



(72) MACEDO, WILLIAM DE ABREU, BR

(72) TORRES, RICHARD DE CASTRO, BR

(71) PRAXAIR TECHNOLOGY, INC., US

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(54) **MELANGE DE GAZ DE PROTECTION POUR LE SOUDAGE A
L'ARC SOUS PROTECTION DE GAZ INERTE AVEC FIL-
ELECTRODE FUSIBLE**

(54) **SHIELDING GAS MIXTURE FOR GAS-METAL ARC WELDING**

(57) A shielding gas mixture for gas-metal arc welding of austenitic stainless steel is provided in which the gas mixture comprises from about 2 to about 5% carbon dioxide, from about 1 to about 4% nitrogen, and the balance being argon. Also, a process for welding austenitic stainless steel is provided by forming an electric arc between a nonconsumable electrode and the workpiece and in which the gas mixture is used.

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SHIELDING GAS MIXTURE FOR GAS-METAL ARC WELDINGAbstract of the Invention

A shielding gas mixture for gas-metal arc welding of austenitic stainless steel is provided in which the gas mixture comprises from about 2 to about 5% carbon dioxide, from about 1 to about 4% nitrogen, and the balance being argon. Also, a process for welding austenitic stainless steel is provided by forming an electric arc between a nonconsumable electrode and the workpiece and in which the gas mixture is used.

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SHIELDING GAS MIXTURE FOR GAS-METAL ARC WELDINGField of the Invention

This invention is generally related to a gas
10 mixture for arc welding. More specifically, this
invention is related to a shielding gas mixture for
gas-metal arc welding of austenitic stainless steel.

Background of the Invention

The performance of the presently existing
15 shielding gases for gas metal arc welding of austenitic
stainless steels is normally optimized for specific
situations such as welding positions and metal transfer
modes. In welding shops, materials of a variety of
thickness may be found and depending on the equipment
20 or structure being manufactured, it is necessary to
weld metals in different positions. The need for
changing the shielding gas, according to material
thickness, metal transfer mode and welding position
dramatically affects the operation and therefore
25 productivity in welding shops. Another important
consideration is that every year, billions of dollars
are spent worldwide in an effort to reduce and minimize
corrosion problems and most of them are related to
welded joints failures. International standards
30 normally do not require any corrosion evaluation for
the qualification of welding procedures for the 300
series austenitic stainless steels.

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The mixtures currently available in the market had been developed by taking into consideration only specific objectives such as bead appearance, welding travel speed and mechanical properties. Besides that, the gas mixtures recommended for such materials do not perform equally in all modes of metal transfer, requiring very skilled welders or optimized arc welding equipment to ensure good results.

Various literatures have been provided in the field relating to shielding gas mixtures. Representative examples include: U.S. Patent No. 5,739,503; N. Stenbacka et al., "Shielding Gases for GMAW of Stainless Steels", Scandinavian Journal of Metallurgy; Lyttle et al., "Select the Best Shielding Gas Blend for the Application", Welding Journal-November, 1990; W. Lucas, "Shielding Gases for Arc Welding-Part I", Welding and Metal Fabrication, June, 1992; and J. Medforth, "Shielding Gases for Stainless Steels", Australian Welding, second quarter, 1993, pp. 12-15. Nevertheless, none of the art, by itself or in any combination, is believed to lead to superior corrosion resistance and mechanical properties for welded joints and for superior stability.

It is therefore an object of the invention to develop a new gas mixture for the gas-metal arc welding of austenitic stainless steels that would enable higher productivity, enhance mechanical properties and corrosion resistance of welded joints.

Summary of the Invention

One aspect of this invention is directed to a shielding gas mixture for arc welding of austenitic stainless steel in which the mixture comprises from about 2 to about 5% carbon dioxide; from about 1 to

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about 4% nitrogen; and the balance being argon. Such mixture may comprise of about 3% carbon dioxide, about 2% nitrogen; and the balance being argon.

Another aspect of this invention is directed to a process for arc welding austenitic stainless steel which comprises the steps of forming an electric arc between a nonconsumable electrode and the workpiece; and at least partially shielding the arc with a shielding gas mixture comprising from about 2 to about 5% carbon dioxide, from about 1 to about 4% nitrogen, and the balance being argon. In a preferred embodiment, the shielding the arc is carried out with a shielding gas mixture comprising about 3% carbon dioxide, about 2% nitrogen and the balance being argon.

Detailed Description of the Invention

This invention is directed to a multi purpose gas mixture for gas metal arc welding. This gas mixture blends austenitic stainless steels, and is suitable for all modes of metal transfer regardless of conventional or electronic power sources being used, with enhanced mechanical properties and corrosion resistance as compared to the presently existing gas mixtures. Through the use of this new gas mixture in this application, it is possible to replace the high cost wires and stick electrodes containing nitrogen, which are intentionally added in their chemical composition class by the common austenitic stainless steels wires for joining the austenitic stainless steels.

The new shielding gas mixture for gas-metal arc welding of austenitic stainless steels in this invention ensures excellent corrosion resistance and superior mechanical properties to welded joints. This new mixture also allows excellent arc stability in all

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welding positions both for manual and automatic welding as well as for outstanding bead appearance. The gas-metal arc welding process is defined as an arc welding method through which an electric arc is established
5 between a consumable wire electrode continuously fed to this arc as it is moved along the joint to be welded and the work piece.

The arc and weld pool are protected by a shielding gas from the atmospheric contaminants. This shielding
10 gas, as provided in the present invention, contains from about 2% to about 5% carbon dioxide, preferably about 3% carbon dioxide, from about 1% to about 4% nitrogen, preferably 2% nitrogen, and the balance being argon.

15 The development work that generated this invention aimed to evaluate the performance of many existing shielding gases for gas metal arc welding of austenitic stainless steels and to identify a new composition that would provide higher versatility to the welding
20 process, better mechanical properties and enhanced corrosion resistance of the welded joints. AISI '304 and AISI 316 steels were used as base materials and both flux cored and solid wires as filler metals. All the welding was manually done.

25 Three different thickness for "T" and groove joints, different welding positions and metal transfer modes were adopted for the experimental procedure.

In order to determine this new mixture, an extensive analysis of thirty-four worldwide existing
30 gas mixture compositions was carried out. These gas mixtures were first classified based on the helium content. For the same helium content, they were classified based on CO₂ content. Finally, using the

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same criteria, the gases were classified based on other components such as oxygen, hydrogen and nitrogen.

For each class, numerous gas mixture samples were reproduced in the laboratory and tested to verify
5 welding properties, mechanical properties and metallurgical characteristics.

After this initial phase, the best performing existing gas mixtures were chosen for comparison with the newly developed gas mixture samples.

10 Tables I and II show the optimized welding parameters used for the qualification of the welding procedures for flat and vertical positions with the new gas blend.

15 Table I shows the optimized welding parameters for flat position using short circuit and spray transfer.

Table I

Shielding Gas	Pass	Current (V)	Voltage (V)	Wire feed speed (ipm)	Welding travel speed (ipm)	Heat Input (J/in)	Technique
95% Ar +	Root	126.00	19.00	264.00	6.50	35.40	back-hand
3% CO ₂ +	Fill-ing	180.00	27.00	425.00	12.00	34.30	fore-hand
2% N ₂	Cover	170.00	26.00	425.00	9.00	47.20	fore-hand

where the diameter of filler wire was 0.035".

Table II shows the optimized welding parameters for vertical position using pulsed spray transfer.

20 Mixture 95% Ar + 3% CO₂ + 2% N₂. vertical down for root pass and vertical up for others.

Table II

Pass	I _b (A)	T _b (msec)	I _p (A)	T _p (msec)	Voltage (V)	Welding travel speed (ipm)
Root	21.00	11.00	300.00	4.80	22.00	9.50
Others	21.00	11.00	300.00	4.80	22.50	9.40

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Where the diameter of filler wire was 0.045", I_b is the base current; T_b is the base time; I_p is the peak current; and T_p is the peak time.

After welding, the gas mixture samples were
 5 evaluated through a number of analyzes including
 mechanical testing for the welding procedure
 qualification based on ASME IX and ASTM A370 codes;
 metallurgical characteristics (macro and
 microstructural analysis); corrosion resistance
 10 analyses through the polarization curves in two
 environments, and water solution with 0.9% NaCl and
 "White Liquor".

Table III shows the results obtained for the
 tensile test, comparing to the values obtained for the
 15 base material and to the specified values for AISI 316
 stainless steel.

Table III

Sample	YS ⁽¹⁾ kSi (Mpa)	TS ⁽²⁾ Ksi (Mpa)	Elongation (%)	Rupture Location
95%Ar+3%CO ₂	42.1 (292)	87.4 (606)	47.00	base metal
+2% N ₂	43.7 (303)	92 (638)	52.00	base metal
Base metal	44.8 (311)	87.2 (605)	66.00	-
AISI 316 standard	30 (205) min.	75 (515) min.	40 min.	-

where (1) YS is the yield strength; and (2) TS is the
 tensile strength

20 Table IV shows the mechanical resistance as well
 as bend tests results.

Table IV

Sample	YS ⁽¹⁾ kSi (MPa)	Bend Test	Results
95% Ar+3%CO ₂ +2%N	87.4 (660) 92 (638)	without cracks	OK
Base metal	87.2 (605)	-	-

where (1) TS is the tensile strength

The results in the macro and microstructural
 25 analysis of the welded joints showed the following
 effects: 1) there was no sensitization in the low

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temperature heat affected zone (HAZ) in any of the samples; 2) the weld metal presented an austenitic-ferritic structure with no significantly large variation as compared to the joints welded using conventional mixtures except for the lower delta ferrite content of weld metal; 3) the best mechanical properties obtained (strength and ductility) were generated by a greater micro-structural refining of the weld metal caused by the solidification rate that this new gas mixture provided; and 4) the best ductility values obtained with the argon, carbon dioxide and nitrogen mixture could be associated to the austenitic phase stabilization promoted by the nitrogen from the shielding gas.

The corrosion resistance of the welded joints was evaluated through the polarization curves in two different environments (solution of 0.9% NaCl and "White Liquor"). The method used for the analysis followed the ASTM G5 standard.

Table V shows the corrosion and pitting potential obtained for each environment.

Table V

Samples	Solution		
	0.9% of NaCl in water		"White Liquor"
	Corrosion Potential (mV)	Pitting Potential (mV)	Corrosion Potential (mV)
95%Ar+3%CO ₂ 2%N ₂	-276	302.00	-407
AISI 316 Standard	-240	336.00	-472

According to these results, it is possible to conclude that for both solutions, sodium chloride and "White Liquor", the welded joints presented technically the same corrosion potential as compared to the base metal.

As a result, nitrogen additions limited to 5% stabilize the austenite reducing delta ferrite content,

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increasing in this way, both the ductility and corrosion resistance.

The high solidification rates of the weld pool promote a highly refined microstructure and consequently, better mechanical properties.

The higher ductility promoted by this new gas mixtures was also noticed through the bend tests in which no cracks were found for all test pieces.

The better corrosion resistance results were obtained through the nitrogen addition in the shielding gas with the consequent stabilization of the austenite and reduction of delta ferrite content in the microstructure of the weld metal.

Specific features of the invention are shown in one or more of the drawings for convenience only, as each feature may be combined with other features in accordance with the invention. Alternative embodiments will be recognized by those skilled in the art and are intended to be included within the scope of the claims.

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The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A shielding gas mixture for gas-metal arc welding of austenitic stainless steel which comprises:

- a) from about 2 to about 5% carbon dioxide;
- b) from about 1 to about 4% nitrogen; and
- c) the balance being argon.

2. The gas mixture of claim 1 wherein said mixture comprises:

- a) about 3% carbon dioxide;
- b) about 2% nitrogen; and
- c) the balance being argon.

3. A process for gas-metal arc welding austenitic stainless steel comprising the steps of:

- a) forming an electric arc between a nonconsumable electrode and the workpiece; and
- b) at least partially shielding the arc with a shielding gas mixture comprising from about 2 to about 5% carbon dioxide, from about 1 to about 4% nitrogen, and the balance being argon.

4. The process of claim 3 wherein the step of shielding the arc is carried out with a shielding gas mixture comprising about 3% carbon dioxide, about 2% nitrogen and the balance being argon.