for forced convection problems. The calculations showed that the maximal error in the
determination of the local values of the composition of the mixture due to the use of the
approximate system of equations (1.1)-(1.4) does not exceed 5% for \( \varepsilon \ll 0.05 \), while the
computing time is shortened by more than an order of magnitude.

In the majority of cases of practical interest, the parameter \( \varepsilon \) takes values much
less than the given value. For example, for air at \( T_0 = 300^\circ K \) and \( L = 10 \) m, \( \varepsilon = 10^{-3} \),
while for hydrogen under the same conditions \( \varepsilon = 7.8 \times 10^{-5} \).

Thus, for the considered class of problems the system of equations (1.1)-(1.4) is
effectively as general as the complete system of Navier–Stokes equations but also pre-
serves the relative simplicity of the traditional Boussinesq approximation and thus sig-
nificantly extends the possibilities of theoretical analysis of unsteady free convective
flows.

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INVESTIGATION OF THE INFLUENCE OF THE UNIT REYNOLDS NUMBER
ON THE TRANSITION OF A BOUNDARY LAYER ON A SHARP CONE


To establish the influence of the unit Reynolds number on the transition of a
boundary layer on the side surface of a cone, the transition was investigated
on a model of a sharp cone with half-angle \( \theta = 7.5^\circ \) and lengths from 150 to
400 mm. The experiments were made in a shock tube at Mach number \( M_\infty = 6.1 \)
in the wide range of Reynolds numbers \( Re_{\infty L} = 1.3 \times 10^5 - 5.5 \times 10^7 \). The position
of the transition region was determined from the results of measurement of the
local heat flux by calorimetric thermocouple converters. Data were ob-
tained on the influence on the transition of the unit Reynolds number at
large values. It was also shown that under the investigated conditions the
base region does not influence the transition of the boundary layer on the
surface of the cone.

Numerous experiments have shown that the position of the transition region of a bound-
dary layer is not uniquely determined by the fundamental dimensionless numbers such as the
Mach number, Reynolds number, or the temperature factor. The position of this region on

Moscow. Translated from Izvestiya Akademii Nauk SSSR, Mekhanika Zhidkosti i Gaza,
geometrically similar bodies also depends on the absolute magnitude of the gas pressure or the "unit Reynolds number," the size and shape of the wind tunnel, and also its construction. Because of the instability of laminar motion at large Reynolds numbers, even small perturbations of various types have a significant influence on the gas flow both under test conditions on the ground as well as in flight conditions.

Some types of perturbation, for example, turbulence of the oncoming flow, were known and studied long ago. At supersonic velocities, the part played by perturbations of this type in wind tunnels is greatly reduced. Acoustic perturbations deriving from the turbulent boundary layer formed on the nozzle walls and in the working part of the tube acquire great importance. In [1] (see also the review [2]) Pate and Schueler established an empirical dependence of the transition Reynolds number $Re_t$ on the flow parameters and the dimensions of the wind tunnel, the dependence being based on the assumption that the acoustic perturbations that derive from the flow boundaries play a decisive role.

However, this picture contradicts the results of an investigation of the transition on cone models in air at rest in an aeroballistic range [3, 4]. The experiments showed that in the absence of any detectable flow perturbations the transition Reynolds number $Re_t$ increases with increasing air pressure.

One can put forward the following hypothetical explanation of the results obtained in the ballistic range: since they were made with models of the same length, the transition Reynolds number increased when the pressure was increased due to the fact that the transition region moved further away from the base region, which is a source of intense turbulent pulsations. The acoustic perturbations can propagate from the base region forward, against the flow, to the subsonic part of the boundary layer and along the wall of the model.

This hypothesis could be tested in a ballistic range in experiments with models of different length $L$ chosen using the condition $Re_{\infty L} = \text{const}$ (as the present work was being carried out, the idea of such an experiment was also proposed in [5]). Because of the lack of a possibility of making such experiments, an analogous investigation in a shock tube was made. Of course, in a shock tube one cannot achieve the same clean experiments as in a ballistic range, because of the acoustic perturbations from the surface of the nozzle and the influence of the support. Therefore, the conclusions of the present paper are not final.

The experiments made in the shock tube did not confirm the hypothesis of an influence of the base region on the transition of the boundary layer. During our work, we obtained data on the influence on the transition of the unit Reynolds number at large values of this parameter.

1. The model is shown schematically in Fig. 1. There are two features of the construction to note: the model consists of individual sections and its support is profiled. The sections are joined together in such a way that the steps on the surface of the model are small, of order $5 \mu m$. This reduces to a minimum the disturbance of the flow at the positions at which the sections are joined. To decrease the influence of the support on the gas flow in the base region, the diameter of the section of the support was made variable, decreasing as the tip of the cone is approached (see the broken line in Fig. 1).

To ensure strength of the model with minimal size of the support sections, the transverse forces exerted on the model by the flow at random angles of attack are transmitted to the support at two places — where the support is joined to the nose section.