The method and results are presented for an experimental determination of the pressure distribution in short cylindrical and conical channels with cooled walls during the laminar flow of a compressible gas. A calculation of this flow is made using the simplified Navier–Stokes equations and the experimental and calculated pressure distributions are compared.

It was shown in [1, 2] that the laminar flow of a compressible gas in a long channel with a smooth contour can be described by the simplified Navier–Stokes equations corresponding in form with the boundary layer equations. The laws of similarity for this flow were also established in [2]. In [3], as a result of an analysis of experimental data on the start-up of cylindrical air intakes with allowance for these laws, the hypothesis was advanced that the laminar flow in a channel of relatively short length can also be described by the simplified Navier–Stokes equations. In this report, moreover, in order to create well controlled conditions in the entrance section of the channel being studied with a Mach number less than one in this section it was proposed to place the channel in a supersonic stream and using a choke located beyond the channel to provide that mode of flow for which the shock wave is located in the entrance section of the channel. A numerical (finite-difference) method of integration of the equations mentioned above was later suggested in [4] and calculations were made of the gas flow in flat and round channels with uncooled walls.

We have attempted to study experimentally and through calculation the flow of a compressible gas in short cylindrical and conical channels with cooled walls. (The results of [3], like [4], pertain to the case of uncooled walls.)

The experiments were carried out by the method of [3] and therefore a low-density wind tunnel in the working section of which a supersonic air stream was produced was used for their performance.

The nozzle of the tunnel was conical with a diameter of 5 mm at the critical section, an aperture half-angle of 22°, and a diameter of 19.3 mm at the exit section.

Since in the working range of pressures \(p_0\) in the tunnel forechamber the value of \(p_0\) markedly affected the parameters of the supersonic stream beyond the nozzle cut, before conducting the main experiments the longitudinal and transverse fields of Mach numbers of this stream were determined for different values of \(p_0\). The fields of Mach numbers were determined at the stagnation temperature \(T_0 = 576^\circ\)K since all the experiments were conducted at just this temperature.

The dependence on \(p_0\) of the distance \(X_{M=4.5}\) from the nozzle cut at which the same Mach number \(M = 4.5\) is attained was constructed from the longitudinal fields of Mach numbers. This was done in connection with the fact that the study of the flow in channels was designed to be conducted at a constant Mach number \(M_1\) at the entrance section of the channels. (We note that \(M_1 = 0.4236\) when \(M = 4.5\) in the case of the method used in [3].)
Fig. 1. Schematic diagram of model and choke chamber: 1) body of model; 2) coil; 3) drain openings; 4) thermocouple; 5) body of coke chamber; 6) tube for measurement of pressure in chamber; 7) choke.

The channels studied consisted of the inner channels of models which were placed in the supersonic stream of the tunnel in accordance with the method of [3]. The models with a choke chamber were placed on a mechanical vacuum coordinator.

A schematic diagram of the models and the choke chamber is presented in Fig. 1, where the direction of the stream impinging on the model is shown by an arrow.

Two models were used in conducting the experiments: the first with a cylindrical inner channel 6.37 mm in diameter and 20.50 mm long and the second with a conical inner channel with a diameter of 6.26 mm at the entrance section, a length of 20.55 mm, and a half-angle of taper of 0.25°.

The body 1 (Fig. 1) of each model was made of copper. The coil 2 through which water was circulated to cool the model was also made of copper and soldered to the body. Two drain openings 3, communicating with U-shaped manometers filled with silicone liquid, were made in the walls of each model. Thermocouples 4 were placed in special cavities at a distance of ~1 mm from the inner surfaces.

The drain openings served for the measurement of the static pressures \( P(1) \) and \( P(2) \) at the first and second measurement sections from the entrance, while the thermocouples served for the measurement of the wall temperature \( T_w \) which, like the temperature \( T_0 \), was kept constant and equal to 288°K in the experiments.

The pressures \( P(1) \) and \( P(2) \) which are attained with different \( p_0 \) when the shock wave is located in the entrance sections of the models were chosen as the experimentally determined values subject to later calculation. The method of determining these pressures, denoted below as \( p^* \), was based on the fact [5] that the movement of the shock wave downstream from the entrance section within the model is discontinuous and is accompanied by a discontinuous decrease in \( P(1) \) and \( P(2) \).

To determine \( P(1)^* \) and \( P(2)^* \) for some \( p_0 \) this \( p_0 \) and the air temperature \( T_0 = 576°K \) were first set in the forechamber of the wind tunnel. Then using the coordinator the model with a closed choke chamber 5 was mounted in such a way that its entrance section was located at the distance \( [x]_M = 4.5 \). After this the flow rate of the water cooling the model was regulated and the temperature of its walls was brought to 288°K. Then the choke 7 was gradually opened and the static pressures \( P(1) \) and \( P(2) \) in the first and second drain openings from the model entrance were measured, as well as the pressure \( P_p \) in the choke chamber using the tube 6. Then the