Technical Commentary: Observations Regarding Electrical Current Flow in the Gas Metal Arc

Comments in response to "Analyses of Electrode Heat Transfer in Gas Metal Arc Welding," by Y.-S. Kim, et al., published in the January 1991 Welding Journal

BY A. LESNEWICH

The recent strong interest shown in modeling metal transfer associated with the GMA welding process stimulated my recall of two experiments made over thirty years ago at Airco. The tests had been made while developing methods for surfacing metal using low-dilution arc processes. The results appeared to demonstrate that little, if any, current is conducted through the inner core of a spray transfer arc; that essentially all of the current is conducted in the outer plasma. These observations are offered with the hope that they will provide some guidance to those who are continuing in their efforts to explain and model the GMA welding process.

In the first experiment, a thin, internally cooled, copper annulus was used to replace the steel workpiece, becoming the cathode in an otherwise conventional GMA welding system—Fig. 1. Using an oxygen-doped argon shield and a welding current above the transition level, the outer plasma became attached to the annulus. The metal drops and the inner jet passed through without interruption. When allowed to impinge on an electrically insulated steel plate, the metal deposited was very narrow and highly crowned. With the exception of a central core, the weld metal was not fused to the plate. When cross-sectioned, the penetration profile also was found to be very narrow. Its depth was essentially the same as that observed for the papilla in a conventional weld made at the same wire feed speed, current and plate travel speed. With the exception of a narrow heat-affected zone immediately surrounding this papilla, no evidence of other heating was observed. Since no current was transferred to the plate, one must conclude the following:

1) The central, deeply penetrating papilla that characterizes the GMA process in the spray mode is caused by mechanical erosion of the drops and surrounding vapor jet. That jet, composed of metal vapor from the wire tip, cools the core of the arc sufficiently to prevent the ionization needed to conduct current through the center of the arc.
2) All of the arc current is conducted by the plasma, which envelops this central region. Where it makes contact with the plate surface, the cathode energy is used to heat the plate, producing the lateral melting and heat-affected zone that typify the outer sections of GMA weld cross-sections. The width of the HAZ (and the weld bead) is inversely proportional to the ease with which the cathode can emit electrons.
3) The anode region is anchored above the wire tip, covering the area needed to provide a stable anode. This is the tapered portion of the wire.

Changing the polarity, making the wire tip negative, the cathode area has been found to be inversely proportional to the work function of the wire surface (assuming it is thermionic). This explains the very long taper at the wire tip that is associated with a DCEN arc shielded with a 5% oxygen-argon gas mixture. Only weakly stabilized by the iron oxide at the wire tip, a large surface area is needed to provide

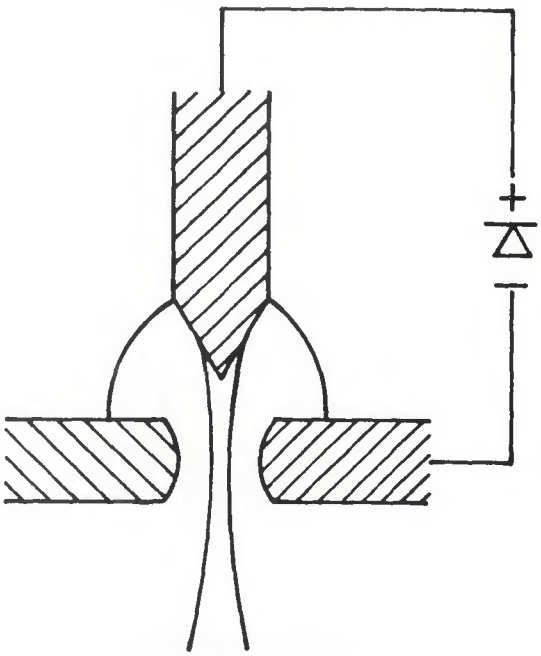

Fig. 1—The outer plasma of the arc attaches to a thin copper annulus while the inner jet and molten metal pass through the opening without interruption.

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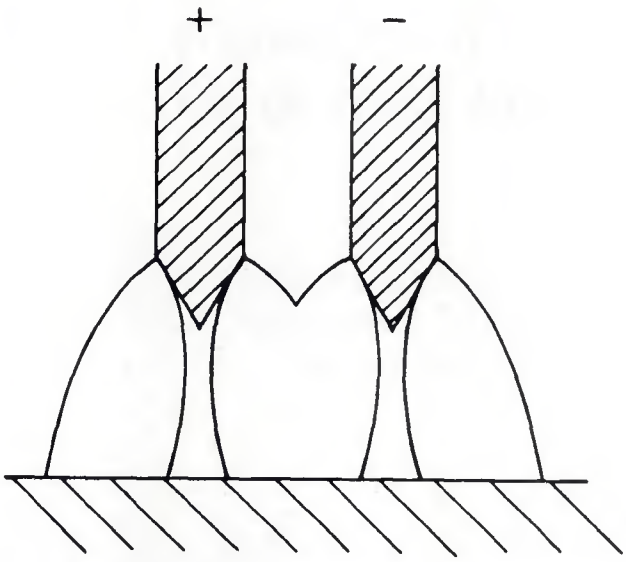

Fig. 2 — Two arcs in series display independent inner vapor jets and transfer of molten metal.

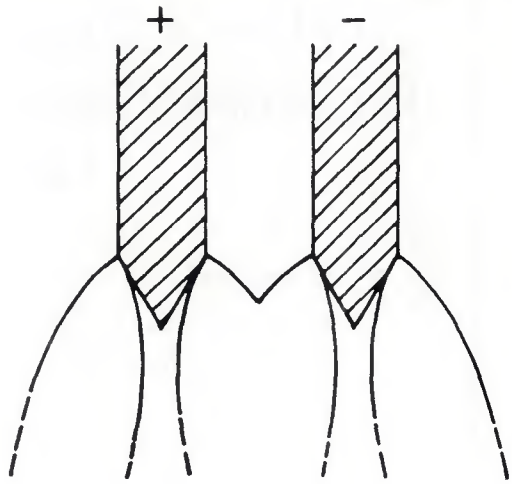

Fig. 3 — Removal of the plate from beneath the arcs resulted in no apparent change in the positions of the wire tips or the inner vapor jets.

the electron source for supporting a stable arc. With reduced work functions offered by surface activators such as rubidium, the conductive areas are reduced, causing both the taper and wire melting rate to be reduced appreciably.

In another experiment with the GMA process, a series arc was established between two wires. The steel wire cathode had been stabilized with a thin coating of rubidium carbonate to obtain spray transfer and a melting rate that was identical to that of the anode wire. The current level was set above that required for spray transfer. The wires were positioned to be parallel and sufficiently close to allow their plasma envelopes to merge. A stable system was established to a plate, which appeared to connect the two arcs in series. The inner vapor jets and spray of drops from the two wires were clearly independent — Fig. 2.

Surprisingly, when the plate was removed from its position under the wires where it had intercepted the jets and drops, no change occurred in the relative positions of either the wire tips or the inner vapor jets. The jets were directed into space, becoming more diffuse with increasing distance from the wire tips, and the drops fell to the floor — Fig. 3. Of greater significance, perhaps, was the fact that the voltage drop between the two wires did not change when the plate was withdrawn. (Note that when using a plate and separating the two wires a sufficient distance to isolate the two plasmas, the voltage measured between the arcs was significantly greater.) From these observations, one would conclude the following, which reinforce the earlier conclusions:

1) Using the spray transfer mode, all of the current with the series arcs can be conducted through merged outer plasmas.
2) The tapered portions of the wire tips in contact with the plasmas served as the anode and cathode of the system.
3) Neither the metal drops nor the vapor jet conduct measurable amounts of welding current.

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WFI/PVRC Moment Fatigue Tests on 4 × 3 ANSI B16.9 Tees

By G. E. Woods and E. C. Rodabaugh

The Markl-type fatigue test data presented in this report have been needed for a number of years to establish i-factors (SIFs) for forged tees with d/D ratios between 0.5 and 1.0 that conform to the ANSI B16.9 standard. These new data will provide improved design rules for both nuclear and industrial piping systems.

Publication of this report was sponsored by the Subcommittee on Piping Pumps and Valves of the Pressure Vessel Research Committee of the Welding Research Council. The price of WRC Bulletin 346 is $25.00 per copy, plus $5.00 for U.S. and $10.00 for overseas postage and handling. Orders should be sent with payment to the Welding Research Council, Room 1301, 345 E. 47th St., New York, NY 10017.