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Expulsion of Plasma in A Gravitational Field

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Abstract

It is shown that a characteristic shape of the arc discharge in the air with a pressure of 0.1 atm is mostly caused not by action of forces of buoyancy, but expulsion of plasma in a gravitational field.

Keywords: gravitation, temperature, plasma, electric arc

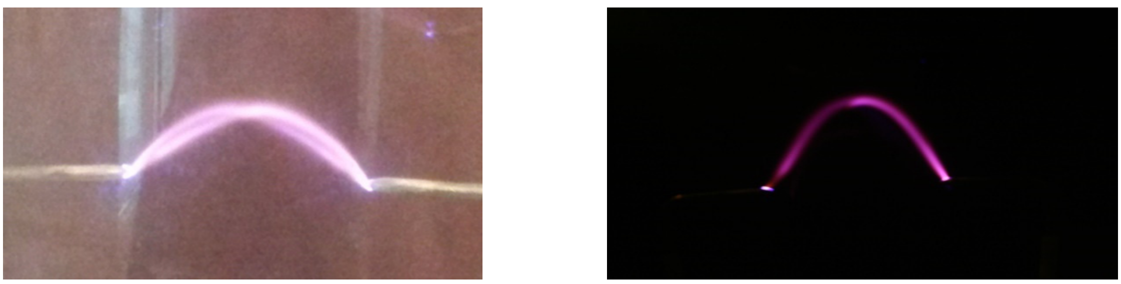
The electric arch has been known for more than 200 years. Effects of buoyancy, convection, air currents, influence of external electric and magnetic fields (Raizer, 1991) traditionally explain its characteristic shape. Experimentally proven influence of body temperature on its weight (Dmitriev, Nikushchenko, & Snegov, 2003; Dmitriev, 2008; Dmitriev & Bulgakova, 2013; Dmitriev, 2015) gives the grounds to consider a question of extent of impact of a gravitational field of the Earth on a shape of an electric discharge. High temperatures, till tens of thousands K, in the channel of a free electric discharge at low pressure of about 0.1 atm support it. Earlier, a little attention was paid to the matter and research of physical properties of "an arch" was, as a rule, conducted in discharge tubes or in special chambers.

The elementary theory of influence of absolute body temperature *T* on its physical weight *P(T)*, not connected with action of buoyancy, convection, thermal expansion and other artifacts, leads to expression

$$P(T) = P_0(1 - A\sqrt{T}) \qquad (1)$$

where *A* is the coefficient which depends on physical characteristics (density and sound velocity) of material of the weighed body and temperature *T* is more than temperature of Debye (Dmitriev, Nikushchenko, & Snegov, 2003; Dmitriev, 2008; Dmitriev & Bulgakova, 2013). From this formula, it is concluded that at rather high temperatures, exceeding $T_0=1/A^2$, the body weight is negative. This may be interpreted as "pushing away" ("expulsion") a body from the center of gravity (the center of the Earth). It is possible to estimate to what degree the specified effect influences the shape of the glow discharge by considering features of an electric arch in an alternating current.

The example of a photo glow discharge with air pressure of 0.1 atm, amperage range of 30-70 mA, voltage across the electrodes of 0.6-1.0 kV, frequency of current of 50 Hz, is shown in Figure 1.



a b

Figure 1. Arc discharge in alternating current in the air with the pressure of 0.1 atm. Exposition: a. – 33 ms, b. – 2.5 ms

During an exposition of 33 ms the two spatially divided discharges are recorded. Specific current direction lasting 10 ms (the half of period of fluctuations) corresponds to each discharge. Relative shift of trajectories of discharges is possibly caused by action of Lorentz force in a magnetic field of the Earth. Obviously, formation of an arch happens in time less or about a half-cycle of current fluctuations.

Assuming that the buoyancy force of ejection is the main reason for an arch shape of the discharge, we will estimate time of "emerging" of the hot channel of such discharge. The temperature and gasdynamic processes accompanying formation of an electric arch in the atmosphere are very complex. Nevertheless, the order of amount of time of emerging of an arch can be estimated approximately by the following elementary calculations.

Electric discharge will be presented as chains of the spheres of radius R filled with plasma with a density ρ_p. Force of ejection of such chain is counterbalanced by its weight and friction force. Stokes formula will be used to assess its value,

$$\frac{4}{3}\pi R^3\left(\rho_a - \rho_p\right)g = 6\pi\nu R u \quad , \tag{2}$$

where ρ_a - air density, g - acceleration of gravity, ν - viscosity of air, u - the average speed of emerging of a chain. Believing $\rho_a \succ\succ \rho_p$, time $t = h/u$ of emerging of a chain to a height h, equals

$$t = \frac{9}{2}\frac{\nu h}{gR^2(\rho_a - \rho_p)} \succ 4.5\frac{\nu h}{gR^2\rho_a} \cdot \tag{3}$$

Substituting the numerical values which closely correspond to experimental conditions in the right part (3) ($h \approx 1.6cm, R \approx 1mm, \rho_a \approx 0.1 \cdot 1.3kg/m^3, \quad \nu \sim 2 \cdot 10^{-5} kg/m \cdot s, g \approx 9.8m/s^2$),

we will obtain $t \succ 1s$; 1 atm corresponds approximately to 1.3 kg/m^3, and for viscosity which value increases with a temperature, the specified minimum value is chosen (Babichev, Babushkina, & Bratkovskii, 1991). The specified value t significantly exceeds time of establishment of the arc discharge (about 10 ms). Therefore, buoyancy (Archimedes force) is not the main reason of a peculiar shape of an arch.

Since in the presented experimental conditions the influence of slow convection streams of the rarefied air is insignificant, the given estimates provide the grounds to assume that the expulsion of plasma by a gravitational field of the Earth described by formula 1 is the main reason for a shape of an electric arch.

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