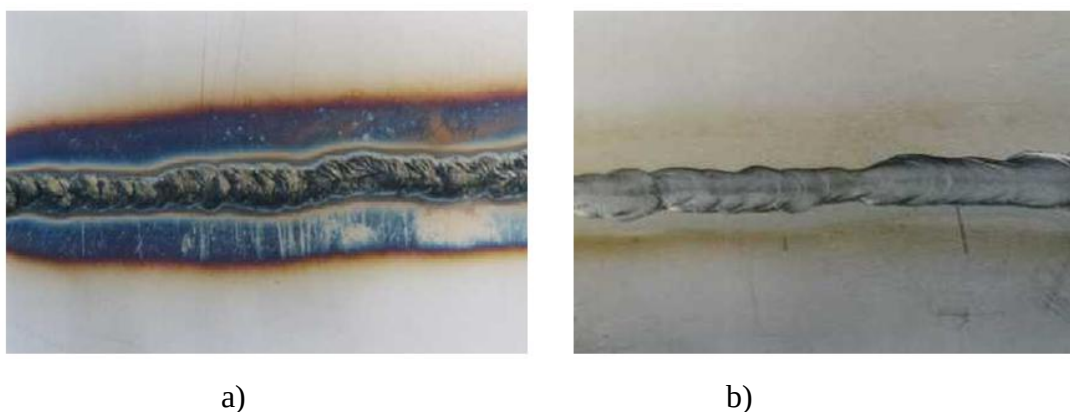
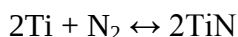


Figure 1. Stainless steel – root without (a) and with back shielding

The oxidation and the oxides have different effects to the material. They can lead to a lower corrosion resistance, less tensile strength, less toughness or to a lower cross - section area. Such oxidized seams and heat affected zones must be cleaned, and that means brushing, grinding, sand blasting or etching. These procedures are expensive and need a lot of time. Another solution is back shielding or forming. It helps to save money and time.

3.2 Nitrogen

Nitrogen in contact with liquid metals forms nitrides at high temperatures or can be diluted in the micro structure of metals. The atoms are able to move and course problems. Nitrides are very small and get embedded into the micro structure of the material. They can have different geometric design depending on their binding partner. The effects may be positive or negative. Not only titanium is very sensitive to nitrogen. The nitrides are very hard and lead to embrittlement directly or after a very short live time.



Especially mild steel is very sensitive to nitrogen. Above 590°C iron can solve up to 0.1% nitrogen. At room temperature the solubility decreases down to nearly zero. Nitrogen courses embrittlement. The hardness raises and the ductility decreases enormously. So aluminium gets added to liquid steel. Aluminium forms nitrides witch are harmless to the material and nitrogen gets dissolved from the microstructure.

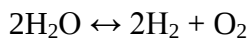
3.3 Hydrogen

Hydrogen is getting solved in form of ions in liquid metals. In the case of iron the ions form molecules again when iron gets cold without leaving the material. As the dimensions of the molecules are very big compared with the ions an enormous stress grows inside the material. This leads to the so called hydrogen induced cracks especially when there is further stress to the material. In the case of stainless steel it is no problem.

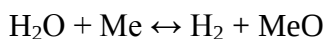
In liquid aluminium also hydrogen gets solved as ions but builds molecules and later bubbles when the liquid material gets colder. Here hydrogen courses a lot of pores. Also other metals have different problems with hydrogen like titanium and copper.

3.4 Humidity

Humidity is getting dissociated in the arc and at high temperatures. If we take a look at our chemistry book we can find a fundamental reaction:



This reaction will happen at temperatures above 2000°C. In presence of metals the dissociation of hydrogen is reduced to possibly 650°C.



Now we have molecular hydrogen which gets spread in the arc to ions and then can be solved in the liquid metal and in its microstructure.

4. FORMING PROCEEDINGS

In order to produce welds with a high quality economically, some basic rules should be followed:

4.1 Laminar stream

One of the most important principles concerning the supply of shielding gas to the welding area is to ensure a controlled transport from the hose to the welding area. A laminar stream of the shielding gas is the basis to this. A turbulent stream leads to a mix of shielding gas and air. If you now have to shield a whole vessel from inside it is nearly impossible to reach an atmosphere without oxygen, nitrogen or humidity (figure 2).

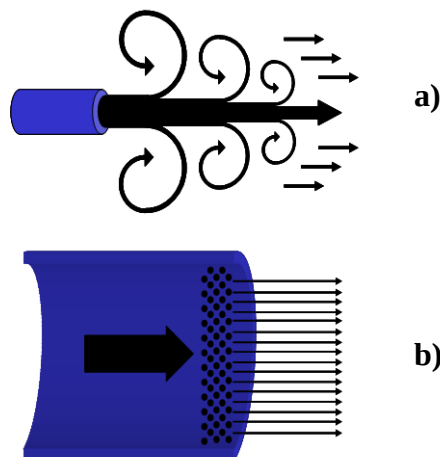


Figure 2. Streams (a – turbulent stream, b – laminar stream)

A laminar flow can be generated using a diffuser. As a diffuser tubes, sheets or casted parts made of sintered material can be used. Through the sintered metal, the gas supply is distributed over a large area whereof the shielding gas can flow out laminar. In case of need, a construction made of perforated sheet metal and steel wool may be helpful.

4.2 Gases lighter and heavier than air

The difference of the different gas mixtures is also caused by the difference in density between air and shielding gas. The back shielding procedures can roughly be divided into:

- back shielding upwards – with gases heavier than air
- back shielding downwards – with gases lighter than air
- back shielding with gases, same density than air

When using gas mixtures with a higher density than air, the vessel must be filled from the bottom to the top. This means that the container is filled from below and has a vent at the top, through which the repressed atmosphere is derived (figure 3).

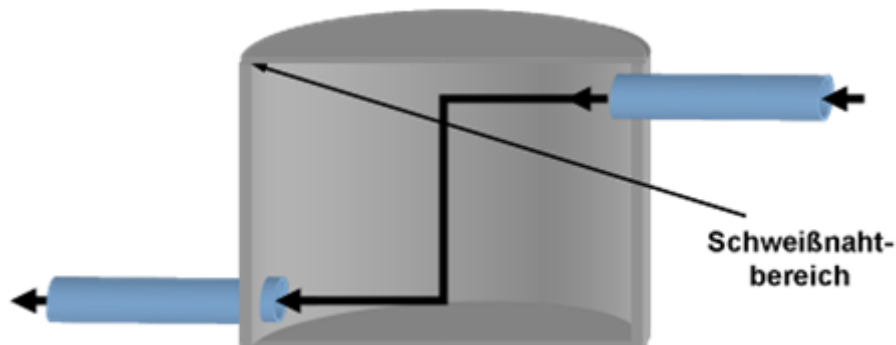


Figure 3. Back shielding from top to the bottom

For gas mixtures with a lower density than air, the mechanism works in reverse (figure 4).

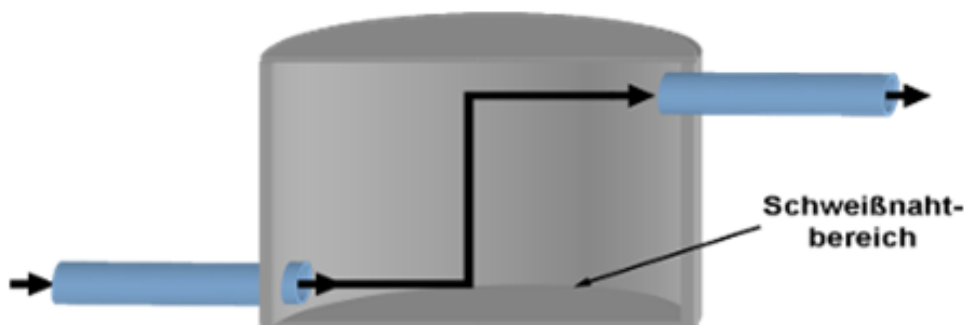


Figure 4. Back shielding from bottom to the top

The selection of the process can depend on the shielding gases present on the spot or can depend on technical requirements as for example the location of the welding area. When filling a vessel from the bottom to the top the required oxygen free area first is reached at the bottom.

5. SIMULATION OF THE PROCESS

From our experiences we knew that a correct forming process, using a diffuser to fill in shielding gas into a vessel, leads to shorter forming times and better results. The problem is to make customers believe this. So we thought about an option to make this process visible. Our handicap is that gases are not visible. But it's possible to measure the presence and concentration of one of the different contents of the air. Oxygen and humidity for example are easy to measure. The only way to make this process visible is to use a simulation.

This simulation must be based on a practical forming process. While forming the oxygen concentration inside the vessel has to be measured at different points. After this it is possible to simulate the whole process.

5.1 Experimental set - up

To simulate the forming proces, we took a cylinder with a diameter of 400 mm and a height of 1 000 mm. Three measurement points were installed to measure the oxygen concentration at these points while filling with forming gas (figure 5).



Figure 5. Cylinder and filling devices

To fill in the forming gas we used two different devices. One device was representing the traditional way to fill in the forming gas (it was a small tube). To fill in the shielding gas in the correct way we used a short cylinder made of sinter metal.

5.2 Results of measuring

The oxygen concentration at the three measuring points inside the vessel measured continuously while filling in the forming gas. All measuring data were saved in a database. We could find out a regressive decrease of the oxygen concentration. The picture 6 shows the concentration of oxygen at measuring point 1. The oxygen concentration is shown on a logarithmic scale. The red line is the result of the tube, the blue one is the result of the sinter metal.

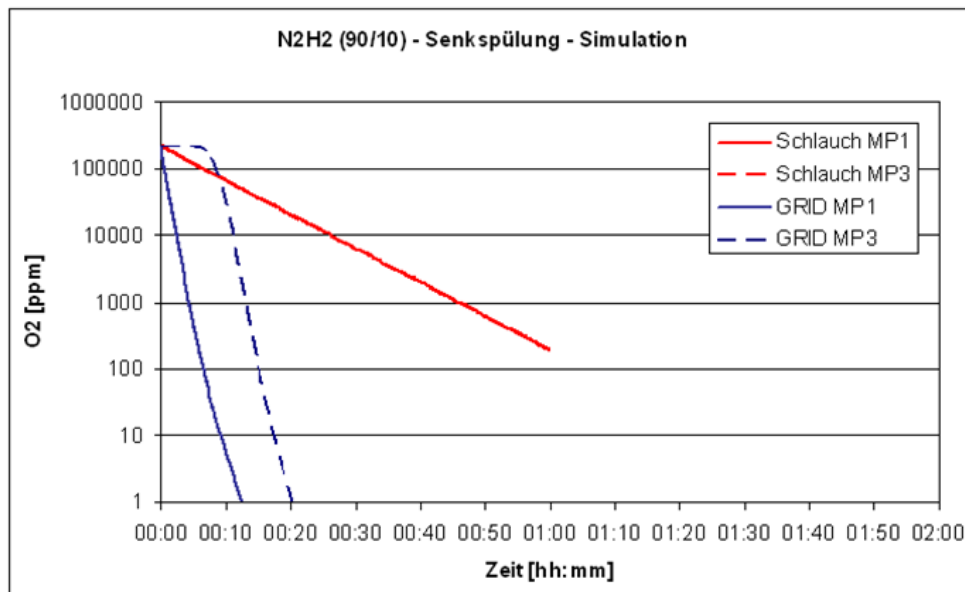


Figure 6. Concentration at measuring point 1

5.3 The simulation

To create a simulation we need to have dimensions of the cylinder, the position of the gas feed, the density of the forming gas and the air, the gas flow, the dimensions of the two devices and the oxygen concentrations at the measuring points.

The pictures are showing simulated oxygen allocation as a result of the different devices and the associated welding results.

Figure 7 shows the oxygen allocation after 3:14 minutes. While the tube is mixing air with forming gas it is possible to see that the sinter metal is filling in the gas under a very controlled way. Once can see that the air inside the vessel gets pushed from the top to the bottom with a low degree of mixing.

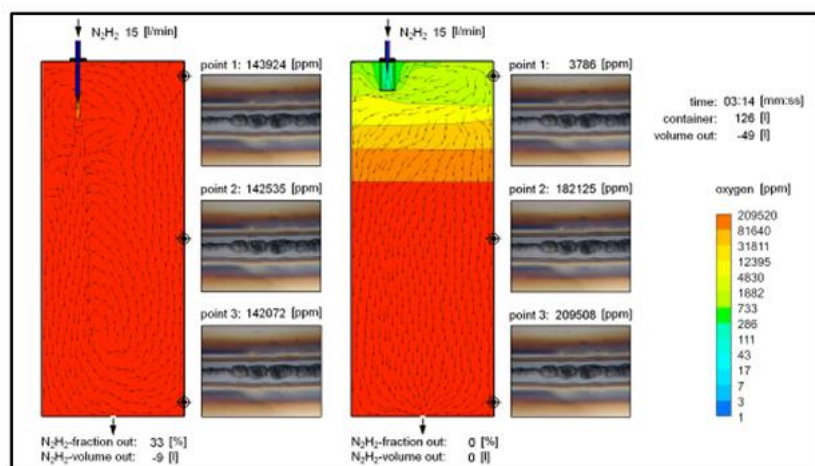


Figure 7. Oxygen allocation after 3: 14 minutes

After 15:58 minutes and 241l forming gas we can see the left cylinder already has a high oxygen concentration because of the high degree of mixing (figure 8).

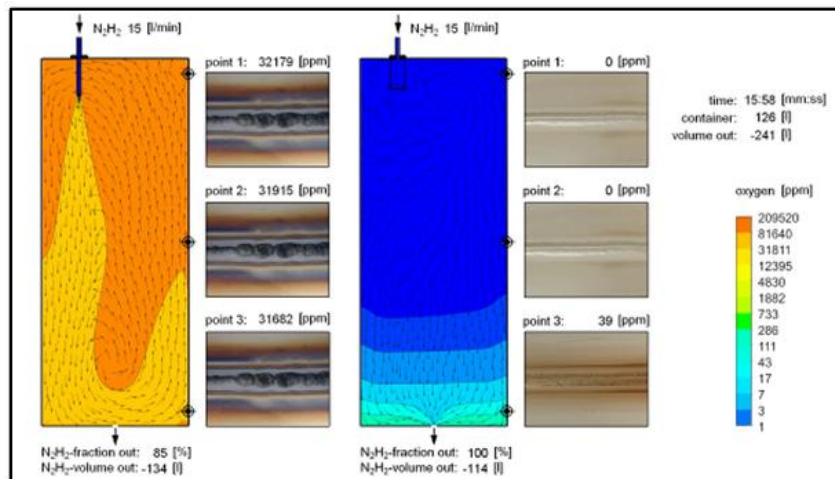


Figure 8. Oxygen allocation after 15: 58 minutes

After 16:38 minutes the right cylinder is ready for welding (figure 9).

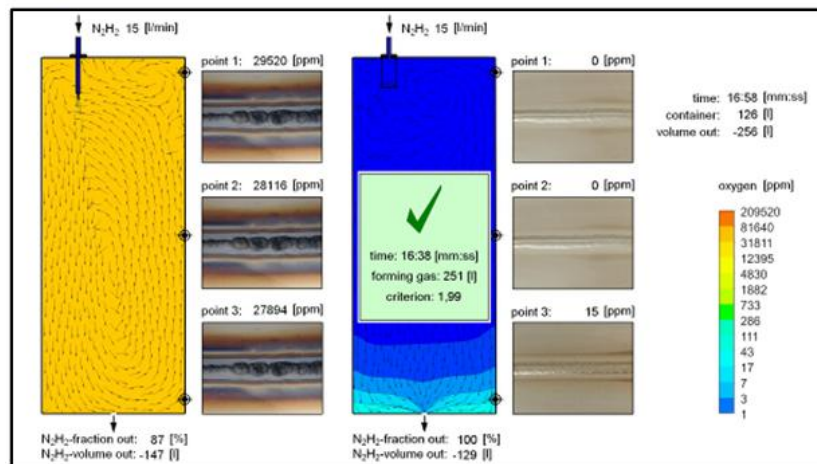


Figure 9. Oxygen allocation after 16: 38 minutes

The last picture shows the situation after half an hour (figure 10). Here we finished the process because of its inefficiency. Also the vessel is not ready for welding.

Most of the people use a higher gas flow to compensate the time witch is needed for an acceptable oxygen concentration but the effect is very low compared with the correct handling and the use of a diffusor.

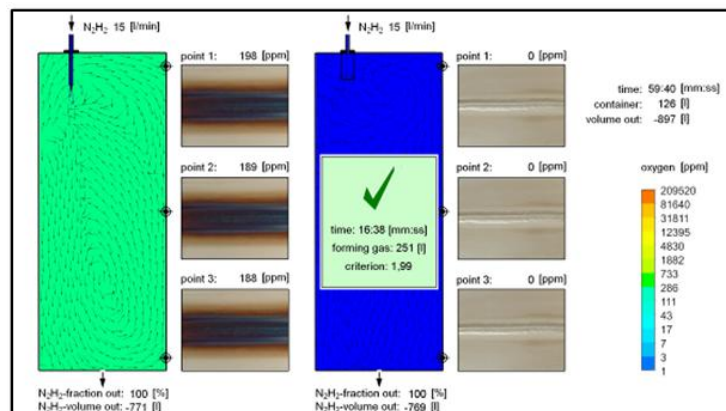


Figure 10. Oxygen allocation after 59: 40 minutes

6. BACK SHIELDING GASSES

As we know that the different materials may be sensitive to different gases, we have the following range of possible back shielding gas and gas mixtures:

- Nitrogen
- Nitrogen / hydrogen mixtures
- pure Argon
- Argon / hydrogen mixtures
- further mixtures

Nitrogen / hydrogen mixtures are very popular. Materials which are not sensitive to nitrogen or hydrogen can be welded with them. Gas mixtures with more than 4% hydrogen are able to form flammable mixtures with air.

6.1 Choice of gases

All popular gas mixtures are based on argon or nitrogen. In order to reduce the residual oxygen, hydrogen is getting mixed into the gas mixtures. Also, helium can be added to reach a special density.

Now, we have three main criteria to choose a shielding gas:

- the density of the shielding gas – heavier or lighter than air
- the material – possible incompatibilities
- hydrogen for reducing residual oxygen

1.1.1 The density of shielding gases

Regarding the density we have the following types of mixtures:

- gas mixtures lighter than air
- gas mixtures heavier than air
- gas mixtures same density as air

Nitrogen is lighter than air: argon is heavier than air. Adding hydrogen in both cases leads to a lower density. These facts are interesting for choosing the right back shielding direction. So it has to be regarded when direction or shielding gas is being chosen (figure 11).

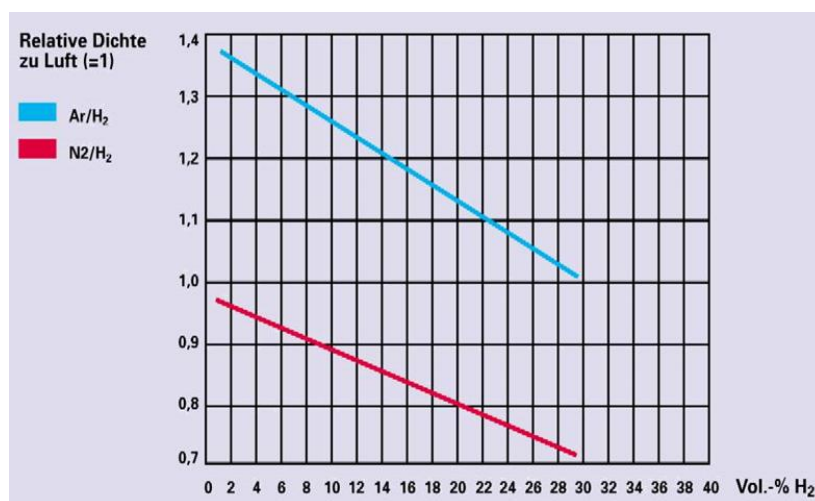


Figure 11. Density of different gas mixtures

6.1.2 Material and possible gas incompatibilities

As described, there are a few incompatibilities between materials and gases. The components of the forming gases can damage the material by forming nitrides, oxides, or hydrogen induced cracks. So this must be regarded when choosing the right shielding gas.

In DVS-Merkblatt 0937 we can find a table with some advises. Argon is universal shielding gas, nitrogen and hydrogen sometimes are problematical in use. Even when mild steel is being welded, nitrogen/hydrogen mixtures may cause problems (figure 12).

shielding gas	material
argon	Austenitic Cr-Ni steels, austenitic-ferritic steels (duplex), gas sensitive materials (titanium, zirconium, molybdenum), hydrogen sensitive materials (highstrength, fine-grained construction steels, copper and copper alloys, aluminium and aluminium alloys and other NF metals), ferritic Cr steels
argon/hydrogen mixtures	Austenitic Cr-Ni steels, Ni and Ni-based materials
nitrogen	Austenitic Cr-Ni steels, austenitic-ferritic steels (duplex)
nitrogen/hydrogen mixtures	Steels (with the exception of highstrength, fine-grained construction steels), austenitic Cr-Ni steels

Figure 12. Advisable gas combinations

6.1.3 Hydrogen in back shielding gases

When loading a tank or pipe with shielding gas – even when working in a very precise way - it comes more or less to a small mixing with the atmosphere. This applies especially to irregularly shaped vessels. This mixing with the atmosphere leads to the so-called residual oxygen who leads to the oxidation of the surface of the root and the heat affected zone. The degree of oxidation is characterized by annealing colours is shown in figure 13.

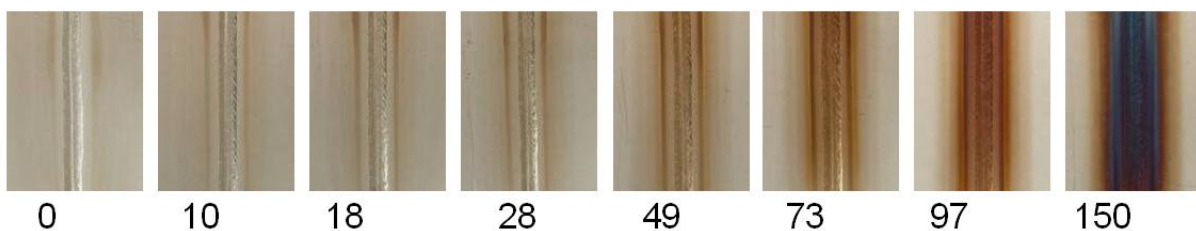


Figure 13. Annealing colors depending on residual oxygen (in ppm)

With continuing back shielding the residual oxygen concentration gets reduced. Depending on the material it is necessary to decrease the oxygen concentration under an acceptable maximum oxygen concentration before starting the welding process. Usually, this is around 20 - 50 ppm when welding stainless steel. The residual oxygen concentration can be influenced by the purging time in most cases.

The measuring of the residual oxygen concentration can be done using a suitable measuring device. If the oxygen concentration can't be reduced as much as required the use of hydrogen containing mixtures is possible. Hydrogen reacts with the residual oxygen to water

6.2 Flammability limits

Most important, the final consideration is "How much hydrogen is necessary for my back shielding process?" Depending on the hydrogen concentration, forming gases are flammable in air. These must be burned off at the exit from the vessel or tube. The ignition limit is 4% H_2 . As written in DVS-Merkblatt 0937, mixtures have to be burned off from 10% H_2 . Differences are made between self - and not self - burning gases. When using not self - burning mixtures, pilot flame is required.

One risk with the use of combustible shielding gases is the explosion. This is given if at the beginning of the welding work already a flammable mixture of shielding gas and air remains in the vessel. The mixture is in the so-called ignition area (figure 14).

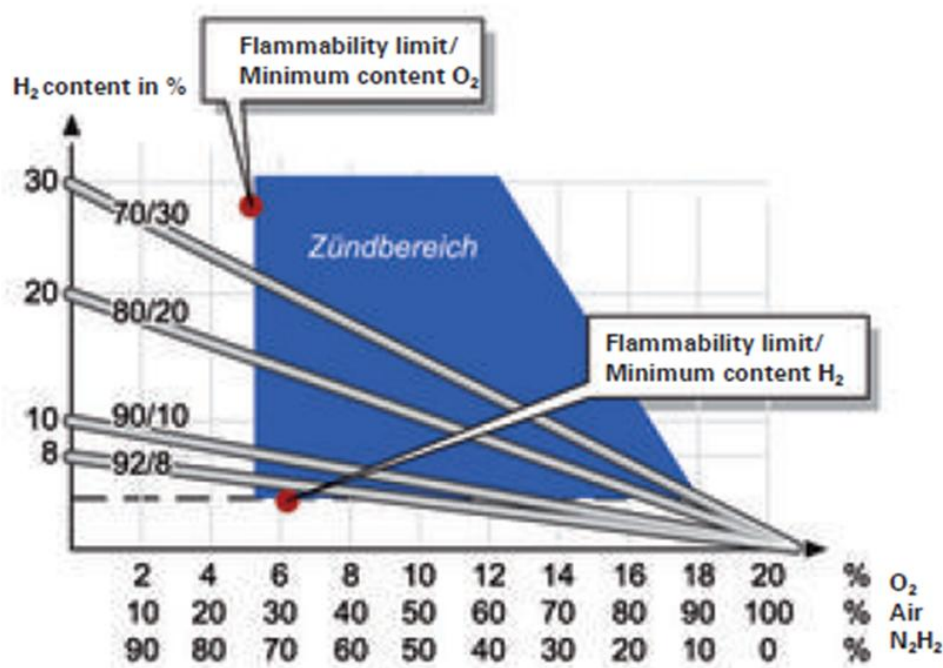


Figure 14. Flammability limits in air and in oxygen

The forming gas/ air mixture composition in the vessel changes continuously during the loading and thereby passing a flammable range. Depending on the shielding gas mixture the range is different. The diagram shows the flammability range of different nitrogen/hydrogen mixtures. For safety reasons, the general statement can be made that the content of the vessel has to be minimum 75% of forming gas before you can start welding.

The oxygen concentration in the vessel then is less than 4% and the forming gas / air mixture is not ignitable. For technical reasons the oxygen concentration is much too high to produce seams without oxidation and without annealing colours.

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