EFFECT OF AN ELECTRIC FIELD ON THE OSCILLATIONS OF A DIFFUSIVE FLAME

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The effect of an electric field on the amplitude of oscillations of an open laminar diffusive flame is analyzed on the basis of test results and a mechanism of this field action is suggested. Experiments have shown that the amplitude of flame oscillations depends on the magnitude of the electric current passing through the flame.

It is well known [1, 2] that, when the gas jet from the burner reaches a certain velocity, an open laminar diffusive flame becomes unstable and passes into the oscillatory mode. This phenomenon has been explained in [3, 4]. Such oscillations are suppressed by the action of an electric field. It is also known that an electric field suppresses the oscillations of a hissing propane flame [5, 6]. In both cases, however, not enough research has been done concerning the mechanism by which the electric field operates here. In this article the authors report some test data and discuss a possible mechanism by which an electric field acts on the oscillations of an open laminar flame.

The flames in our experiments were characterized by either a high degree of ionization (propane, $n \sim 10^{12}$ cm^{-3}) or a low degree of ionization (carbon monoxide, $n \sim 10^6$ cm^{-3}). The test apparatus consisted of two vertical plane-parallel electrodes and a burner 4 mm in diameter (for propane) or 9 mm in diameter (for carbon monoxide) between them with a metallic spout discharging gas at a rate of 3.8 cm^3/sec or 10 cm^3/sec, respectively. A positive or a negative potential was applied to both electrodes, while a potential of opposite polarity was always applied to the burner. Analogous experiments were also performed with an alternating electric field. A series of Schlieren photographs of an oscillating flame were taken with motion picture cameras "Kiev 16C-3" and "SKS-1M," then using a Tepler IAB-451 shadowgraph. A filament 0.08 mm thick held vertically in the focal plane of the viewing tube served as the Foucalt knife-edge. A UPU-1M device served as the high-voltage source.

The magnitude of the electric current passing through the flame [7] may serve as the measure of the mechanical effect on the flame behavior. The tests which have been performed here confirm this hypothesis. It is shown in Fig. 1 how the amplitude of flame oscillations varies as a function of the current passing through the flame (the amplitude of oscillations A was measured in relative units, as the ratio h/d). It

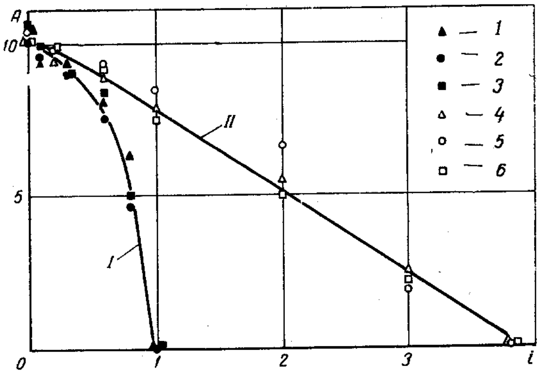

Fig. 1. Amplitude of flame oscillations, as a function of the electric current at various distances between electrodes. I) Electrodes grounded and burner under a high positive potential: 1) l = 12 cm; 2) 18 cm; 3) 31 cm; II) burner grounded and electrodes under a high positive potential: 4) l = 12 cm; 5) 18 cm; 6) 31 cm. Current i, μA.

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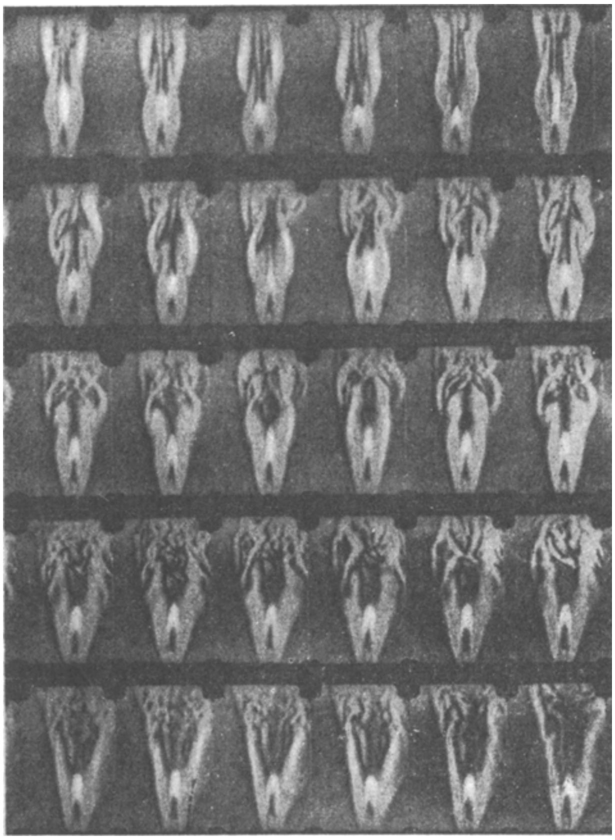

Fig. 2. Schlieren photographs of a propane flame changing as a result of an applied electric field. Film speed 64 frames/sec.

is evident here that, when the direction of the field remains constant, the amplitude remains the same at the same current, regardless of the distance between electrodes and regardless of their potentials. The rate at which the amplitude of oscillations decreases depends on the direction of the field. This is, evidently so, because the mobility of positive and negative ions is different. Since the electric field intensity is low in and around the combustion zone [7, 8], it is too weak to have an appreciable direct effect on the hydrodynamics in the flame proper. Significant changes are produced by an electric field within the layer of combustion products. In the presence of an electric field, both positive and negative ions [9, 10] acquire a velocity in a certain direction and subsequently transfer the mechanical momentum to the neutral gas particles, which generates perturbations in this layer. Schlieren-film frames of an oscillating propane flame, taken by a motion-picture camera and shown in Fig. 2, indicate the glow region of the flame and the layer of hot reaction products. In the absence of an electric field, the undular layer of reaction products remains laminar along the entire flame. When an electric field is applied and then increased (the field intensity in Fig. 2 increases from the top frame down), then the laminar layer of reaction products becomes thicker and, at the same time, a more intensive turbulence develops in its upper portion. In this case oxygen is supplied to the combustion zone through molecular diffusion as well as by local jets and whirls. This increase in the oxygen supply results in a higher combustion rate and thus in a reduced flame height. A further rise in the electrode potentials (which in turn causes a heavier current to pass through the flame) increases the amount of air sucked in and decreases the difference between "node" and "loop" widths in the layer of combustion products, until they become equalized at the outer edge. Oxygen is then supplied more uniformly over the entire flame length and the flame ceases to oscillate.

The degree of ionization is low in a CO flame ($n \sim 10^6$ cm^{-3}) and, therefore, an electric field has a weaker effect here on the flame oscillations. The electric current passing through the flame, up to the breakdown-voltage level, is small and an electric field does not always suppress the flame oscillations. When the degree of ionization is raised (by injecting fast-ionizing additives into a CO flame, by adding propane), an electric field will suppress the oscillations of a CO flame.

NOTATION

A is the relative amplitude of flame oscillations;
h is the amplitude of flame oscillations;
d is the diameter of burner;
l is the distance between electrodes;
n is the concentration of charged particles.

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