

EFFECT OF FLUORINE ON THE PLASMA COMPOSITION OF DC ARC
FREE BURNING IN AIR

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ABSTRACT

The equilibrium composition of the gaseous system containing N, O, C, F and Ca in various amounts was calculated in the temperature range between 298 and 6000 K. These conditions correspond to the plasma of dc low current arc free burning in air between the graphite electrodes, with added F and Ca.

1. INTRODUCTION

In this paper our investigations of the effect of added fluorine on the composition of dc arc plasma are presented.

The change of the plasma composition causes:

- the change of temperature and electron density.
- a decrease of the concentration of atomic and ionic components of the investigated substance due to the chemical reactions with fluorine.
- the change of residence time of particles in the plasma due to the change of the transport parameters (D, μ).

The purpose of this work was to calculate the composition of the plasma corresponding to a low current ($I \sim 9A$) dc arc free burning in air between the graphite electrodes with added fluorine and calcium. These calculations are connected with our experimental investigations of the effect of added fluorine on dc arc plasma [1], [2], [3].

2. CALCULATIONS OF THE PLASMA COMPOSITION

The composition of the arc plasma in the temperature range between 298 and 6000 K was calculated under the assumption of local thermal equilibrium. It was assumed that the system was onephase one, with a constant N/O ratio (0.79:0.21).

The concentrations of carbon, fluorine and calcium were varied (C: 0%, 1%, 10%; F: 0%, 0.001%, 0.1%; Ca: 0%, 0.0001%, 0.01%), approximately corresponding to the conditions of our experiments. Calcium was taken into account because it was an element whose reactions with fluorine can be easily experimentally registered by observing the CaF bands. The equilibrium particle densities of about 60 compounds whose free energy data were available [4], [5] were calculated using the method given by White et al [6].

3. RESULTS AND DISCUSSION

A part of results of the calculation is presented in Fig. 1-5. The particle densities of the neutral, ionic and fluorine containing compounds are presented separately for the sake of clarity.

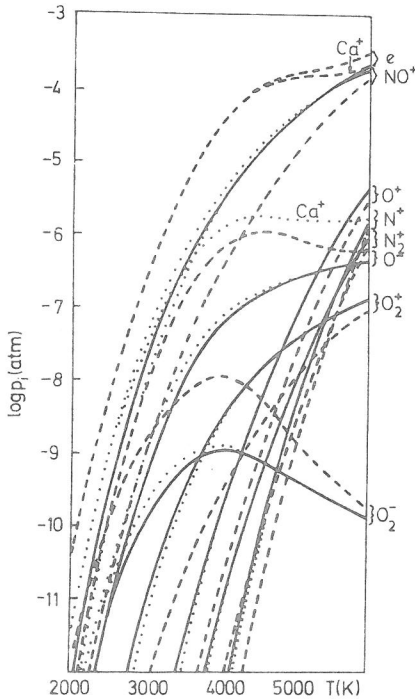


Fig. 1. Partial pressures of the ionic components of the air plasma (N=79%, O=21%)
 — without Ca; ··· with 10⁻⁴%Ca; --- with 10⁻²%Ca.

On the basis of these results the following predictions about the plasma composition can be made:

- the concentrations of the atoms and molecules of the plasma (N, O, C) are not significantly altered in the presence of fluorine in the amount $\leq 0.1\%$.
- a decrease of electron density at the lower temperatures ($T < 4000$ K) in the presence of fluorine, due to the formation of F ions is expected; in the arc column it remains practically unaltered.
- at the temperatures above 2000 K, fluorine is present almost completely in the form of F-atoms. At the lower temperatures it forms some very stable compounds with the main components of the plasma (CF_4 , COF_2 and FNO , FNO_2 in the absence of carbon). It should be mentioned that these results are obtained with the free energy data available till 1976. The thermodynamical data are subject of permanent corrections (for example, C_2F_2 was predicted as the main component of a 1:1 C:F system [7]; however, with the latest free energy data [4] it should be much less

stable.) so that these results should be taken with caution. - calcium as the element with a relatively low ionization potential (6.11 eV) shows a larger influence than F on the electron density in the plasma, especially at the lower temperatures (Fig.1). At the Ca concentration of 10⁻³% and in

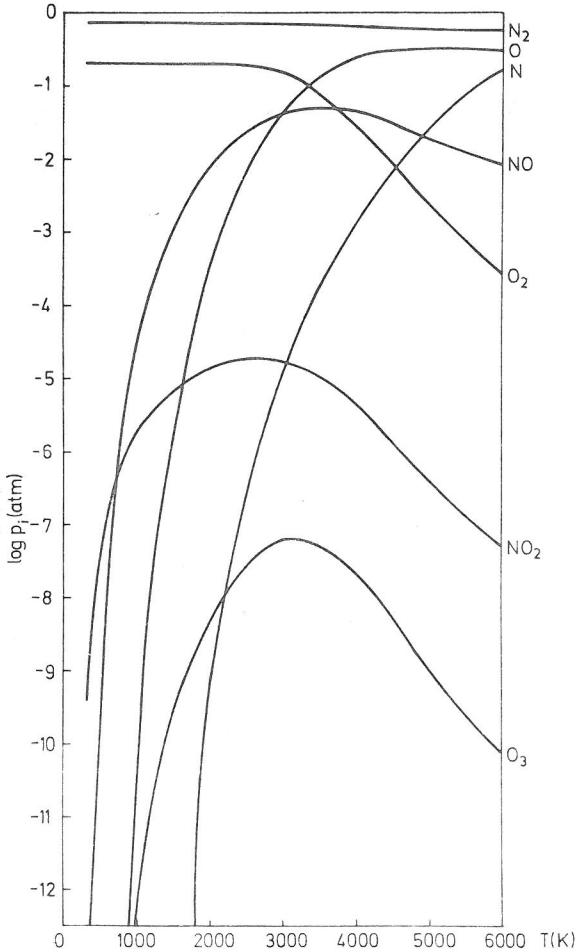


Fig.2. Partial pressures of the main components of the air plasma (N=79%, O=21%, C=0%)

the temperature region below ~ 4000 K a remarkable amount of the electrons is produced by the ionization of Ca, while at the higher temperatures, especially near the arc axis ($T \geq 6000$) the influence of Ca in this concentration on the electron density can be neglected. However, at 10⁻³% Ca, practically all electrons at the lower temperatures ($T < 4000$ K) are due to the Ca-ionization, and even at $T = 6000$ K the electron density is 1.5 times larger in the presence of calcium.

In Fig.5. the partial pressures of the various compounds including calcium are plotted as functions of the temperature. It is obvious that the addition of fluorine into the plasma should cause a great decrease of Ca, Ca⁺ and CaO concentrations at

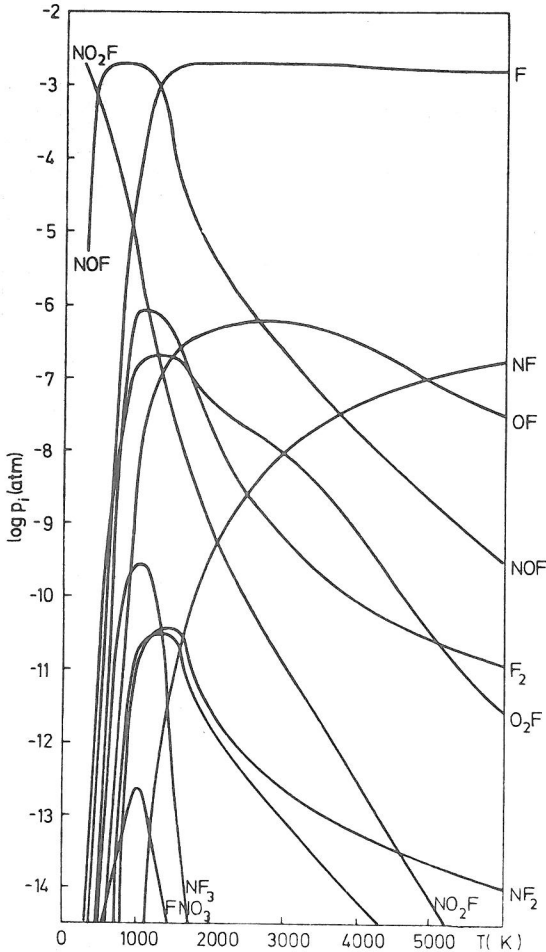


Fig.3. Partial pressures of the fluorine containing compounds of the air plasma (N=79%, O=21%, C=0%, F=0.1%)

the lower temperatures due to formation of CaF and CaF₂ molecules.

Although the calculations reported in this paper were made for the temperature and particle density ranges corresponding to a low current arc free burning in air between the graphite electrodes (the maximal temperature in such an arc is between 6000 and 7000 K and the concentration of carbon in the plasma does not exceed 10% [8], the results of these calculations can not be completely transferred to a real picture of the radial particle distributions in the dc arc plasma.

The partial pressure distributions for the Ca-compounds presented in Fig.5. correspond to a uniform distribution of the whole amount of calcium in the plasma, not taking into account the radial mass separations

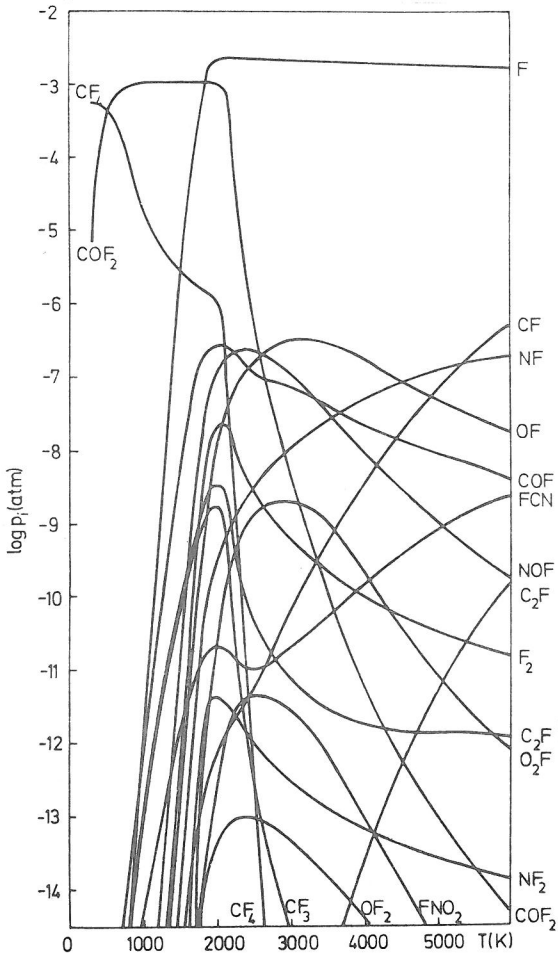


Fig.4. Partial pressures of the fluorine containing compounds of the the arc plasma (N=71.1%, O=18.9%, C=10%, F=0.1%)

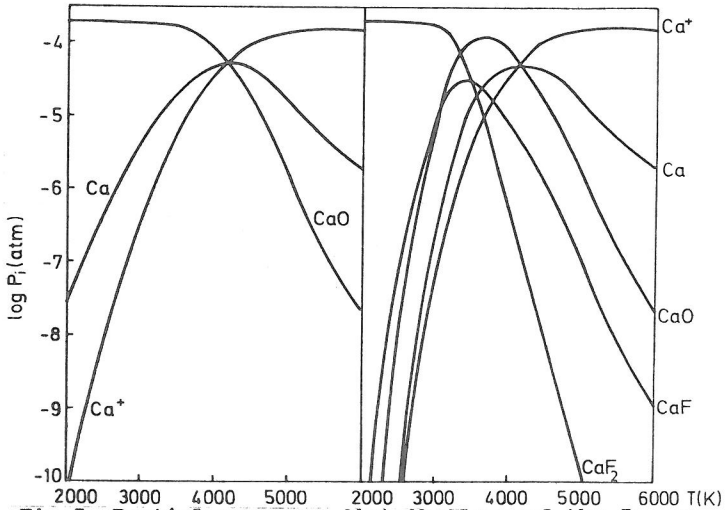


Fig.5. Partial pressure distributions of the Ca-compounds. a-in the air plasma without F; b-in the air plasma with 0.1%F.

effects [9], [10] causing a larger concentration of calcium in the colder arc zones. The predictions concerning the effect of added fluorine and calcium on the electron density (and in this way indirectly on the temperature) are in accordance with our experimental investigations [3].

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