Self-excited oscillations in cylindrical combustion chambers burning a homogeneous mixture are investigated theoretically and experimentally. It is shown that two low-order tangential-longitudinal modes differing slightly in frequency are excited in the model chamber. Judging from the closeness of the experimental and theoretical values obtained for the mass flow rate of the mixture at the self-excitation boundary, it is postulated that excitation is due to the dependence of chemical reaction rate on the pressure (temperature) of the medium.

The procedure used in the present study to analyze the high-frequency instability of the combustion process is based on the results of combustor model experiments [1] and involves small-scale model combustion chambers operating with a homogeneous gasoline-air mixture. Unstable combustion was investigated experimentally and theoretically in a chamber having cylindrical walls lined with acoustic absorbers.* The absorber effectiveness was assessed in the experiments on the basis of the acoustic self-excitation boundary plotted in the plane of the fuel-injection parameters, "percentage air excess versus mass flow rate of the mixture." The boundary separates the plane into domains of stable and unstable combustion. The most effective absorber is judged to be the one that minimizes the unstable combustion domain.

The model chamber (see the schematic diagram in Fig. 1a) includes a water-cooled nozzle 5 and water-cooled cylindrical sections 1. One of the sections is lined with an acoustic absorber 2, the length of which can be varied by means of heat-resistant spacers 6. This particular model makes it possible to preclude the influence of the cooling air for the absorbers on the unstable combustion boundary. The flame is maintained behind two V-shaped annular stabilizers 7, blocking off 70% of the chamber cross section. The temperature in the absorber cavity was measured with a Chromel-Alumel thermocouple 3, and the pressure oscillations in the chamber by means of three water-cooled tensometers 4 placed in the same cross section at a 90° angle relative to one another. The tests were conducted on model chambers with air cooling of the absorber. The air inlet line in this case is partitioned off from the absorber section by clusters of grids mounted in 16 connecting pipes spaced uniformly over the circumference. The absorber length (L_e) and distance from the absorber to the edge of the stabilizer (l_e) were varied within the following limits: 0 ≤ L_e ≤ 138 mm; 30 mm ≤ l_e ≤ 240 mm.

The principal geometrical parameters of the acoustic absorber include the permeability σ (ratio of the single-perforation area to the surface area associated with one perforation), the perforation diameter d_o, the thickness t_e of the absorber walls, and the distance h_e between the absorber and the casing wall of the chamber. Constant values of h_e = 10 mm and t_e = 1 mm were used in all the experiments. The experimental absorbers had the following parameters: I) d_o = 2 mm, σ = 0.03; II) d_o = 4 mm, σ = 0.03; III) d_o = 6 mm, σ = 0.03; IV) d_o = 8 mm, σ = 0.05; V) d_o = 4 mm, σ = 0.01; VI) d_o = 10 mm, σ = 0.05.

*Inasmuch as the excitation of pressure oscillations in full-scale combustors for liquid-fuel rocket engines and gas turbine engines has a destructive effect on the combustor components, any prolonged oscillation, even of relatively small amplitude, cannot be tolerated. It was decided, therefore, to assess the instability of the combustion process and the effectiveness of methods for its abatement on the self-excitation boundary.

The frequency response, i.e., the dependence of the absorption coefficient (ratio of the absorbed energy to the wave energy at normal incidence on the absorber surface) on the oscillation frequency, was determined experimentally (using the procedure and apparatus of Bruel and Kjaer A/S) and analytically (by the method of Blackman [2]) for each of the absorbers. The frequency responses of absorbers I–VI are given in Fig. 2a–f, respectively. The acoustic frequency f is plotted on the horizontal, and the absorption coefficient $\alpha_p$ on the vertical, axis. The curves and dots give the results of the calculations under the measurement conditions, and the dot-dashed curves give the results of the calculations under flame-test conditions (acoustic intensity level 180 dB; pressure 147.5 k Pa; temperature 293 K). The values of the