TIG and plasma processes

File: TIG welding and plasma welding
Table of Contents

1 Introduction ........................................................................................................................................................................ 3

2 Electric arc gas-shielded welding with non-consumable electrode ................................................................. 4
   2.1 TIG process  
       Principles and implementation of the process ................................................................................................................ 4
   2.2 Plasma process  
       Principles and implementation of the process ................................................................................................................. 5

3 Performance levels ........................................................................................................................................................... 7
   3.1 Productivity improvement through welding speed or penetration .......................................................... 7
       3.1.1 TIG welding with arc deviation in automatic mode ......................................................................................................... 7
       3.1.2 Double flux TIG welding ........................................................................................................................................ 7
       3.1.3 Multi-electrode welding in automatic mode ......................................................................................................................... 8
       3.1.4 Plasma + TIG welding ........................................................................................................................................ 9
   3.2 Productivity improvement through joint quality, compactness and penetration .............................................. 10
   3.3 Productivity improvement through tolerance on preparations in manual welding ........................................ 10
   3.4 Productivity enhancement using position welding ..................................................................................... 10
       3.4.1 Vertical (up or down) longitudinal welding ..................................................................................................................... 10
       3.4.2 Horizontal circular welding .................................................................................................................................. 11
   3.5 Productivity improvement through reduction or elimination of finishing (finishing quality) .................. 11
   3.6 Productivity improvement through hot wire TIG and hot wire plasma deposition rate .......................... 11
   3.7 Productivity improvement through arc-striking reliability .............................................................................. 11

4 Application examples ...................................................................................................................................................... 12
   4.1 Plasma welding in pipe prefabrication ................................................................................................................... 12
   4.2 Plasma and plasma + TIG sheet-metal welding ............................................................................................. 13

5 Equipment ........................................................................................................................................................................ 14

6 Filler metals and gases ................................................................................................................................................... 15
   6.1 Filler metals ................................................................................................................................................................. 15
   6.2 Gases .......................................................................................................................................................................... 15

7 Conclusion ....................................................................................................................................................................... 15
1 Introduction

A well-controlled principle

The Tungsten Inert Gas (TIG) process consists of creating a source of heat from an electric arc in an inert gaseous atmosphere between a non-consumable tungsten electrode and a workpiece acting as an anode.

Plasma welding represents a progression of the TIG process towards high energy densities, since in a plasma torch, the arc undergoes a constricting effect when it passes through a highly cooled nozzle.

Excellent quality on all materials: source of productivity gains

TIG and plasma welding produces assemblies with a flawless appearance which, in many cases, do not require subsequent resealing runs. Another very important aspect is that these processes apply to materials as widely varied as carbon steel, stainless steel, nickel, titanium, zirconium and tantalum alloys and, for TIG welding, aluminum and copper-base alloys.

Energy density: comparative table

<table>
<thead>
<tr>
<th>HIGH ENERGY BEAMS</th>
<th>TIG</th>
<th>DOUBLE FLUX TIG</th>
<th>KEYHOLE PLASMA</th>
<th>ELECTRON BEAM</th>
<th>LASER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy density</td>
<td>50W/mm²</td>
<td>150W/mm²</td>
<td>10³W/mm²</td>
<td>10⁶W/mm²</td>
<td>10⁶W/mm²</td>
</tr>
<tr>
<td>Constriction</td>
<td>Pneumatic (nozzle)</td>
<td>Electromagnetic (focalization coil)</td>
<td>Optical (focalization lens)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MELTING METHOD

Collapse | Collapse | Keyhole collapse | Keyhole | Keyhole
2 Electric arc gas-shielded welding with non-consumable electrode

2.1 TIG process
Principles and implementation of the process

By means of an appropriate electric current whose type varies with that of the parent metal (for example: direct current for stainless steels), one creates an electric arc in a stream of inert gas (argon or a gas mixture), between a tungsten electrode (infusible) and the workpiece. The heat given off by this arc causes the workpiece to melt locally, along with the filler metal, thus forming the welded joint.

This inert gas, generally with an argon or helium base, protects the molten metal and the surrounding hot areas from the air, and avoids any oxidation of the tungsten electrode.

Electric power supply

- **Direct current**: direct current electrode for welding all metal materials (carbon steels, stainless steels, titanium, nickel-based,...), including aluminum alloys (with helium protection).

- **Pulsed current**: with the same polarity as above, the welding energy is controlled in high-and low-current pulses, enabling the reduction of the volume of metal melted. Thus, pulsed current facilitates position welding and the welding of thin sheet metal.

- **Alternating current and variable polarity**: is used mainly for welding the light alloys such as aluminum. Oxides are cleaned or removed during the reverse polarity part of the cycle and penetration during the negative polarity part of the cycle. Control of the cycle and time spent in each phase allows better control of the welding cycle.

These rules must be followed:

- extreme cleanliness of the edges to be assembled and of the filler metal.
- eliminate any oxides and traces of grease.
- preheat from 200 to 400 °C (392 to 752 °F) the large parts made of light alloys and especially copper alloys.
- prepare the parts according to the thicknesses, the type of joint, the type of parts, etc.
- vary the current value according to whether the welding is manual, automatic, or position welding, as well as according to the thickness, preparation, type of parts.
- for materials which are highly oxidizable when hot (titanium, tantalum, zirconium), additional protection with a gas of the same kind is absolutely essential behind the weld bead. This protection is accomplished by using a trailing shield.
2.2 Plasma process
Principle and implementation of the process

PAW = Plasma Arc Welding

The contribution of energy necessary for welding is ensured by the passage of an electric arc in an atmosphere of inert plasma gas between an infusible electrode and the parts to be assembled. The eventual addition of wire is carried out on the outside of the torch.

This arc is mechanically and kinetically confined by means of a nozzle through which it is forced to pass.

**MECHANICAL CONSTRICTION OF THE ARC**

The arc flux is forced through a narrow cylindrical opening (nozzle) which constricts it mechanically. The voltage in the arc column increases in relation to that of a free arc with the same current value, and the energy increases proportionally.

**PNEUMATIC CONSTRICTION OF THE ARC**

In this case, the cylindrical opening is replaced by a convergent-divergent nozzle in which the tapered tip of the electrode, depending on its position in the nozzle’s opening, modulates, by acting on the flowrate/speed ratio of this gas, the Venturi effect to which the plasma gas is subjected. The confinement of the arc is therefore obtained by the plasma gas itself, hence the term, “pneumatic constriction”.

A second gas, which may be identical or of a type different from the first one, depending on the applications, flows between the nozzle and the welding tip, and confines the plasma thermodynamically. This gas is also intended to protect the weld bead (Fig. 2).

- **Mechanical constriction**
- **Pneumatic pinching nozzle**

---

**Figure 2**

- Shield gas
- Plasma gas

**Temperature °C (°F)**
- 4,000-10,000
- (7,000-18,000)
- 10,000-16,000
- (18,000-29,000)
- 16,000-24,000
- (29,000-43,000)
- ≥ 24,000
- (≥ 43,000)

**PLASMA ARC**

- 150 A - 28 V

- It diverges very little outside of the nozzle which is cooled.
- The 10,000 - 16,000 °C (18,000 - 29,000 °F) temperature zone is transferred to the part in a concentrated beam.
TYPE OF ARC

First of all, it is necessary to differentiate two types of arcs:

- **The non-transferred arc** is established between the electrode connected to the - pole of the power source and the tip connected to the + pole of the power source. In this case, depending on the cases, the arc may establish at different points of the nozzle, and the high flowrate of the plasma gas allows it to be blown out of the tip.

  Its applications are:
  - welding parts that conduct, or do not conduct, electricity,
  - as a pilot arc to establish the main arc.

- **The transferred arc** is established between the electrode and the parts to be assembled. The welding current goes completely through the plasma jet. The anode spot is on the workpiece and thus more heat is transferred to the workpiece. The constriction of the arc also concentrates the arc energy.

ELECTRIC POWER SUPPLY

- **Direct current**: electrode - at the electrode for welding metal materials (carbon steels, stainless steels, nickel-based and titanium).

- **Pulsed direct current**: with the same polarity as above, welding energy is controlled in high and low pulses of current. Pulsed current aids in welding thin material and for out-of-position work.

- **Alternating current with variable polarity**: devoted to welding aluminum and its alloys. At present, this is the only way to weld with plasma in keyhole mode with argon protection. The variable polarity allows to optimize the welding and cleaning phases essential for welding light alloys.

IMPLEMENTATION

This depends mainly on the thickness to be welded.

**Thicknesses less than 3 mm (0.12\)"**: the penetration bead is obtained through progression of the molten pool through the thickness to be welded. The welding current values used are low, and this is why the plasma jet is not piercing (conduction welding).

**Thicknesses greater than 3 mm (0.12\)"**: in this thickness range, the most interesting technique is the keyhole, in which the plasma jet goes through the entire thickness of the parts to be assembled. The molten metal is pushed towards the rear where, when cooling, it forms the weld bead. Its main advantage is that it ensures good penetration and, at the same time, eliminates any support on the back side. The keyhole technique is used in automatic welding on an industrial scale.
3 Performance levels

3.1 Productivity improvement through welding speed or penetration

3.1.1 TIG welding with arc deviation in automatic mode

Automatic welding equipment can be fitted with a special torch designed to create axial electrical deflection of the TIG arc by means of a magnetic field generated by an induction coil. With this system, the heat zone is considerably lengthened along the weld axis, and can therefore generate a speed increase on the order of 30% on thicknesses less than 2 mm (5/64”). This particularity is especially important for continuous welding of thin tubes shaped from strips, cable sheathes, sheathing of electrical resistance.

3.1.2 Double flux TIG welding

The double flux TIG process enables:

• constriction of the arc by the gas stream, thus focusing the energy on a restricted width, which enables constant, even penetration, greater than in standard TIG.

• the reduction of constraints and warpage by substantially reducing the section of weld metal,

• increased economy:
  - the elimination of preparation of joints up to 6 mm (0.24”); beyond, there are fewer preparations in relation to TIG;
  - the reduction in consumption of filler metal;
  - work in a single pass up to 6 mm (0.24”) for light alloys.

• implementation and use which are easy, due to:
  - use of a single axial and annular gas,
  - use of a single type of thoriated tungsten electrode (Ø 1.6 mm (1/16”) for carbon steels and stainless steels, Ø 3.2 mm (1/8”) for light alloys).

To sum up: with the same penetration, less energy is needed in double flux TIG, or else the welding speed can be increased by 20% in relation to simple TIG.

### CARBON STEEL AND STAINLESS STEEL

<table>
<thead>
<tr>
<th>Type of preparation</th>
<th>Intensity in A*</th>
<th>Thickness/Type of preparation</th>
<th>Intensity in A*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st run: 80</td>
<td>4 mm (5/32”)</td>
<td>65 - 70</td>
<td></td>
</tr>
<tr>
<td>2nd run: 100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### ALUMINIUM ALLOYS

<table>
<thead>
<tr>
<th>Type of preparation</th>
<th>Intensity in A*</th>
<th>Thickness/Type of preparation</th>
<th>Intensity in A*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st run: 100</td>
<td>4 mm (5/32”)</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>2nd run: 150</td>
<td>6 mm (0.24”)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>in 2 runs</td>
<td>in 2 or 3 runs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*average current value in flat welding
3.1.3 Multi-electrode welding in automatic mode

This process, used above all on tube manufacturing lines, (by associating several electrodes whose functions are different: preheating, penetration and copping) attains welding speeds up to three times faster than those obtained in single-torch welding.

Welding speed is related to the quality of the forming operation in a tube mill.
3.1.4 Plasma + TIG welding

The use of plasma and TIG welding in tandem produces deep penetration from the plasma lead torch and increased speed and appearance due to the trailing TIG torch.

This process is mainly used in sheet-metal work for long-length welds.

For the plasma + TIG process, a TIG torch, as well as a cold wire feeder, are positioned approximately 160 mm behind the plasma torch. The plasma arc ensures the penetration of the entire thickness of the joint, while the TIG torch, complete with magnetic oscillation and a cold wire feeder, produces a simultaneous finishing pass. This configuration increases the speed by 30 % in relation to single-torch plasma.

The plasma + TIG process is generally applicable to welds with a length > 3,000 mm (10’), or with parts with diameters greater than 2,200 mm (7’).

The plasma + TIG process (bi-cathode) has significant advantages:

- single-pass operation,
- reduction in the quantity of filler metal used,
- high-speed welding,
- low deformation,
- narrowness of the heat-affected area,
- high-quality X Ray,
- reduced thickness, very nice appearance of the weld bead, reducing grinding and polishing times.

### Comparison of welding speeds

<table>
<thead>
<tr>
<th>THICKNESS</th>
<th>PLASMA</th>
<th>PLASMA + TIG</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm (in)</td>
<td>Welding speed cm/min (in/min)</td>
<td></td>
</tr>
<tr>
<td>3 (0.12)</td>
<td>50 (19)</td>
<td>65 (26)</td>
</tr>
<tr>
<td>4 (5/32)</td>
<td>35-40 (14-16)</td>
<td>50-60 (20-24)</td>
</tr>
<tr>
<td>5 (0.2)</td>
<td>25-30 (10-12)</td>
<td>40 (16)</td>
</tr>
<tr>
<td>8 (5/16)</td>
<td>15-20 (6-8)</td>
<td>25 (10)</td>
</tr>
</tbody>
</table>
3.2 Productivity improvement through joint quality

**Compactness**

You can easily see the weld puddle with the TIG or plasma process, enabling perfect control of the pool and the metal deposit, when applicable.

This arc stability in an inert atmosphere also leads to excellent weld metal soundness.

**Penetration**

In automatic plasma complete penetration of material up to 8 mm (5/16") thick is possible on square edge butt joints. Productivity is improved as well, due to simplification of preparation.

3.3 Productivity improvement through tolerance on preparations

Manual TIG allows greater tolerances on edge preparations and is well suited to the repair of weld defects.

3.4 Productivity enhancement using position welding

This sketch shows clearly that, using vertical manufacturing for large tanks used in petrochemical, chemical and food industries, it is possible to:
- minimize the required production floorspace
- reduce handling time
- eliminate fixturing

3.4.1 Vertical (up or down) longitudinal welding

It is recommended to use a specifically designed welding bench for this type of welding position, since it will avoid part tacking, and ensures backside gas shielding.
3.4.2 Horizontal circular welding

The tank can be placed on a turntable with welding torch fixed for horizontal circular welding. However, if the tank cannot be rotated, the torch will be installed on a moving carriage which performs the circular path.

With this welding position, the plasma process allows welding on 3 to 6 mm (0.12 to 0.24") with welding speeds from 25 to 40 cm/min (10 to 16 in/min). For material thicker than 6 mm (0.24"), bevel preparation and two passes are required.

3.5 Productivity improvement through reduction or elimination of finishing

The total absence of spatter and the perfect control of the metal deposit lead to a controlled weld bead appearance (top and back side of the weld); therefore, finishing operations which are necessary with other processes are not required. Moreover, the TIG process is sometimes used as a complementary finishing process (life improvement through the use of TIG temper beads).

3.6 Productivity improvement through deposition rate

Hot wire TIG and plasma

Hot wire filler metal additions are cost effective on sheet metal or thicker material. Hot wire filler metal addition can increase deposition rates to the level of 2.5 to 3 kg/hr (5.5 to 3 lb/hr) in high-quality multi-pass welding.

In order to fill a bevel with a depth of 40 mm (1.58"), as in the nuclear industry, hot wire addition is a very interesting solution, and one which is perfectly adapted to applications requiring superior quality of welded joints. In this special technique, melting the wire is no longer ensured only by the TIG arc, but by an additional current, which brings its end to a state close to melting.

3.7 Productivity improvement through arc-striking reliability

The pilot arc allows reliable and consistent arc starts without contaminating the tungsten.
4 Applications

4.1 Plasma welding in pipe prefabrication

Assemblies are prepared upstream of the plasma equipment by one or more fitters who prepare the fit-up, tack and install gas baffles. Gas flow is controlled by the manager.

<table>
<thead>
<tr>
<th>Tube outer Ø mm (in)</th>
<th>Wall thickness mm (in)</th>
<th>Grade of steel</th>
<th>Preparation of joint</th>
<th>Duration of automatic plasma welding operation (excluding preparation)</th>
<th>Approximate duration of the same operation in manual welding</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 (2.36)</td>
<td>2.9 (0.11)</td>
<td>carbon</td>
<td></td>
<td>2 minutes (2 linked runs)</td>
<td>15 minutes</td>
</tr>
<tr>
<td>133 (5.24)</td>
<td>3.8 (0.15)</td>
<td>carbon</td>
<td></td>
<td>4 minutes (2 linked runs)</td>
<td>24 minutes</td>
</tr>
<tr>
<td>406 (15.98)</td>
<td>9.52 (0.38)</td>
<td>carbon</td>
<td></td>
<td>14 minutes (2 linked runs)</td>
<td>24 minutes</td>
</tr>
<tr>
<td>114 (4.49)</td>
<td>8 (5/16)</td>
<td>AISI 304</td>
<td></td>
<td>4 minutes 10 seconds (2 linked runs)</td>
<td>38 minutes</td>
</tr>
<tr>
<td>170 (6.69)</td>
<td>3.2 (1/8)</td>
<td>AISI 304</td>
<td></td>
<td>2 minutes (1 run)</td>
<td>55 minutes</td>
</tr>
</tbody>
</table>

Examples of work carried out by means of plasma welding
4.2 Plasma and plasma + TIG sheet-metal and plate welding

At present, plasma and plasma + TIG processes are used throughout the world to carry out longitudinal and circular sheet welds. The keyhole plasma process is a single-pass welding process, with total penetration, enabling welding to be carried out from a single side.

The plasma / plasma + TIG process (bi-cathode) has the following significant advantages:

- single-pass operation,
- reduction in quantity of filler metal used,
- low deformation,
- narrowness of heat-affected area,
- high-quality X Ray,
- reduced weld build-up, improves appearance of the weld bead, enabling reduction of grinding and polishing times.

The welding equipment is fitted with a joint-following device, which can be backed up by video display devices, which free the operator and ensure precise following.

For penetration passes, the plasma and plasma + TIG processes have a significant advantage over other processes. In fact, they allow to considerably increase welding speed in relation to TIG, especially in light of the fact that this is a single-pass operation.

From the point of view of welding time, substantial gains can be achieved.

<table>
<thead>
<tr>
<th>THICKNESS</th>
<th>PLASMA</th>
<th>PLASMA + TIG</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm (in)</td>
<td>Welding speed cm/min (in/min)</td>
<td></td>
</tr>
<tr>
<td>3 (0.12)</td>
<td>50 (19)</td>
<td>65 (26)</td>
</tr>
<tr>
<td>4 (5/32)</td>
<td>35-40 (14-16)</td>
<td>50-60 (20-24)</td>
</tr>
<tr>
<td>5 (0.2)</td>
<td>25-30 (10-12)</td>
<td>40 (16)</td>
</tr>
<tr>
<td>8 (5/16)</td>
<td>15-20 (6-8)</td>
<td>25 (10)</td>
</tr>
</tbody>
</table>
In automatic mode, a TIG or plasma welding set is generally composed of:

- a welding power source,
- a control panel managing the welding parameters: current value, voltage, wire speed, cycle and gas flowrate and movement feeder,
- one or more torches and additional systems: wire torch positioning and voltage regulation system.

**Standard Installation**
6 Filler products and gases

6.1 Filler metals
When it is necessary to use filler metal, its grade will generally be identical to that of the parent metal.

6.2 Gases
Implementation of TIG and plasma processes requires:

For plasma: minimum of 2 gases
- 1 plasma gas, 1 annular gas (shielding), and back shielding gas

The interaction of these gases determines:
- the welding speed (torch/piece relative displacement)
- the structure and shape of the weld bead

For TIG: minimum of 1 gas
- 1 inert gas and back shielding gas

The role of these gases is very important:

<table>
<thead>
<tr>
<th>PLASMA</th>
<th>PLASMA GAS</th>
<th>ANNULAR OR SHIELDING GAS</th>
<th>TIG</th>
<th>INERT GAS</th>
<th>BACKING GAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLASMA</td>
<td>- Low ionization potential (striking and stability of arc)</td>
<td>- Protection of plasma - Protection of molten pool</td>
<td>TIG</td>
<td>- Protection of molten pool</td>
<td>- Protects the weld bead from oxidation</td>
</tr>
<tr>
<td>PLASMA</td>
<td>- Good thermal conductivity</td>
<td></td>
<td>TIG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PLASMA</td>
<td>- Good enthalpy (kinetic energy of moving particles)</td>
<td></td>
<td>TIG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PLASMA</td>
<td>- Substantial atomic weight (kinetic energy of moving particles)</td>
<td></td>
<td>TIG</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table for choice of gases:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>CARBON AND LOW ALLOYED STEELS</th>
<th>PLASMA GAS</th>
<th>ANNULAR OR SHIELDING GAS</th>
<th>BACKING GAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon + H₂: Blueshield 12</td>
<td>Argon</td>
<td>Argon + H₂: Blueshield 12</td>
<td>Argon</td>
</tr>
<tr>
<td>Argon + H₂: Blueshield 11</td>
<td>Argon + H₂: Blueshield 11, 12</td>
<td>Argon + H₂: Blueshield 11, 12</td>
<td>Argon + He: Blueshield 1</td>
</tr>
<tr>
<td>Argon + H₂: Blueshield 11</td>
<td>Argon + CO₂: Blueshield 6, 7, 8</td>
<td>Argon + H₂: Blueshield 11, 12</td>
<td>Argon + He: Blueshield 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AUSTENITIC STAINLESS STEELS</th>
<th>PLASMA GAS</th>
<th>ANNULAR OR SHIELDING GAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon + H₂: Blueshield 11</td>
<td>Argon + H₂: Blueshield 12</td>
<td>Argon</td>
</tr>
<tr>
<td>Argon + H₂: Blueshield 11</td>
<td>Argon + H₂: Blueshield 12, 11, 12</td>
<td>Argon + H₂: Blueshield 11, 12</td>
</tr>
<tr>
<td>Argon + H₂: Blueshield 11</td>
<td>Argon + H₂: Blueshield 12</td>
<td>Argon + H₂: Blueshield 11, 12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NICKEL-BASED</th>
<th>PLASMA GAS</th>
<th>ANNULAR OR SHIELDING GAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon + H₂: Blueshield 12</td>
<td>Argon</td>
<td>Argon + H₂: Blueshield 12</td>
</tr>
<tr>
<td>Argon + H₂: Blueshield 12</td>
<td>Argon</td>
<td>Argon + H₂: Blueshield 11</td>
</tr>
<tr>
<td>Argon + H₂: Blueshield 12</td>
<td>Argon</td>
<td>Argon + H₂: Blueshield 11, 12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PRECIOUS METALS (titanium, tantalum, zirconium)</th>
<th>PLASMA GAS</th>
<th>ANNULAR OR SHIELDING GAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon + H₂: Blueshield 12</td>
<td>Argon</td>
<td>Argon + H₂: Blueshield 12</td>
</tr>
<tr>
<td>Argon + H₂: Blueshield 12</td>
<td>Argon</td>
<td>Argon + H₂: Blueshield 11</td>
</tr>
<tr>
<td>Argon + H₂: Blueshield 12</td>
<td>Argon</td>
<td>Argon + H₂: Blueshield 11, 12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ALUMINUM &amp; ALLOYS</th>
<th>PLASMA GAS</th>
<th>ANNULAR OR SHIELDING GAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon + H₂: Blueshield 12</td>
<td>Argon</td>
<td>Argon + H₂: Blueshield 12</td>
</tr>
<tr>
<td>Argon + H₂: Blueshield 12</td>
<td>Argon</td>
<td>Argon + H₂: Blueshield 11</td>
</tr>
<tr>
<td>Argon + H₂: Blueshield 12</td>
<td>Argon</td>
<td>Argon + H₂: Blueshield 11, 12</td>
</tr>
</tbody>
</table>

7 Conclusion
- simplification of preparations in plasma butt-joint welding
- very substantial reduction, or even elimination, of finishing
- speed increase in multi-process.

The excellent quality level obtained in TIG and plasma welding enables very sizeable productivity gains.