



WELDING BASICS SERIES

MAKE SOMETHING BETTER



PLASMA CUTTING BASICS



Plasma Cutting Basics

PLASMA ARC CUTTING TECHNOLOGY

CUTTING MECHANISM

ELECTRODE LIFE

NOZZLE LIFE

PROCESS VARIABLES

- (1) CURRENT
- (2) GAS TYPE
- (3) GAS FLOW
- (4) SPEED
- (5) VOLTAGE
- (6) STANDOFF
- (7) CUT WATER FLOW

Plasma Cutting Basics

PLASMA ARC CUTTING

INTRODUCTION

Oxygen and plasma arc cutting methods are most often employed in thermal metal cutting. In oxygen cutting the metal burns, reacting with the oxygen; in plasma arc cutting the metal evaporates due to the high temperature of the plasma jet.

Oxygen cutting is performed with the use of simple, highly reliable equipment and yields quite satisfactory results. However, the method has its limitations. First, it is difficult or even impossible to cut nonferrous metals and their alloys, stainless steel and other special steels, and cast iron. Secondly, the speed of oxygen cutting carbon steels for which it is used is limited by the speed of the chemical reaction of oxygen with iron, thus restricting the increase of labor productivity.

Plasma arc cutting is performed with the use of more sophisticated equipment, however, this method of cutting can be applied to any metals and even to nonconducting materials, whereas carbon steels thinner than 2 inches (50 mm) can be cut at accelerated speeds.

Due to the high speed of cutting the deformation of sheet metals is greatly reduced. Plasma arc cutting is finding ever increasing application. At the present time, it occupies a leading position among other methods of plasma working of materials both in the scope of commercial application and in the diversity of the equipment produced.

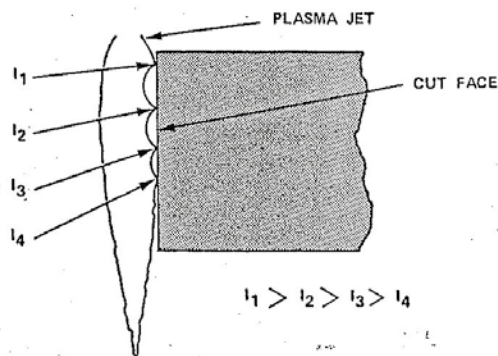
Plasma arc cutting is performed with the direct plasma arc which differs from the welding arc by a higher degree of constriction of the column and a higher speed of the plasma jet. Due to its thermal and mechanical action, the arc column penetrates the metal, transferring heat to it.

With the optimum correlation between the metal thickness, arc power and speed of cutting the plasma arc column penetrates the entire metal thickness, and its anode region is at the level of the lower surface of the sheet.

The quality and speed of cutting, far from being fully dependent on the power parameters of the plasma arc, are much influenced by thermophysical and chemico-metallurgical properties of the plasma-forming gas.

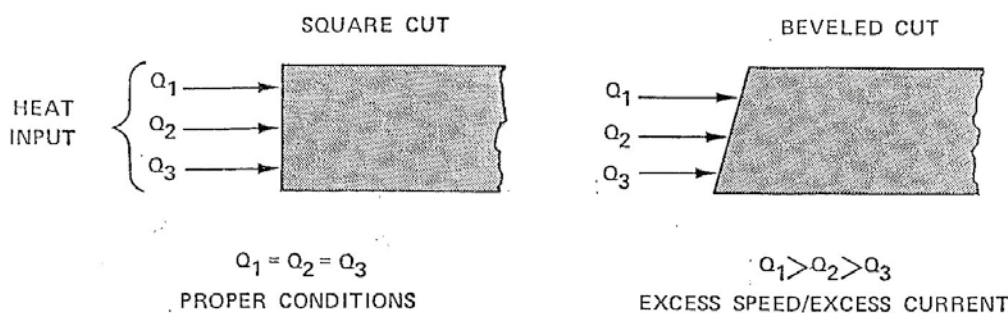
CUTTING MECHANISM

Just how the plasma arc cuts metal is not well understood. The most plausible theory is that the arc attachment points (anode feet) form at the top of the cut and are blown downward as shown below. New anode feet eventually form at the top of the cut and shunt out the "old" anode feet at the bottom. The process then repeats itself.

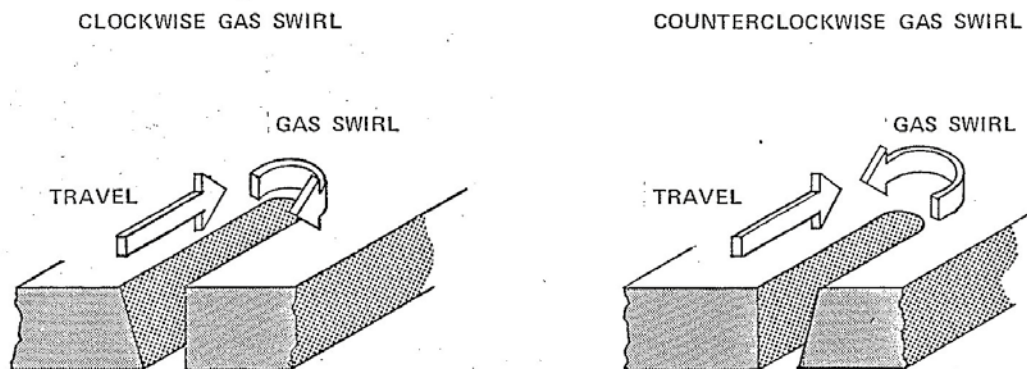


Plasma Cutting Basics

On materials less than 1-1/2 inch thick very little "shunting" of the bottom anode feet takes places, so the cut squareness will mostly depend on the cutting speed. If the speed is too high most of the anode activity will be on the top of the cut causing a bevel as shown below.



Gas swirl causes one side to be square, the other side to be bevelled. The square side depends on the direction of gas swirl. In water cutting, it is important that the water and gas swirl in the same direction to prevent instabilities in the arc. In terms of cut quality, water and gas swirling in opposite direction will cause dross and excessive bevel.



ELECTRODE LIFE

Electrode life will be long if the heat developed at the electrode is low or if cooling is extremely good.

Plasma Cutting Basics

Electrode heat load is governed by $V_{cath} \times I_a$. Unfortunately, V_{cath} is not a constant and will vary with gas type, current, plenum pressure (pressure inside the nozzle near the electrode). Experience has shown the following statements to be true.

- (i) Nitrogen has a larger cathode drop than H-35 and will cause the electrode to fail at lower currents.
- (ii) High plenum pressure (high gas flow) will cause the electrode to fail at a lower current.
- (iii) Swirling the cutting gas causes the cathode spots to move around on the tungsten, thereby distributing their heat load more uniformly.

The maximum current of an electrode in nitrogen can be increased substantially (< 30%) by tapering the nozzle inlet bore.

This design reduces plenum pressure and allows the nozzle to be operated at higher currents. Another way to accomplish the same thing is to reduce the throat length; however, this approach tends to reduce cut quality.

NOZZLE LIFE

The maximum current limit of a nozzle depends on both the diameter and the throat length: The larger the nozzle diameter the higher the current rating; the longer the throat length the lower the current rating.

Double arcing is usually the cause of most nozzle failures. This is generally caused by low gas flow or insufficient gas swirl. Both of these reduce the thickness of the cool boundary layer of unionized gas.

Gas swirl is desirable since it increases the thickness of the cool gas layer. The swirling action forces the cooler gas to move to the outside.

Plasma Cutting Basics

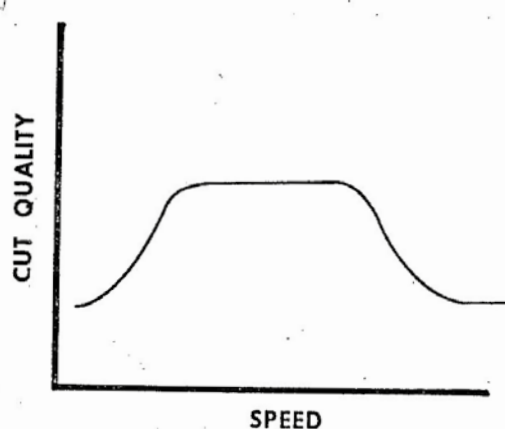
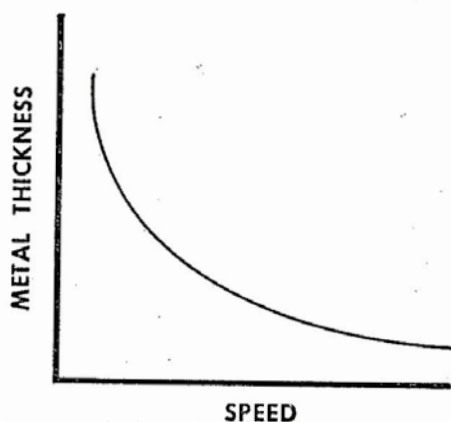
PROCESS VARIABLES

An understanding of the variables associated with plasma arc cutting will help to eliminate many of the problems encountered while using the process. These variables comprise the essential elements of the process and optimization will result in efficient cutting. A short summary of each variable is given below.

1. Current

The current which can be applied for cutting is limited by the heat load on the electrode. Current density is, therefore, limited by the durability of the nozzle under conditions of double arcing.

With an increase in the thickness of the metal, the current density in the nozzle has an ever diminishing influence on the cutting efficiency which is due to the weakening of the column constraining effect, drop of temperature and speed of the plasma jet with distance. The increment of the arc power becomes insufficient owing to the increased length of the arc. This necessitates a substantial increase of current I_{arc} . The increased current leads to an enlarged cut width and reduced arc power utilization for which reason, in spite of the increase in power, the cutting speed drops as the metal thickness increase and the quality of the cut deteriorates.



In practice, the maximum current used for plasma cutting is not in excess of 1000A.

2. Gas Type

Recently natural or artificial mixtures which are various combinations of four principal gases, argon Ar, nitrogen N₂, hydrogen H₂ and oxygen O₂, have been used as plasma-forming media.

Due to high heat capacity, hydrogen has the maximum heat content (enthalpy) at a comparatively low plasma temperature, and due to high heat conductivity it

Plasma Cutting Basics

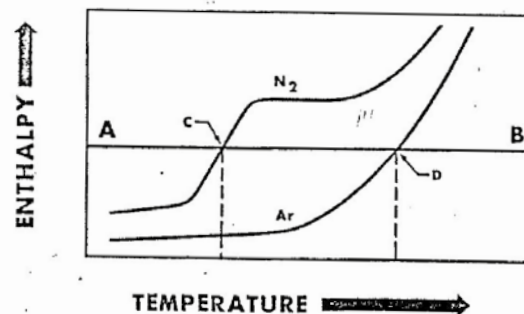
makes it possible to achieve the best conditions for the transfer of the plasma arc power to the work piece. For this reason, hydrogen-containing mixtures should be used for cutting thick, high-alloy steel plates and such good heat conductors as copper and aluminum. In addition, hydrogen provides a smooth cutting surface.

With oxygen in the plasma, heat is applied to the cut not from the arc alone but also due to the heat transfer as a result of the iron oxidation when cutting steel.

Water is an ideal plasma-forming medium which is a fortunate and cheap combination of hydrogen and oxygen.

Argon is rather inefficient as a plasma cutting gas because of its low-enthalpic value.

ENTHALPY CURVES



3. Gas Flow

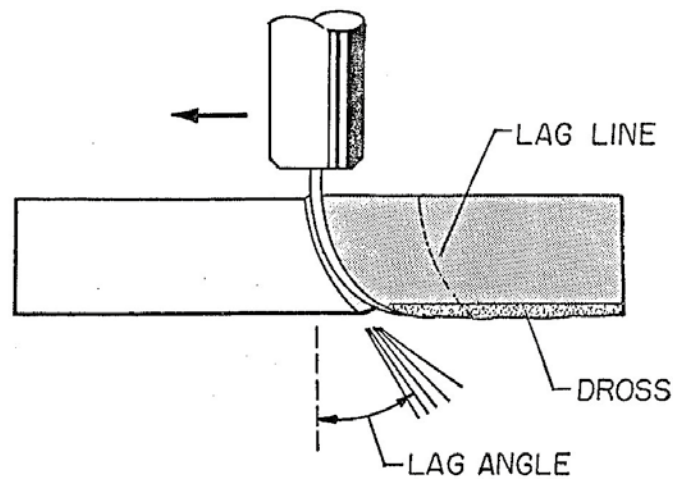
This variable does not seem to be critical to cut quality; it has much less effect than the electrical energy of the arc current. Within the limits (for a given orifice diameter) established, there can be deviations of 10-15 percent in the flow rate without adversely affecting the cut quality.

4. Speed

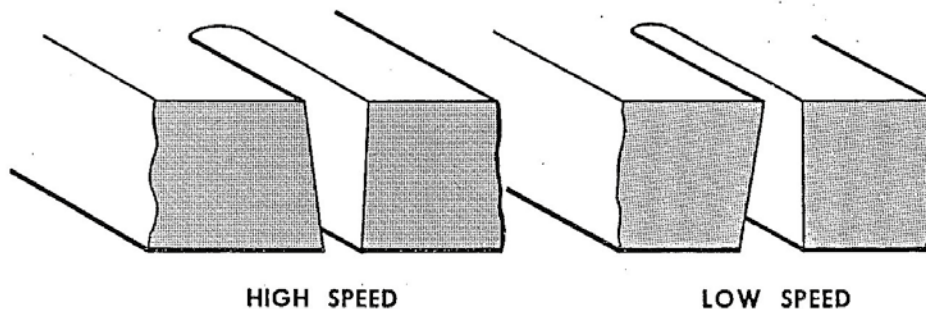
This is the most obvious variable and has the widest range. There is a maximum and a minimum speed within which high quality cuts are achieved. The cutting speed is influenced among other things by: (a) nozzle size (affects kerf width), (b) gas type and flow rate (affects constriction), (c) arc current, and (d) arc voltage.

An indication of the correct speed can be obtained by an examination of the cut face.

Plasma Cutting Basics



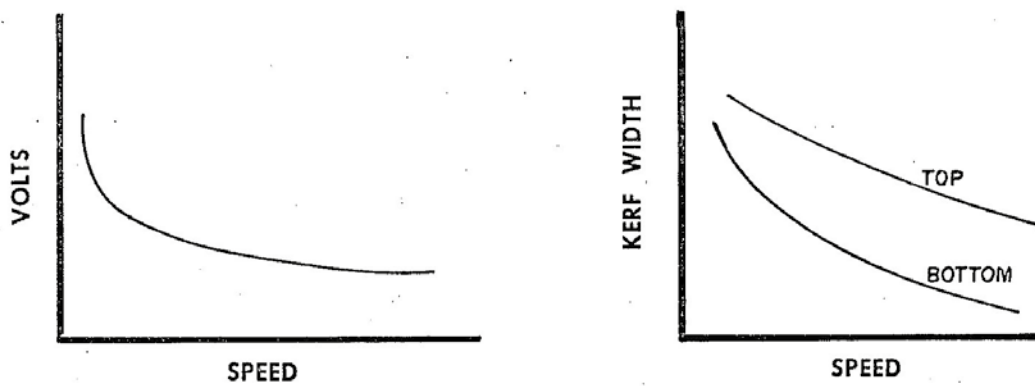
With the optimum correlation between the metal thickness, arc power and speed of cutting the plasma arc column penetrates the entire metal thickness, and its anode region is at the lower surface of the plate. An increase of the cutting speed leads to a reduced depth of immersion of the column and of the anode region and consequently to a narrowing of the cut in the lower portion. In the case of excessive speed, this can lead to incomplete cutting. On the other hand, the reduction of speed below the optimum will cause a widening of the kerf at the bottom



Plasma Cutting Basics

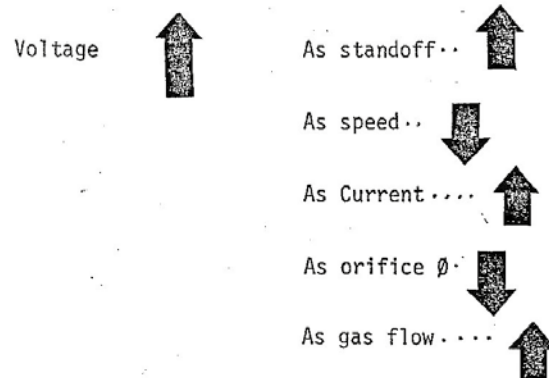
Cutting speed may be increased, for a given thickness of material without increasing the current, by raising the arc voltage. This may be accomplished by increased arc constriction or through the use of high-enthalpy plasma forming molecular gases such as N_2 , H_2 , and O_2 .

The effect of cutting speed on cut angle, lag angle kerf width and arc voltage is shown in the appropriate sketches.



5. Voltage

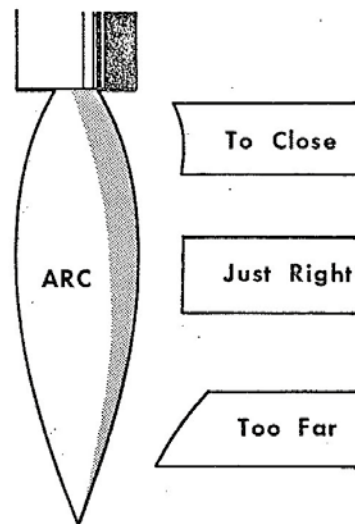
This is not an independent variable, but is a function of (a) nozzle size, (b) speed, (c) gas type (d) gas flow, (e) current, and (f) standoff.



Plasma Cutting Basics

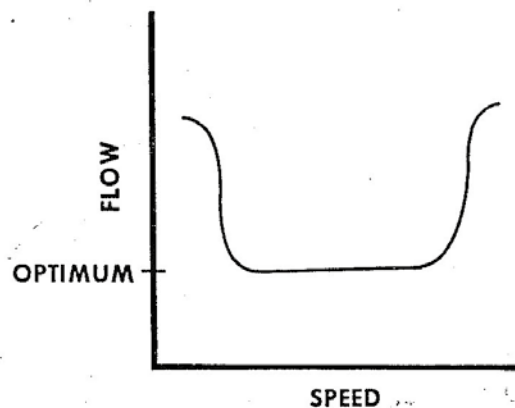
6. Standoff

An increase of the stand-off distance reduces the depth of penetration of the column, and hence narrows the cut width at the bottom. With an excessive reduction of the stand-off distance, damage might result to the torch. Some torches are more sensitive to stand-off than others. The standoff can also affect cut quality as shown below.



7. Cut Water Flow

While excessive cut water flow has been shown to reduce consumable life, higher than average cut water flow has been shown to produce higher cut quality; i.e., reduced dross and cleaner cut surfaces.





Plasma Cutting Basics

VARIATIONS OF THE PLASMA CUTTING PROCESS

*CONVENTIONAL

*AIR

*DUAL FLOW

*WATER SHIELD

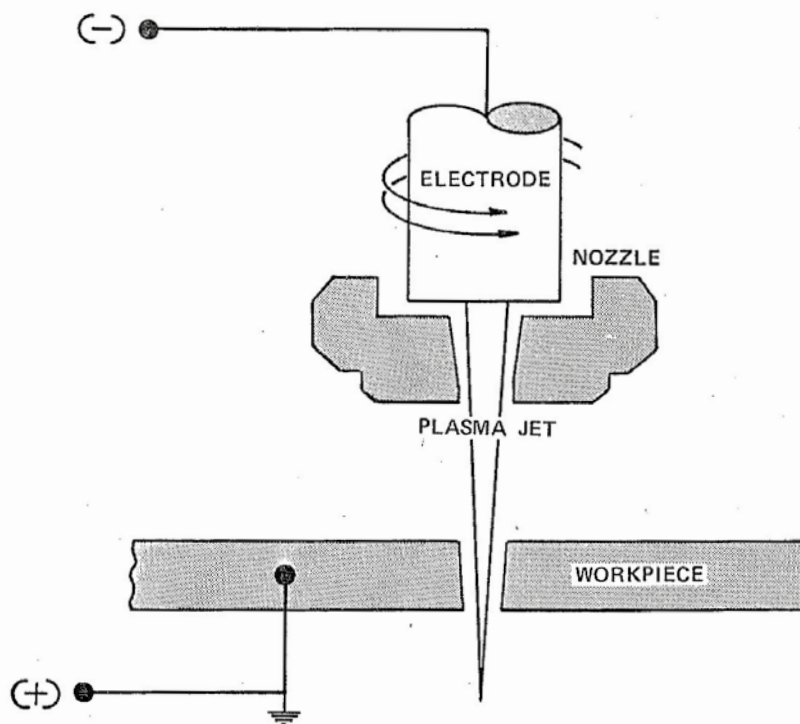
*OXYGEN INJECTION

*WATER INJECTION

Plasma Cutting Basics

"CONVENTIONAL" PLASMA CUTTING

This method of arc constriction is by a nozzle only; no water or shielding gas is added. Generally the cutting gas is tangentially injected around the electrode as shown below:



The swirling action of the gas causes the cooler (heavier) portions of the gas to move radially outward and form a protective boundary layer on the inside of the nozzle bore. This prevents double arcing thereby extending nozzle life. Electrode life is also improved since the arc attachment point (cathode spot) is forced to move about and distribute its heat load more uniformly. This mode of plasma cutting was the most popular technique up until 1970 when water injection was introduced. Conventional plasma cutting is still the best way to cut stainless steel and aluminum 3-inches and up.

"AIR" PLASMA CUTTING

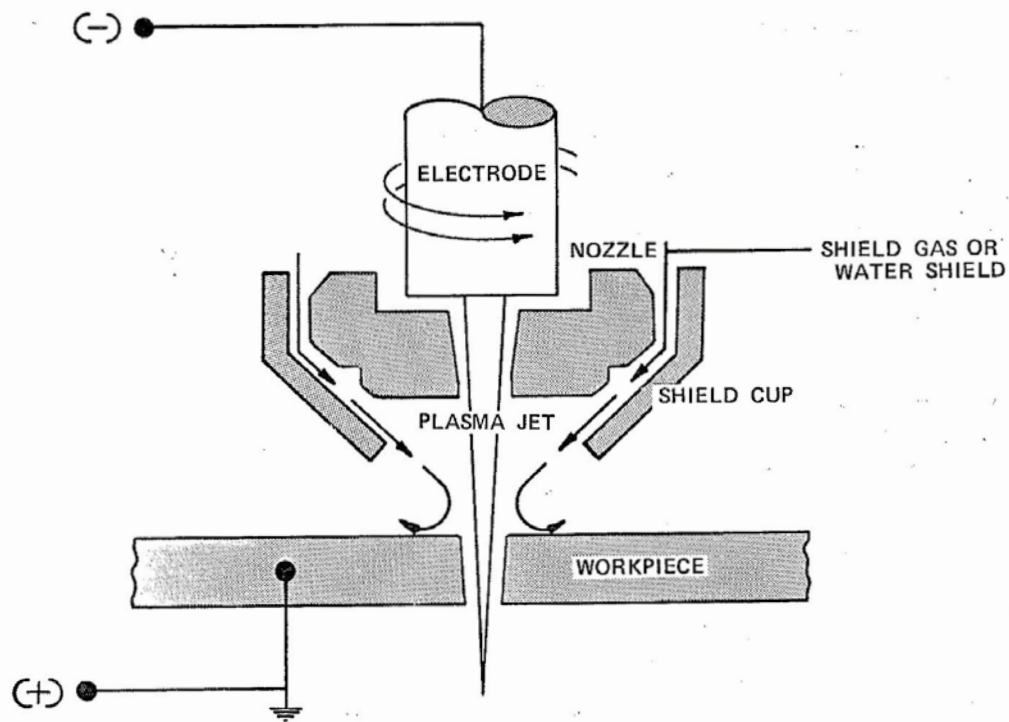
Air cutting was introduced in the early 1960's for cutting mild steel since the oxygen in the air provides the additional energy from the exothermic reaction with molten steel. This additional energy boosts the cutting speeds by about 25 percent. Although this process can also be used to cut stainless steel and aluminum, the cut surface will be heavily oxidized and often unacceptable for many applications.

Special electrodes, made of zirconium or hafnium, must be used since tungsten will erode instantaneously if the cutting gas contains oxygen. Even with these special electrodes, the service life is much less than what can be achieved with the conventional plasma cutting process.

Plasma Cutting Basics

"DUAL FLOW" PLASMA CUTTING

The dual flow technique is a slight modification of the conventional plasma cutting process that was developed around 1965. Essentially, it incorporates the same features as conventional plasma cutting except that a secondary shield gas is added around the nozzle.



Usually the cutting gas is nitrogen and the secondary shielding gas is selected according to the metal to be cut.

- Mild Steel - Either air or oxygen
- Stainless Steel - CO_2
- Aluminum - Argon-Hydrogen mixture.

Cutting speeds are slightly better than conventional cutting on mild steel; however, cut quality is inadequate for many applications. Cut speed and quality on stainless steel and aluminum is essentially the same as the conventional process.

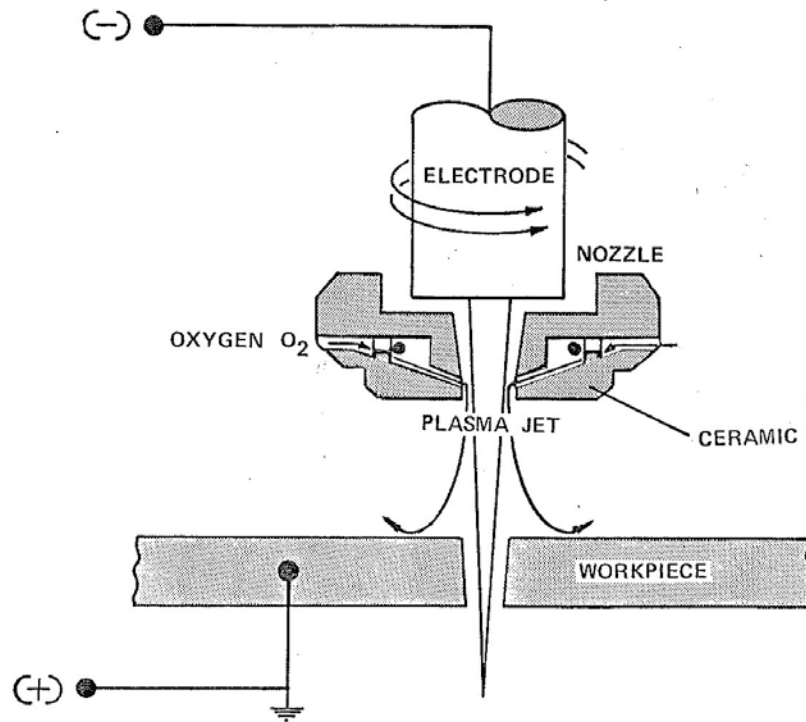
"WATER SHIELD" PLASMA CUTTING

Similar to dual flow except that water is substituted for the shield gas. Cut quality and nozzle life are improved because of the cooling effect provided by the water.

Plasma Cutting Basics

"Oxygen Injection" Plasma Cutting

This process refinement circumvented the electrode life problem associated with air cutting by using nitrogen as the cutting gas and introducing oxygen downstream in the nozzle bore as shown below:

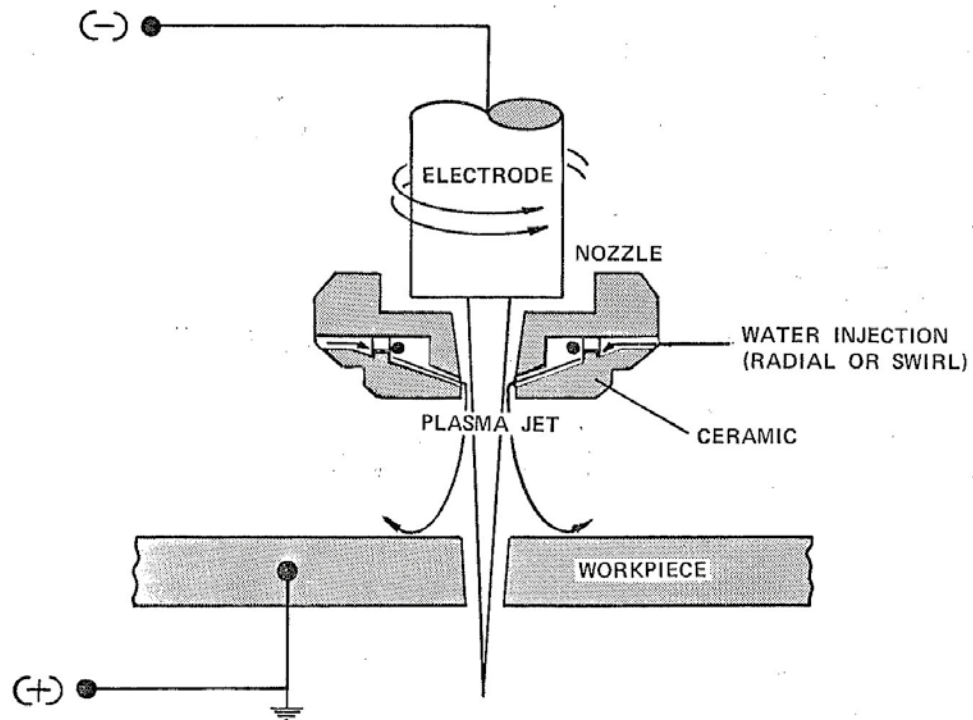


This process is used exclusively on mild steel and increases cutting speed by about 25% if the optimum gas mixture is used (80% N₂ -20% O₂). The major disadvantages of this process are: lack of cut squareness, short nozzle life and poor versatility (mild steel only). Although this process is still being used at some locations, it has been almost entirely displaced by water injection cutting.

Plasma Cutting Basics

"WATER INJECTION" PLASMA CUTTING

Water is introduced inside the nozzle to provide additional arc constriction as shown below:



Two modes of water injection have been developed: Radial injection - the water impinges the arc with no swirl component; swirl injection - the water is introduced as a vortex swirling in the same direction as the cutting gas. The increased arc constriction provided by the water improves cut squareness and increases cutting speed. The water also protects the nozzle since it provides cooling at the point of arc constriction. The water completely protects the bottom half of the nozzle from the intense radiation, allowing complete insulation of the nozzle; hence, resistance to double arcing is greatly improved. This approach allows enough freedom in torch design to insure component durability, cut quality and high cutting speeds.



**MAKE SOMETHING
BETTER**

**ANY QUESTIONS?
CONTACT US!**

Tel: 01234 345111
Email: info@pwpind.com