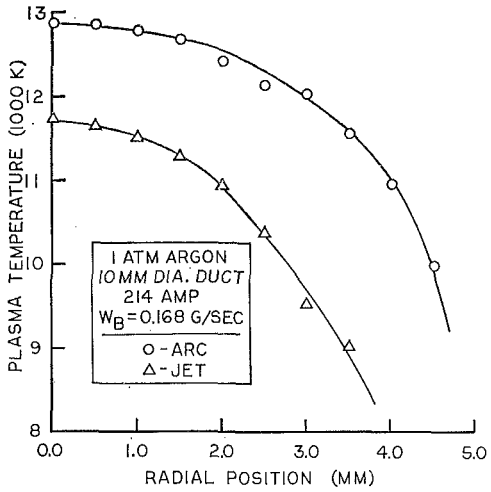

Fig. 7 Jet and arc temperature profiles for operation without LFC

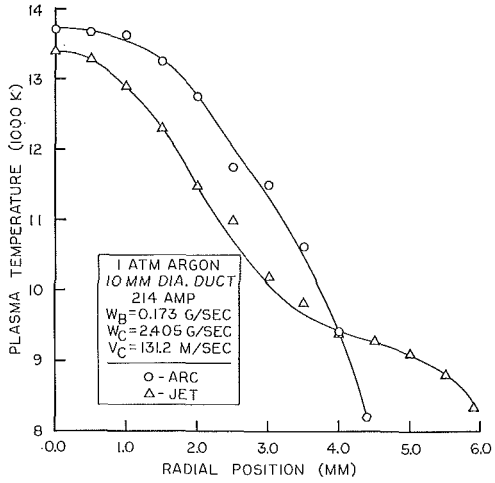

Fig. 8 Jet and arc temperature profiles for operation with LFC

in terms of the increased total mass flow alone, however. The jet center-line temperature has increased by over 1000 deg K and the radial extent of the LFC jet is nearly twice that of the non-LFC jet. The latter effect may be attributed to both the increase in center-line temperature and the transition from laminar to turbulent flow from the jet in Fig. 7 to that in Fig. 8. Clearly, the tendency for an increase in total mass flow to dilute the plasma jet has been more than offset by the increase in energy input resulting from the manner in which the additional mass was introduced.

Conclusions

The performance of a confined-discharge plasma generator can be significantly improved by introducing some of the working fluid into the fully developed discharge column with a high radial velocity. The fluid is injected into the confining duct through a narrow circumferential slit in the duct wall. This inflow and the concomitant enhanced mixing of the cold gas with the arc plasma causes a local constriction in the arc column, forcing it to redevelop downstream as it accommodates the cold gas. It is this local fluid constriction and subsequent redevelopment of the discharge column that is responsible for the noted improvement in performance.

The local electric field and the local center-line temperature both increase with increases in either LFC mass flow or velocity. In addition, it has been demonstrated that both the energy conversion efficiency and the mean plasma enthalpy can be caused to increase with an increase in the level of LFC. Finally, it has been noted that operation in the LFC mode may be optimized when the injection slit is located at or perhaps slightly upstream of the point where the discharge just becomes thermally fully developed.

Acknowledgment

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References

1 Maecker, H., "Messung und Auswertung von Bogencharakteristiken (Ar, N_2)," *Zeitschrift für Physik*, Vol. 158, 1960, pp. 392–404.

2 Incropera, F. P., and R. K. Scott, "Flow Calculation for an Argon Arc Plasma Scalpel," HTGDL-1, Purdue University, June 1970.

3 Ludwig, H. C., "The Plasma Jet in Chemical Processing," *Instruments and Control Systems*, Vol. 41, May 1968, p. 81.

4 Mahan, J. R., "An Experimental Study of the Effects of Local Fluid Constriction on the Confined Discharge Plasma Generator," PhD dissertation, The University of Kentucky, Dec. 1970.

5 Smelyanski, M. Y., E. K. Zhigalko, and A. B. Kuvalbin, "Experimental Studies of the Energy Relationships in a Plasmatron With Arc Stabilized by an Argon Flux," *High Temperature*, Vol. 5, 1967, pp. 855–858.

6 Bower, W. W., and F. P. Incropera, "Heat Transfer, Development Length, and Friction Factor Correlations for the Asymptotic Region of a Laminar Arc Constrictor," *Wärme- und Stoffübertragung*, Vol. 2, 1969, pp. 150–162.

7 Soehngen, E. E., Director of Thermomechanics Branch of Aerospace Research Laboratories, Wright-Patterson Air Force Base, Ohio, personal communication, June 1968.

8 Kirschstein, B., and F. Koppelmann, "Der elektrische Lichtbogen in schnellströmendem Gas," *Wissenschaftliche Veröffentlichungen aus den Siemens-Werken*, Vol. XVI, Parts I and II, Springer, Berlin, 1937.

9 Tannen, P. D., *Experimental Study of a Transpiration-Cooled, Wall-Stabilized DC Arc*, Master's thesis, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio, GA/ME/62-6, Aug. 1962.

10 Baran, M. F., "An Experimental and Theoretical Study of the Wall-Stabilized, Transpiration-Cooled DC Electric Arc," Master's thesis, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio, Phys/63-2, 1963.

11 Jones, R. N., "An Investigation of the Wall-Stabilized, Transpiration-Cooled DC Electric Arc," Master's thesis, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio, GAW/Mech 64-11, 1964.

12 Elliott, H. F., and R. V. Gomez, "Energy Exchange in the Column of An Electric Arc with Radial Gas Inflow," Master's thesis, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio, GA/EE/64-6, 1964.

13 Anderson, J. E., "Transpiration Cooling of a Constricted Electric-Arc Heater," Report No. ARL 66-0517, Aerospace Research Laboratories, Wright-Patterson Air Force Base, Ohio, 1966.

14 Pfender, E., G. Gruber, and E. R. G. Eckert, "Experimental Investigation of a Transpiration-Cooled, Constricted Arc," *High Temperature Technology*, Butterworth & Company, Ltd., London, 1969.

DISCUSSION

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This paper describes an interesting concept for improving the performance of arc gas heaters utilizing constricted arcs. Although injection of cold gas reduces the average enthalpy at the location of injection, this effect is obviously overcompensated by the resulting increase of energy dissipation in the arc. The increased radiation losses due to a substantial increase of tem-

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perature by LFC do not destroy the observed trend for the parameter range covered by this investigation.

In addition to variations of the mass flow rate, LFC offers another option, namely, variations of the injection velocity. It would be interesting to see the effect of this parameter further explored in order to answer the question whether better performance can be achieved by increasing the injection velocity or the injection mass flow rate which, in turn, is intimately associated with the turbulence level downstream of the injection slit.

For most of their work, the authors chose an inherently inefficient arc for comparison which already becomes fully developed over a fraction of the total constrictor length. A more realistic comparison should be based on a conventional constricted arc where constrictor length and development length match.

Authors' Closure

The authors wish to express their appreciation to Professor Pfender for his interest in this work. As he has suggested, further experimental studies are presently under way designed to delineate the separate effects of LFC mass flow and velocity on the energy conversion efficiency and mean plasma enthalpy. Professor Pfender's remarks regarding the comparison of the LFC results with those of an inherently inefficient design are well taken. It is for this reason that direct comparison between the non-LFC device and the LFC device was not stressed in the paper. Rather instead, the non-LFC results were used principally to demonstrate the inverse relationship between the energy conversion efficiency and the mean plasma enthalpy characteristic of devices of this type in contrast to the behavior observed for the LFC device.