WELDING BASICS SERIES

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PLASMA ARC WELDING

Introduction

Plasma jets as found in electric arcs consist of high velocity high temperature ionized gas streams. By artifically constricting the arc, the plasma effect may be accentuated and the resultant heat source takes the form of a stable uni-directional high intensity jet with temperatures between 16,000°C and 33,000°C being reported. It is this heat source that is utilized in plasma arc welding, or, as it is more correctly termed, constricted arc welding. The plasma welding process can operate using either a transferred or non-transferred arc mode. With the former, Figure 1, the arc is established between an electrode in the torch and the work piece, and in the latter instance, Figure 2, the arc is established between the electrode and the nozzle.

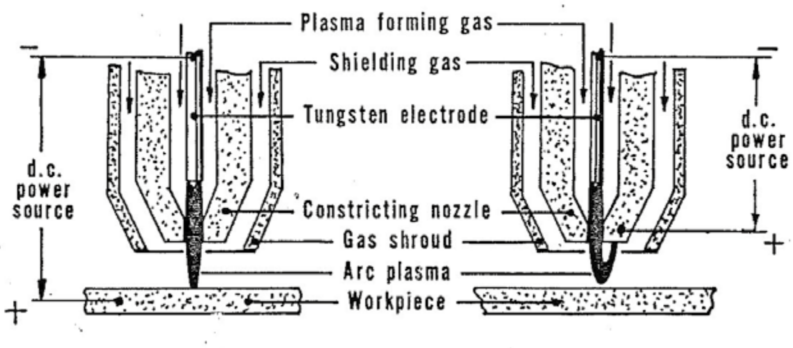

FIG. 1 TRANSFERRED ARC FIG. 2 NON-TRANSFERRED ARC

Transferred arcs have the advantage of greater energy transfer to the work but require an electrically conductive work piece. The majority of plasma welding systems operate using the transferred mode. Non-transferred arcs are useful for non-conductive work pieces or when lower energy concentration is desirable. Very often a non-transferred arc is used as a method of initiating a transferred arc, Figure 3.

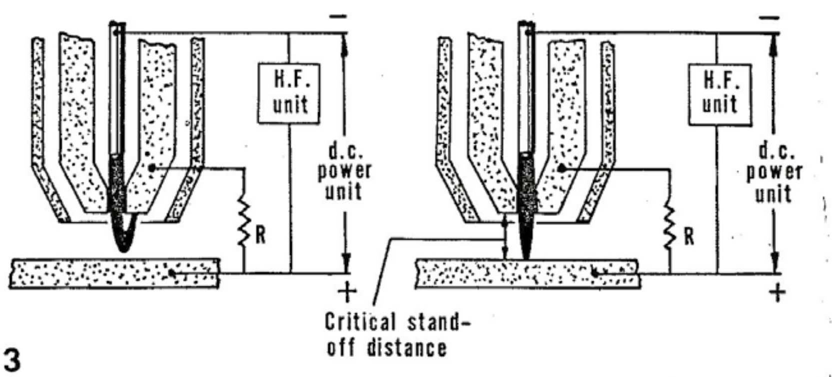

FIG. 3

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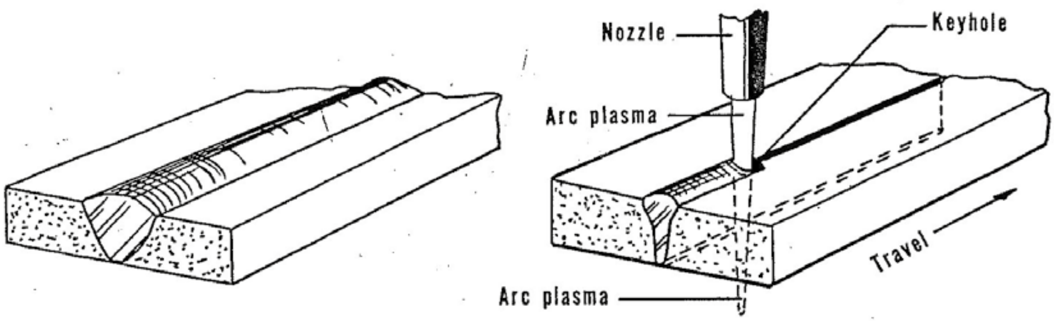
Arc Ignition

The high frequency discharge between the electrode and nozzle ignites the pilot arc (non-transferred). The pilot arc current is limited resistance (R). The ionized gas from the pilot arc causes the nozzle-to-work gap to become conductive and at a critical stand-off distance the main transferred arc will ignite.

Welding Modes

Plasma-arc welding, using a transferred arc mode, can be applied using two different techniques. The first is called the "melt-in" method, where the plasma impinges on the work and melts or penetrates the surface to some depth and is similar to the way in which tungsten inert gas (TIG) welding is utilized (Figure 4a). A second method is called the "keyhole" mode and produces an entirely different effect. Using a higher plasma gas flow than for the melt-in technique forces the plasma arc to pass completely through the weld pool forming a keyhole. Surface tension forces cause the keyhole to close behind the arc as the torch progresses and thus produces a fully penetrated weld (Figure 4b). This method has the advantage that the arc can be seen on the underside of the work and so full penetration is assured.



(a) Melt-in mode (b) Keyhole welding

FIG. 4

Process Characteristics

The plasma arc process in certain applications, offers a number of advantages over the tungsten inert gas (TIG) welding process from which it was developed. These include:

1. The ability to weld at higher speeds.
2. Reduced joint preparation and filler metal consumption.
3. Elimination of tungsten inclusions and arc stability at low current operation.
4. Tolerance to variations in stand-off distance.

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High Speed Welding

In a number of applications the substitution of the plasma arc process for the TIG process has resulted in significant economies in spite of the initial higher capital cost of the equipment.

The plasma process produces an inherently stable, high intensity, heat source, comparative heat input figures for other processes are given in Figure 5.

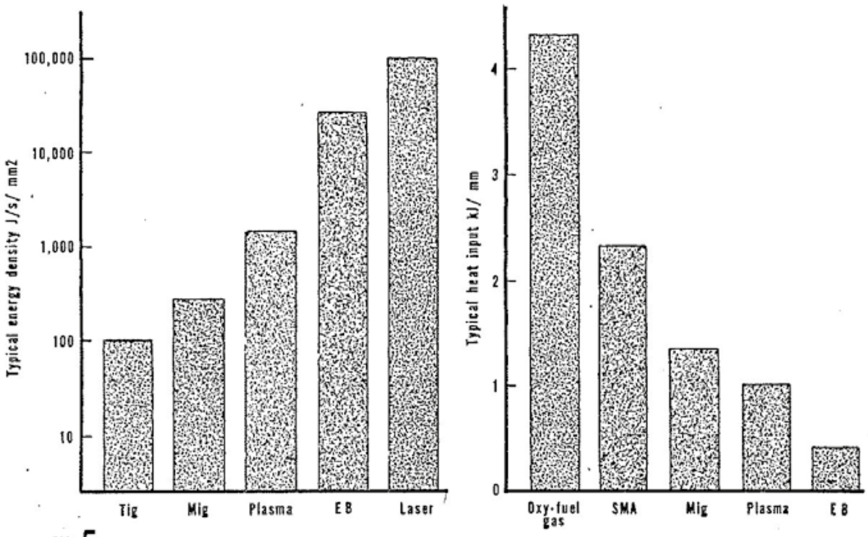

FIG. 5

The high energy localized heat source of a plasma system enables single-pass keyhole welds to be made at high speed in materials up to 3/8" (9.5 mm) thick For this reason, the most economic applications of plasma welding to date have been in the continuous production of fairly thick welded tubes. However, many applications exist involving small high quality joints in expensive materials where, although economically inferior, plasma is technically superior to other processes. In general, these applications lie outside the scope of conventional TIG and would otherwise be performed by electron-beam welding. However, electron-beam equipment would be at least ten times the capital cost and have all the associated difficulties of welding in vacuum.

Reduced Joint Preparation

It is generally accepted that it is possible to keyhole weld materials up to 3/8" (9.5 mm) thick using a simple square edge preparation, although larger thicknesses have been welded successfully according to the literature. For thicknesses greater than 3/8" (9.5 mm) thick, generally a Vee-preparation would be required with the addition of filler metal (Figure 6).

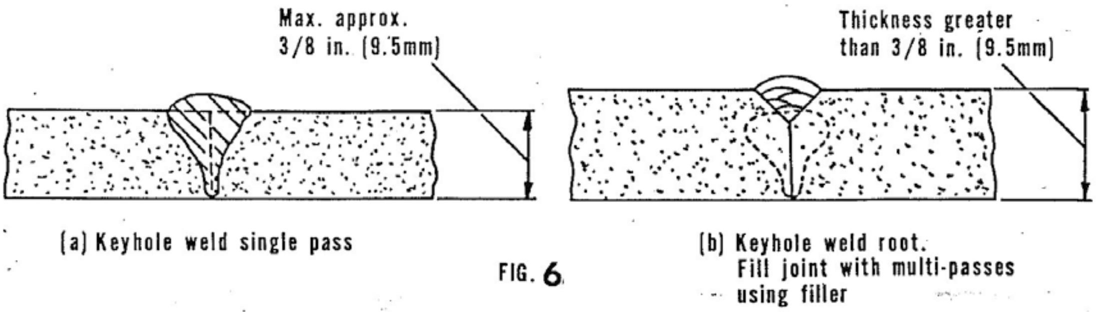

FIG. 6

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Various arguments exist as to the accuracy required for the square edge preparation. It is possible to keyhole flame-cut edges but setting up and final weld quality are superior when machined edges are utilized and there is no gap.

Elimination of Tungsten Inclusions and Improved Arc Stability

a. Inclusions

Difficulty is often encountered at low currents with conventional TIG due to the possiblility of tungsten contamination by the transmission of electrode material to the weld pool by electrode shorting to the work. Tungsten contamination can also occur at high current operation due to electrode melting (tungsten drop) especially using DC electrode positive or AC current. These problems are eliminated in the plasma process by virtue of the long arc column, improved heat extraction from the electrode and the fact that the electrode is contained within the torch body.

b. Improved Arc Stability

At low current, it is difficult to weld with a TIG arc due to the very short arc which becomes unstable when the torch to work distance varies. Instability of low current TIG arcs may take the form of arc extinctions or the tendency of the arc to wander, usually to high spots at joint edges. These problems do not occur in plasma welding due to the stiff, unidirectional arc column.

Tolerance to Stand-Off Distance

The tolerance to stand off is illustrated in Figure 7. Since the arc column is long and narrow the change of heating effect with torch-to-work separation is very small for plasma.

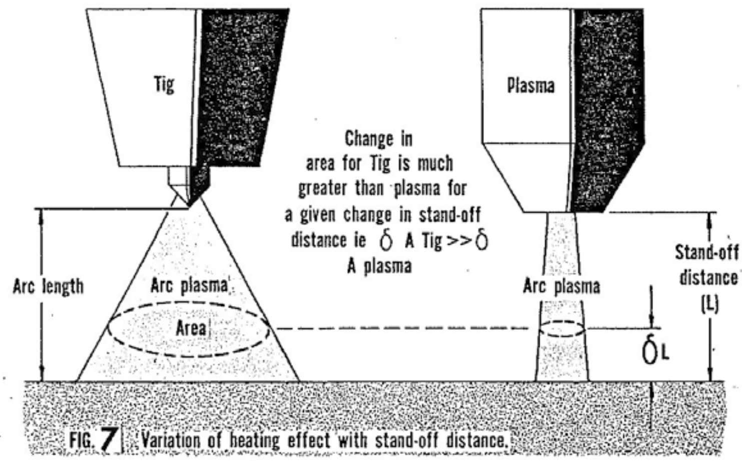

FIG. 7 Variation of heating effect with stand-off distance.

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