LETTERS TO THE EDITOR

NOTE ON THE APPEARANCE OF VORTICES IN VIBRATORY COMBUSTION

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The theory of steady propagation of a flame in a tube with a previously prepared combustible mixture predicts the excitation of circulatory motion of the stream near the flame front surface ([1], p. 217). Experiment confirms the existence of such motion ([1], p. 255). The stream of combustion products behind the flame front remains stationary, with approximately a Poiseuille-type velocity distribution. The formation of discrete vortices does not occur.

In vibratory propagation of a flame in a tube, the nature of the flow changes: discrete vortices appear in the stream of combustion products. So far two species of vortex have been observed experimentally: 1) boundary vortices—(Fig. 1, a), the stream being forced to flow in a loop between them; 2) egg-shaped vortices, occupying the whole section of the tube (Fig. 1b). It is clear that there is no translational motion of the gases at the moment of formation of the egg-shaped vortices. Both species of vortex exist only in association with oscillatory motion in the tube.

An investigation has been made in a number of papers of nonresonance vibratory combustion of diffusion flames of gaseous and liquid fuels [2, 3]. The experimental material obtained by the authors is evidence of the regular appearance of annular vortices alongside the combustion surface. Figure 2a, taken from [2], shows an instantaneous composite photograph of an oscillating flame (direct photography, matched with an interference picture). It is as if the flame split up along the axis, as a result of which each annular vortex appears in the form of a pair of plane vortices, symmetrically located relative to the flame.

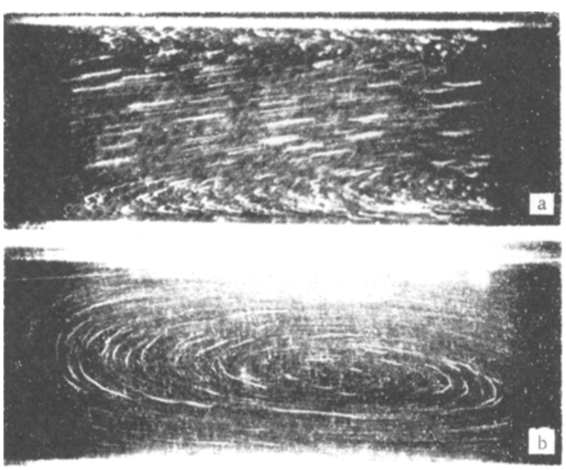

Fig. 1. Vortices in the combustion products in one of the sections of a vertical tube (a–boundary; b–egg-shaped). The flame is propagated from below upwards in the vibratory regime.

An even more interesting picture is observed under vibratory combustion of a thin jet of fuel gas in a tube. The combustion process here is specific for that found under the action of a standing acoustic wave. As the composite pictures show (direct photography combined with a schlieren picture), the flame is enveloped by a whole garland of annular vortices (Fig. 2b). The annular vortices are formed in the lower part of the flame and are displaced discontinuously upwards strictly in accordance with the period of the acoustic oscillations [4].

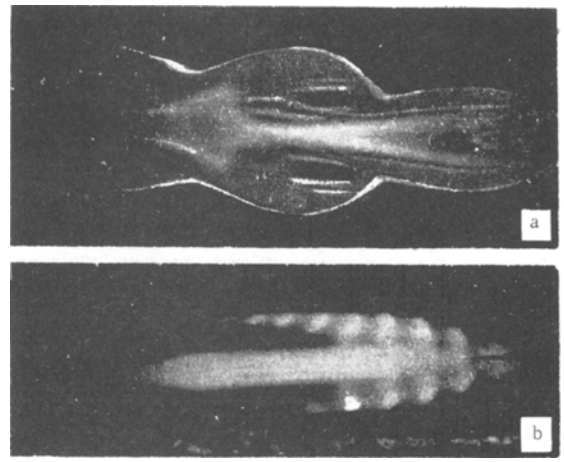

Fig. 2. Annular vortices in the combustion products of an open diffusion flame a) in the oscillatory regime, and of an enclosed difusion flame in a tube b) in the vibratory regime.

The examples presented show that a connection exists between vibratory combustion and the formation of discrete vortices. In [5], for example, such a connection was displayed in the case of vibratory combustion in a furnace.

One naturally attempts to explain the effects of intensification (improvement of combustion density and burning rate, and increase of heat transfer) which accompany vibratory combustion by the presence of periodic vortex formation.

Further study in this area would permit more definite identification both of the causes of the appearance of discrete vortices and of their influence on the nature of the processes associated with vibratory combustion.

REFERENCES

1. Combustion Processes [in Russian], FM, 1961.
2. A. I. Maklakov, Dissertation, KGU, 1955.
3. V. I. Blinov and G. N. Khudyakov, Diffusion Combustion of Liquids [in Russian], Izd. AN SSSR, p. 55, 1961.
4. V. N. Podymov, Dissertation, KGU, 1961.
5. A. Putnam and W. Dennis, Heat., Piping and Air Condit., July. 131–138, 1956.

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