(NASA-TM-77477) GAS PRESSURE AND ELECTRON DENSITY AT THE LEVEL OF THE ACTIVE ZONE OF HOLLOW CATHODE ARC DISCHARGES (National Aeronautics and Space Administration) 10 p HC A02/MF A01 CSCL 20H G3/70
N85-12648
Unclas
24490

GAS PRESSURE AND ELECTRON DENSITY AT THE LEVEL OF THE ACTIVE ZONE OF HOLLOW CATHODE ARC DISCHARGES

M. Habibollah Minoo

Translation of "La pression du gaz et la densite des electrons au niveau de la zone active des decharges d'arc a cathode creuse", Academie des Sciences(Paris), Comptes Rendus, Serie B.- Science Physiques, Vol. 272, No. 5, February 1, 1971, pp. 314-317.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON D.C. 20546 JUNE 1984

STANDARD TITLE PAGE

1. Report No. NASA TM-77477	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle GAS PRESSURE AND ELECTRON DENSITY AT THE LEVEL OF THE ACTIVE ZONE OF HOLLOW CATHODE ARC DISCHARGES		5. Report Date JUNE 1984
		6. Performing Organization Code
7. Author(s) M. Habibollah Minoo		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address SCITRAN Box 5456 Santa Barbara, CA 93108		11. Contract or Grant No. NASw- 3542
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of "La pression du gaz et la densite des electrons au niveau de la zone active des decharges d'arc a cathode creuse", Academie des Sciences (Paris), Comptes Rendus, Serie B.- Science Physiques, Vol. 272, No. 5, February 1, 1971, pp. 314-317. (A71 23843)

16. Abstract

A model for the longitudinal variations of the partial pressures of electrons, ions, and neutral particles is proposed as a result of an experimental study of pressure variations at the level of the active zone as a function of the various discharge parameters of a hollow cathode arc. The cathode region where the temperature passes through its maximum is called 'active zone'. The proposed model embodies the very important variations which the partial electron and neutral particles pressures undergo at the level of the active zone.

ORIGINAL PAGE IS OF POOR QUALITY

17. Key Words (Selected by Author(s))	18. Distribution Statement Unclassified and Unlimited

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 10	22. Price

PLASMA PHYSICS.--Gas pressure and electron density at the level of the active zone of hollow cathode arc discharges.

(*)By M. Habiboilah Minoo, presented by M. Alfred Kastler.

After an experimental study of the variation of pressure (P) at the level of the active zone (Z.A.) as a function of different discharge parameters, we are led to propose a model for the longitudinal variations of the partial pressures of electrons (P^e), ions (P^i), and neutral particles (P^n). According to this model, P^e and P^n undergo very important variations at the level of the Z.A. Simple calculations show that, in this zone: $P \approx P^e$ and $0.5 < n_e < 3.5 \times 10^{15}/cm^3$, where n_e is the electron density. /314*

*Numbers in margin indicate foreign pagination

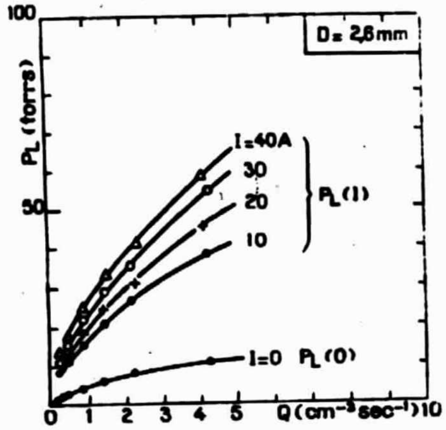

Fig. 1.

Fig. 1.--Variation of P_L as a function of Q and I.
P_L = gas pressure upstream of the Z.A. on the abscissa L (cf. Fig. 4B); Q: volume flow of argon injected by the cathode (TPN); I: discharge current; D: interior diameter of the cathode.

Fig. 2.--Variations of ΔP as a function of Q and D.
$\Delta P = P_l - P_l^o$: difference in pressure between the total pressure (P_l) and the neutral particle pressure (P_l^o) at the level of the Z.A.

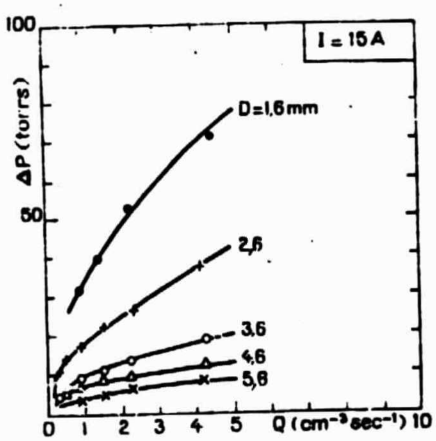

Fig. 2.

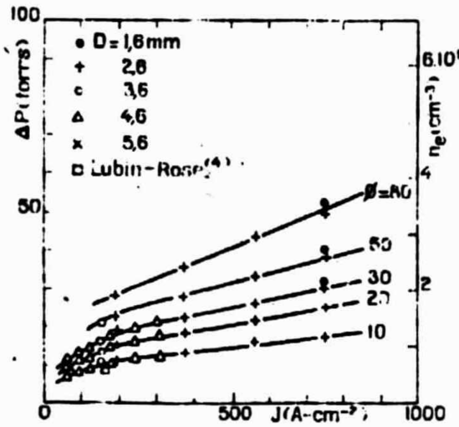

Fig. 3.--Variations in ΔP and n_e as a function of J and Φ.
J: longitudinal current density in the cathode; Φ: argon flux injected by the cathode (cm³/cm³.s; TPN);
n_e : electron density obtained from relation (3).

1.INTRODUCTION.--Under normal operating conditions of hollow cathode arc discharge (1), the cathode tube (of tantalum, in our experiment) is heated to incandescent temperature by the discharge current (I). The region of the cathode where the temperature passes through a maximum is called the "active zone" (Z.A.) (cf. Fig. 4). The recent measurements of the fall of pressure in the cathode tube [(2), (3)] show that this loss of charge increases rapidly when one increases I. In this work we have studied this phenomenon for different values of the argon flow (Q) introduced by the cathode and the interior diameter of the cathode (D). We have attributed /315
this increased pressure fall principally to that of the partial pressure of electrons at the level of the Z.A.

2. EXPERIMENTAL RESULTS.--An example of the variations of gas pressure upstream of the Z.A. as a function of Q and I is given in Figure 1. In this figure, $P_L(I)$ and $P_L(0)$ are the gas pressures at the entrance of the cathode (the abscissa L, Fig. 4b) where I ≠ 0 and I = 0 respectively. Figure 2 shows the variations of $\Delta P = P_L(I) - P_L(0)$ as a function of Q and D. From a series of curves similar to those presented in figures 1 and 2 we have determined the variations of ΔP as a function of the longitudinal current density in the cathode (J). The results are presented in Figure 3. In this figure, $\Phi = 4Q/\pi D^2$ and $J = 4I/\pi D^2$.

3. DISCUSSION.--From the results presented in Figure 1, one can show that the establishment of the discharge current is accompanied by an important increase of the pressure in the cathode. If we call P_ℓ the total pressure and P_ℓ^0 the neutral particle pressure at the level of the Z.A., we can show that (3):

$$\Delta P = P_L(I) - P_L(o) = P_l - P_l^0. \quad (1)$$

This pressure increase (ΔP) can be explained:

--either by a diffusion equilibrium such that the sum of the partial pressures of electrons, ions, and neutral particles is almost constant along the cathode tube. [There is a weak decrease in pressure along the tube from the fact that there is an outflow of the gas (Q) in the tube and that the region of outflow is laminar and viscous ([3])];

--or by more complex phenomena of ionic pumping.

After a rapid evaluation of the orders of magnitude, we were led to consider the first explanation. In this case, for the total pressure at the level of the Z.A. (P'_l) we can write /316

$$(2) \qquad P'_l = K(n_0 T_0 + n_i T_i + n_e T_e) = P^0_l + P^i_l + P^e_l,$$

where n_0, n_i, n_e are the densities of the neutral particles, ions, and electrons: T_0, T_i, T_e, their temperatures; and P^0_l, P^i_l, and P^e_l, their partial pressures, respectively. Outside of the sheath, or where $n_e \approx n_i$, equation (2) becomes

$$(3) \qquad \Delta P' = P'_l - P^0_l = K n_e (T_e + T_i).$$

We have demonstrated that at the level of the Z.A. ([3]), T_e = 12 eV, T_i = 0.2 eV, and thus relation (3) is reduced to /317

$$(4) \qquad n_e = 6{,}83 \cdot 10^{13} (\Delta P') \qquad (n_e \text{ en } cm^{-3} \text{ et } \Delta P' \text{ en torrs}).$$

We make here the fundamental hypothesis that P_l = P'_l and ΔP = $\Delta P'$, which allows us to evaluate n_e from ΔP.

ORIGINAL PAGE IS OF POOR QUALITY

The results are given in Figure 3 with an experimental point by Lubin and Rose (4). One concludes therefore that the values of n_e so determined are not too large.

Also, in evaluating P_i^l and P_i^e from the results of Figure 3 and with T_i = 0.2 eV, T_e = 12 eV, we can establish that $P_i^l \ll P_i^e$. On the other hand, according to the results of Figure 1 for $P_{L(O)}$ and the fact that $l \ll L$, we can see that P_i^o is also very weak and negligible compared to P_i. Consequently, we can conclude that at the level of the Z.A. the increase in P_i is mainly related to that of P_i^e. This suggests to us a longitudinal variation of the pressure (P) in the vicinity of the Z.A. such as that presented in Figure 4.

Figure 4. (A) Longitudinal variations of T, P, P^o, P^e and P^i in the region of the Z.A. (I = 15 A, D = 2.6 mm, Q = 1.5 cm^3/s; TPN.
T = temperature of the exterior surface of the cathode tube (T_M = 2150°C); P: total pressure; P^o, P^e, P^i, partial pressures of neutral particles, electrons and ions, respectively.
At the level of the Z.A. (abscissa 1): $\Delta P = P - P^o = 17$ Torr (≈ P); P^e = 16.7 Torr P^i = 0.3 Torr (≈ P^i); T_e = 12 eV, $T_i \approx T_o$ = 0.2 eV, $n_e = n_i = 10^{15}/cm^3$.
Upstream and near the Z.A.: P = P^o, n_o = 8 × $10^{16}/cm^3$ (where T_o = 0.17 eV).
(B) Simplified diagram of the cathode region.
1: Z.A.; 2: plasma column; 3: ionic sheath; 4: equipotential sides (Ta)

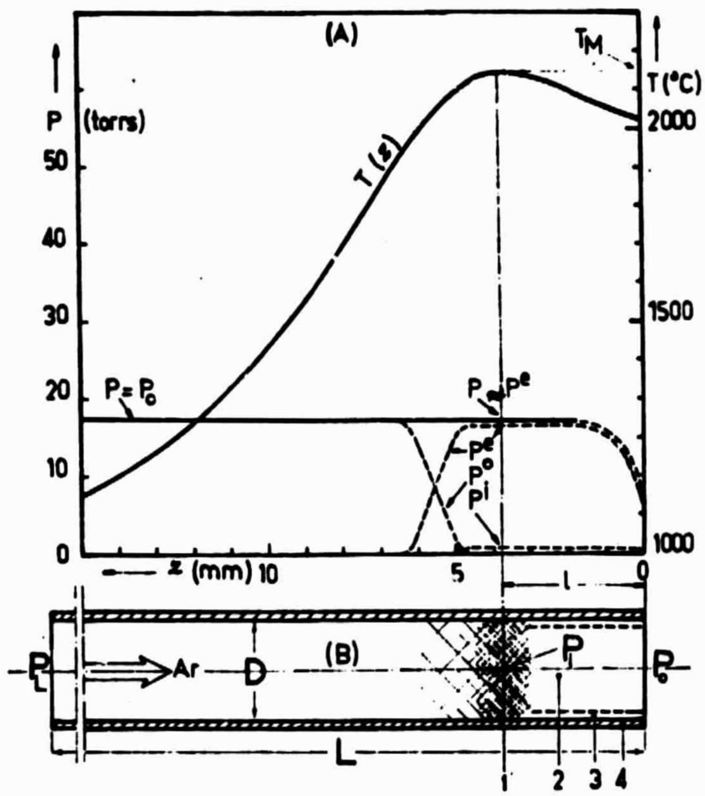

Fig. 4.

ORIGINAL PAGE IS
OF POOR QUALITY

*Meeting of 11 January, 1971.

REFERENCES

(*) Seance of January 11 1971.

(1) H. Minoo, These d'Etat, Report L. P. 94, 1969.

(2) A. Lorentc-Areas and A. Bouchoule, Comptes Rendus, 271, vol. B, 1970, p. 180.

(3) H. Minoo, Report L. P. 119, 1970.

(4) M. O. Lubin and D. J. Rose, Bull. Amer. Phys. Soc., 12, 1967, p. 694.

(Laboratory of Plasma Physics, Faculty of Sciences, Bldg. 212, Assoc. Laboratory of the CNRS, 91-Orsay, Essonne.)