SPACECRAFT UTILIZING THE LIFTING REENTRY TECHNIQUE

PART II

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Section I - Comprehensive Report

Section II - Annotated Bibliography

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ABSTRACT

This report (comprehensive report with annotated bibliography) is based on Soviet Satellite open sources published 1957-1964, although some earlier articles are included. It is the first in a series of reports reviewing theoretical studies in lifting reentry. Part I (Reentry and Recovery of Soviet Manned Space Vehicles) was published as ATD Report P-64-60 (29 October 1964) and dealt with descriptions of launchings, flights, and reentries of Vostok-type space vehicles. Part II comprises two sections: Section I--a comprehensive report, and Section II--an annotated bibliography. Although the two sections are bound in one volume, they are independently paginated and have separate tables of contents. Section I (62 pages) is a comprehensive review of sources on theoretical and experimental studies of problems in fields of space sciences, i.e., problems of lifting and ballistic hypervelocity flight, and atmospheric reentry techniques. There are four parts following the Introduction: Group A. High-speed aerodynamics and gas dynamics; Group B. High-speed aerothermodynamics; Group C. High-speed flight mechanics; Group D. Strength of flight-vehicle components (thin and sandwich plates and shells). A brief conclusion is given. In writing this report articles and monographs having a closer relation to the reentry problem and showing either an original approach to the problem or a new method applied to its solution were selected from the bibliography and used. Section II (304 pages) is an annotated bibliography containing 861 entries arranged by subject in a manner similar to Section I: Group A. Aeromechanics of high-speed flows (451 entries); Group B. Aerothermodynamics of high-speed flows (168 entries); Group C. Flight mechanics (53 entries); Group D. Strength of space vehicle components (175 entries); Group E. Miscellaneous (14 entries). Within each subject group, the entries are further arranged chronologically by year of publication and source. There are three appendices to Section II: Appendix A. List of Source Abbreviations, Appendix B. Glossary of Abbreviations, and Appendix C. Alphabetical Index of Authors and Associations.

ATD Report 66-34   1 April 1960

Surveys of Communist World Scientific and Technical Literature

SPACECRAFT UTILIZING THE LIFTING REENTRY TECHNIQUE

Part II. Review of Theoretical Studies in Lifting Reentry
(Report no. 1 in this series)

Section I - Comprehensive Report

Section II - Annotated Bibliography

ATD Work Assignment No. 52

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FOREWORD

The present document is the first in a series of
reports on atmospheric reentry. The report is based on
Communist World open technical literature available at
the Aerospace Technology Division in the Library of
Congress, covering primarily the period from 1 January
1957 to 31 December 1964. Some earlier articles (the
earliest of July 1942 to December 1956) have been in-
cluded.

Part I: Reentry and Recovery of Soviet Manned Space
Vehicles, published as ATD Report P-64-60 dated 29 October
1964, deals with descriptive aspects of reentry problems.
It covers the period between 1959 and 1964 and is based
mainly on general technical literature and articles in the
daily press of Communist countries on the launching of
Soviet space vehicles.

Part II: The present report (No. 1 in this series)
comprises two sections. Section I is a comprehensive re-
view of papers published in Communist World scientific
sources on theoretical and experimental studies relating
to the problems of lifting and ballistic hypervelocity
flight, and atmospheric reentry techniques. The materials
on which this review is based have been arranged according
to their content, as shown in the Table of Contents of
Section I. All the papers reviewed were selected from
Section II, which is an annotated bibliography containing
861 entries. The arrangement of this bibliography is as
follows: The entries are divided into groups according to
a fairly detailed subject matter breakdown (see Table of
Contents, Section II). Within each subject group, the en-
tries are further arranged chronologically by year of pub-
lication and source.

Both sections of Part II, the comprehensive review
and the annotated bibliography, are here bound in one vol-
ume, with a colored separator sheet between them. The two
sections are independently paginated: Section I thus
contains pages 1 - 62, and Section II pages 1 - 304. Appen-
dices A, B, and C, located at the end of Section II, con-
sist respectively of a List of Source Abbreviations, a
Glossary of Abbreviations, and an Alphabetical Index of
Authors and Associations.

This Report will be followed by Report No. 2 of
Part II which will also include ballistic reentry and will
have the same arrangement as Report No. 1. It will contain
information published on the topic in the Communist World
during 1965 and the first half of 1966. The entries in
the annotated bibliography in Report No. 2 will be numbered,
starting with No. 1001.

SPACECRAFT UTILIZING THE LIFTING REENTRY TECHNIQUE

PART II

Section I - Comprehensive Report

ATD Work Assignment No. 52
(Report no. 1 in this series)

SECTION I

COMPREHENSIVE REPORT

TABLE OF CONTENTS

INTRODUCTION

The fields of science pertinent to the technology of the lifting reentry can be divided into the following prinicpal groups:

A - High-speed aerodynamics and gas dynamics, including rarefied-gas flows and design of minimum-drag bodies;

B - High-speed aerothermodynamics, including kinetic heating, injection cooling, and ablation shielding;

C - High-speed flight mechanics, including orbital and reentry mechanics, flight dynamics, oscillatory motion of flight vehicles, and meteorite hazards;

D - Strength of space vehicles, i.e., dynamic and thermal stress analyses of their components, mainly thin (solid, and sandwich-type) plates and shells

A more detailed breakdown of these groups can be found in the table of contents of this comprehensive report.

The articles and monographs having a specially close relation to the problem of reentry and showing either an original approach to the problem, or a method of its solution have been selected from the annotated bibliography and used in writing this comprehensive report. Kinetic heating with subsequent radiation, dissociation, ionization, and recombination processes in the air flow, and ablation and sublimation of the vehicle material are widely discussed topics related to the elements of the reentry process.

When reviewing the Soviet-Bloc literature one gets an impression of even more thorough discussion of topics associated with protection against the kinetic heating — porous cooling, ablation shielding, and thermal insulation — than of the kinetic heating itself.

Considerable attention is also given to problems in high-speed flight mechanics (see group C in the table of contents). The open scientific and technical literature associated with lifting-reentry elements leaves one with the impression that the scientists and engineers of the Soviet Bloc are capable of developing methods which will result in advanced reentry techniques.

The term "flight vehicle" is used in its broadest sense and includes spacecraft (space vehicles) and aircraft. The term "aircraft" encompasses airplanes, rockets, etc.

Group A. HIGH-SPEED AERODYNAMICS AND GAS DYNAMICS

1. Lift and Pressure Distribution

The distribution of lift and pressure over bodies in high-speed gas flows are very important to an aircraft designer. Around 1955 there were two methods for determining the pressure distribution over bodies of revolution: 1) a method of linearizing the equations of motion, and 2) a method of characteristics. At that time A. A. Dorodnitsyn proposed a new method [269], based on approximate integration of equations of axisymmetric flow characteristics, which is applicable for small and large Mach numbers. The pressure distribution over an axisymmetric arbitrarily shaped body and other parameters in a plane-parallel supersonic flow with a detached shock wave are discussed in detail by O. M. Belotserkovskiy [282], who presents a critical survey of previous studies and various approaches to this problem. A mixed turbulent flow of a compressible gas in the region between the shock wave and the surface of the body is analyzed as well as the boundary-layer characteristics in that region. A computation method (based on Dorodnitsyn's method of integral relations) of reducing the problem to a numerical solution of an approximating system of ordinary differential equations is introduced so that the final results can be obtained with a desired degree of accuracy by using electronic computers. The parameters of a flow with a detached shock wave at $M_\infty = 3.0, 4.0,$ and 5.0 past a circular cylinder are computed, and the results are presented in tables and diagrams.

The pressure distribution above airfoils in supersonic and hypersonic airflows has been investigated by E. Carafoli [387]; he gives some practical considerations in deriving a solution for a large range of Mach numbers from $M = 1$ up to the Newtonian region ($M_\infty \to \infty$). Expressions for pressure coefficients in flow behind a shock wave and for the Prandtl-Meyer expansion are derived and used for determining the aerodynamic characteristics of an airfoil (e.g., lift, moment, wave-drag coefficients).

The lifting force in rarefied-gas flows at hypersonic speeds is discussed in [124], and it is shown that the lift of large bodies (wedge, cone, etc.) at hypersonic speeds and arbitrary Knudsen numbers can be negative at any angle of attack between 0 and 90°. It is proven that this statement is applicable to a hypersonic flow of a continuum past bodies when the pressure distribution over the body can be determined by the Newtonian flow theory.

The qualitative analysis of slip-flow effects (the order of values of velocity and temperature jumps at the walls of a body) in a slightly rarefied-gas flow is presented in [205]; the effects of interaction and slip on flow parameters (friction, pressure) in a flow past a thin wedge are discussed, and the applicability of the boundary-layer theory is considered. The effect of velocity and temperature jumps on the heat transfer between the body and the heated basic portion of the boundary layer (where the temperature is proportional to the squared Mach number at infinity) is examined. The atmospheric entry of a space vehicle is the final and most formidable problem for a spacecraft returning either from

travel in space or from orbiting. An attempt to determine the effect of thermal radiation on the entry parameters is made by applying the relationships which are used in determining the parameters of a gas heated by a shock wave in a hypersonic flow past a slender body.

The solution of the entry problem of a slender body moving at high hypersonic speeds into the dense layers of the terrestrial atmosphere is presented in [427]. It is shown that radiation greatly influences the temperature and density distribution in the flow, whereas the pressure and velocity are less affected; numerical results of a calculation of the radiation effect on the flow parameters are presented in tables and diagrams.

The hypersonic similitude of temperature profiles in bodies during atmospheric entry at high velocities is discussed in [585]. The similitude conditions are examined, and it is found that the temperature profiles on the greater part of the entry trajectory (so long as the velocity is tically constant) can be determined by only one parameter. The effects of radiatvve heat excnange (with Sun, Earth, etc) and aerodynamics heat flow are examined, and the similitude parameters of temperature profiles in the presence of mass ablation, taking into consideration physicochemical transformaitons in the body material, are determined and discussed.

2. Radiation, Dissociation, Ionization, and Recombination Processes in Gas Flows

With the increasing kinetic heating of a gas, the processes of radiation, dissociation of molecules, and ionization and recombination of atoms take place in it, which affect the gas-flow parameters in many ways. The hypersonic flow of a radiating gas behind a shock wave in the vicinity of the stagnation point of a blunt body is studied in [133] taking into consideration the absorption process; the effect of the radiation (most essential in this region because of high temperatures and low velocities) on the flow parameters is investigated. The dependence of the extent of the radiation influence on the absorption coefficient and the optical thickness of the shock layer, as well as on the geometric parameters of the body, results in the effect of radiation growing with increasing absorption coefficient and body dimensions, and diminishing with increasing optical thickness of the shock layer.

The study of the dissociation process behind a shock wave facilitates the analysis of transient processes in perfect gases. The nonequilibrium dissociation of a two-component gas mixture, consisting either of two diatomic or one diatomic and one monatomic gas is analyzed in [137], and the results of a numerical calculation of process parameters (temperature, density, width of the relaxation region) for an oxygen-argon mixture at $M_\infty = 10.2$, $p_\infty = 10$ mm Hg, and $T = 298^\circ K$ are discussed and illustrated by diagrams. When air passes through a very strong shock wave, it acquires a plasma state, and the processes of atom ionization and recombination take place in it. An analysis of these processes is presented in [541]. Formulas are derived for the coefficients of ionization by electron impact in the hot air from all energy levels, and for the coefficients of recombination (in cases of recombination with emission of a quantum of radiation, and as result of a three-particle collision) by using the hydrogenic approximation. The application of these formulas to the ionization and recombination of complex atoms is discussed, and an expression for a correcting factor (for the ionziation coefficient) taking account of the multiplicity of the atom is given. The variation of the parameters of a gas passing through a strong shock wave and the equilibrium behavior of the gas behind the shock are discussed in [94], using the equations of state conservation and relaxation as the initial ones. From an approximate solution of these equations (assuming a constant heat capacity), the width of the nonequilibrium-dissociation region is determined, as well as variations of gas parameters (e.g., density, temperature), in the equilibrium state and during the relaxation process. The gas-dissociation processes in the boundary layer at hypersonic velocities with $M > 10$ have a noticeable effect on friction and heat exchange. Analytical expressions for the laws of friction and heat exchange in a turbulent boundary layer of a dissociated gas derived in [578] are based on the limit-law theory and, therefore, do not contain (at least for large Reynolds numbers) any empirical constants. The comparison of numerical data concerning a certain friction parameter computed by using the formulas derived with data obtained by W. Dorrance (ARS Journal, v. 31, no. 1, 1961) shows satisfactory agreement.

3. Boundary Layer

Considerable attention is paid by Communist-World scientists to the investigation of plane and three-dimensional boundary-layer problems. Knowledge of the boundary-layer structure and properties is very important because the transport phenomena between the fluid flow past a body and the body surface are confined to this thin layer of gas. The study of a compressible boundary layer (at large velocities) is of especially great importance because of a considerable temperature increase due to frictional heating. An analysis of the parameters of a two- and a three-dimensional, compressible, turbulent, boundary layers over an arbitrarily curved surface is presented in [155], on the assumption that there are neither longitudinal nor transverse pressure gradients. Simple formulas are given for calculating the heat exchange on the faces and the surface of pointed and blunted cones under a given angle of attack (with regard to the shock curvature), and on a cylindrical surface in a slip flow.

The hypersonic similitude is an important tool in studying the hypersonic-flow problems, and has been considered in Soviet technical scientific literature by G. G. Chernyy, V. V. Lunev, and others. The similarity of two hypersonic flows which differ in scale is established by the intensity of nondimensional parameters and functions characterizing the flows. These similitude conditions are investigated in [389] for hypersonic flows past plane and axisymmetrical slender blunted bodies having on their surfaces turbulent boundary layers with variable entropy along their outer boundary. This boundary layer is developed within an inviscid highly turbulent high-entropy layer formed in the gas which passed through a section of an oblique shock wave near the stagnation point; the high-entropy layer has a high temperature and low density, so that the pressure is assumed to be constant. Equations of momentum and energy of the turbulent boundary layer are used in integral form together with empirical formulas to derive expressions which describe the similitude conditions investigated. A hypersonic-similitude law based on these expressions is formulated which states that the hypersonic flows past slender blunt bodies with a turbulent boundary layer will be similar if certain of their (enumerated) flow parameters and functions are correspondingly identical. The application of these similitude conditions to flows past bodies whose form is described by a power function, and to a laminar boundary layer is discussed.

The effect of thermal radiation and absorption on the parameters of the boundary layer is investigated in [73] by using a general system of equations of gas dynamics, taking radiation into account, for a laminar boundary layer, on a plate, and the solution is obtained (assuming the viscosity law $\mu\rho$ = const where μ is the viscosity coefficient and ρ - the density) in the form of a series in terms of two nondimensional parameters determining the radiation effect on the boundary layer; expressions are derived for the radiation flux into the plate, the velocity profile, and the skin friction.

Simplifications in boundary-layer analysis in plane and axisymmetrical flows of a radiating gas over surfaces like a double-wedge airfoil or a flattened nose of a body of revolution are discussed in [239]. Conditions are established under which certain simplifying assumptions (such as neglect

of some radiant-energy flux components) can be used, greatly reducing calculation without sacrificing accuracy. The wall temperature is assumed to be equal to that of the gas at the stagnation point, as in case of sublimation.

An interaction between a viscous radiating gas flow and the surface of a body at very high hypersonic speeds is examined in [163]. Computation results for conditions behind the normal shock at certain atmospheric-entry speeds (up to 10—15 km/sec), altitudes (up to 70 km), and temperatures (up to 20,000°K) are shown graphically and compared with the phenomenon of a steady gas discharge under high pressure.

The determination of the drag-velocity relationship in a turbulent boundary layer on a plate in a gas flow is discussed by using the Kármán boundary-layer equation and assuming a constant friction stress over the layer [364]; it is shown that the Kármán theory on the drag of a plate in an incompressible fluid can be easily generalized to gas flows with large Mach numbers. The results of the analysis are illustrated in diagrams by curves showing the dependence of a nondimensional friction coefficient on the Mach number values up to $M_\infty = 10$.

The flow of a compressible fluid in a steady turbulent boundary layer is examined in [437]; the velocity profile in the layer is determined, and the relationship between the friction stress on the wall and the thickness of the boundary layer is established for a thermally noninsulated wing and an axisymmetrical body.

The same problem in the case of accelerated or retarded motion, when an unsteady turbulent boundary layer is formed, is discussed in [323]; the variation in the location of the separation point is analyzed, and the effect of drag is evaluated. The boundary-layer parameters in sections close to the stagnation point are of special importance, particularly when the gas reacts chemically with the material of the body.

The equations of a laminar boundary layer at the stagnation point of a blunt body are used in calculating the parameters of a multicomponent boundary layer in the presence of chemical reactions on the body surface [152]. The burning of a body consisting of many elements (various carbon, oxygen, and hydrogen compounds) in a high-temperature air stream is analyzed, and the rate of burning and the surface temperature are determined. The burning of a graphite body is discussed briefly.

The problem of cooling the surface of a porous body by injecting a chemically active or inert fluid through its walls is often discussed in Soviet literature, in connection with the effects of gas injection on such physical properties as the heat exchange and skin friction in the mixture on the plate surface.

The laminar boundary layer characteristics on a porous plate in a gas flow with a fluid injected into the layer in the presence of chemical reactions are analyzed in [158]. The effect of chemical reactions on the heat and mass exchange is investigated, and the dependence of friction stresses, and thermal and diffusion fluxes at the wall on a nondimensional

fluid-injection parameter and the Mach number of the flow are established. The approximation and generalization of results obtained is used in deriving the engineering formulas which can be used in determining the necessary amount of coolant for porous cooling at a given surface temperature, the rates of burning, and the sublimation of the body material.

A laminar boundary layer on an axisymmetrical, blunt body moving at a high supersonic speed is examined in a steady flow at the stagnation point where the pressure and temperature conditions provide for phase change or evaporation [141]. The high temperature in the boundary layer allows the presence of chemical reactions. A numerical sample analysis is made for an oxygen flow past a graphite body with equilibrium chemical reactions in the boundary layer.

A steady flow of a binary gas mixture in a laminar boundary layer on a surface which causes a weak transverse mass flow (e.g., a porous or evaporating surface) is studied [130]; the physical properties of perfect-component gases are different, and their specific heats are independent of temperature. A general case is treated when the free-stream velocity and surface temperature are time-dependent, and the law of dependence of transfer coefficients on temperature is arbitrary. The equations of a two-component boundary layer are transformed into a system of three second-order nonlinear differential equations of the same form, which are reduced to a system of three linear differential equations. For integration of these equations, a certain method of linearization, called "the method of straight lines" is used. As an example the boundary-layer and gas-injection parameters in a gas flowing past a porous plate are discussed, and results of a numerical evaluation of a uniform injection of hydrogen into a boundary layer of air are presented in diagrams.

Suction of the boundary layer can be used to increase the flying range of winged aircraft. The optimum bleed on a porous plate in an incompressible gas flow over a plate is discussed in [204]. The optimum bleed means such a distribution of the normal velocity component on the plate surface such that the local Reynolds number in every boundary-layer cross section is equal to its lower critical value; a porous plate is one on whose surface the normal-velocity component is distinct from zero. Coefficients of laminar friction and the local and total amount of gas bleed are determined for the optimum-bleed conditions.

A laminar boundary layer consisting of two separate phases - liquid and gas - is analyzed in [191]. The liquid phase is formed on the surface of a body in a stream of gas by surface melting or by injecting a liquid through its pores. The densities of both the liquid and the gas are constant, and their physical properties are independent of temperature. Partial differential equations with boundary conditions for the flow of each phase and on their interface are given as well as their solutions. The interrelations of variations in the flow velocity, the rate of liquid-phase forming, and body-surface conditions are discussed. The second approximations in solving the problem of a laminar boundary layer on a plate under various conditions (e.g., constant Prandtl number and parameter $K = \rho\mu$ where ρ - is density, μ - viscosity conditions) with equilibrium dissociation taken into account

are derived in [89] for a thermally insulated plate and for a plate with a prescribed surface temperature. A numerical analysis of the boundary layer on such a plate for M_∞ = 10, 20, and 30 is presented, illustrated by diagrams showing the dependence of layer parameters (layer thickness heat content, velocity variation) on M. The error induced by assuming that K = const is pointed out.

4. Shock Waves

The study of shock-wave phenomena and relationships, and irreversible changes in gas and flow parameters in passing through a shock wave, e.g., decreases in velocity associated with increases in pressure, density, temperature, entropy, etc., are of vital importance in the kinetic heating, stagnation-point flow, and boundary-layer parameters.

A longitudinal, supersonic, gas flow past a body of revolution or a symmetrical airfoil with a forward detached shock wave of large curvature has been discussed in [250], and the effects of viscosity and heat conductivity of the gas (usually neglected in flows with shock waves of a smaller curvature) on the parameters of the flow behind the shock wave (flows have large velocity and pressure gradients in this case) are investigated. The continuity, impulse, and energy equations are used to describe the relationships between characteristics on both sides of the shock wave. The formulas of the temperature and pressure ratios ahead of and behind the shock wave are given, and the change of these parameters in the case of a perfect gas and their dependence on the Reynolds number are pointed out.

The dependence of the curvature of a shock wave on the curvature of the outer surface of an annular body of revolution in a supersonic gas flow is mathematically analyzed in [268]. A flow is considered when there is no bow shock wave in front of the whole body, and an oblique shock surface is attached to the leading edge of the body. The author comes to the conclusion that the law of dependence of the curvature of a shock wave on the sum of curvatures of the body and of the streamline in a conical flow is analogous to ₋ne law of dependence of the shock-wave curvature on the curvature of an airfoil in a plane-parallel flow.

The effect of the transverse curvature of a convex (cylinder) or concave (channel) surface on the turbulent-layer parameters in a high-speed flow in the presence of heat exchange is investigated in [200] for various Reynolds and Mach numbers and various values of certain temperature parameters, assuming that the molecular and turbulent Prandtl numbers are distinct from unity, the viscosity and heat-conductivity coefficients are independent of pressure (but dependent on temperature), and c_p is constant (c_p - is the heat capacity under constant pressure). Equations of an averaged steady gas motion in an axially symmetrical turbulent boundary layer without a longitudinal pressure gradient, and the equation of state are used in determining the temperature distribution, the velocity profile, and the drag law in the boundary layer. The results of computing the boundary-layer parameters and evaluating the surface-curvature effects for a cylinder (at $M = 0$ to 10, $Re = 10^4$ to ∞, and $T_w/T_r = 0.2$ to 1.0) and a channel ($M = 0$, 0.5, 1.0; $Re = 10$; and $T_w/T_\delta = 0.2$, 1.0, 2.0) are discussed and compared with experimental data in a number of diagrams. Here T_w is the wall surface temperature, and T_r and T_δ are the temperature of the outer boundary-layer surface for the cylinder and the channel, respectively.

The propagation of unsteady shock waves is investigated in [58] by an approximate method in which the equation of the state of the medium $p = p(V)$ (where p is the pressure and V, the volume) is replaced by a broken line $p = -A^2V + B$ (where A and B are constant along a segment); by

reducing the length of the straight segments, the desired accuracy in determining the wave parameters can be obtained. The propagation and reflection of a plane unsteady shock from a rigid wall is analyzed.

The propagation of an explosion shock wave is investigated in [78] by applying the method of integral relations to the total energy of the moving gas and using the piston-theory technique. An expression is derived from which the law of the shock-wave propagation and the pressure can be determined. The exactness of propagation-rate and pressure functions obtained is discussed for the piston expanding at a constant rate, and according to a power-law function; the case of a strong explosion is also analyzed. By using the law of plane sections (equivalence principle), the shape of the shock wave formed in a hypersonic flow past an airfoil or a body of revolution can be determined as well as the pressure distribution over the surfaces of these bodies, even in cases when their noses are slightly blunted.

The gas flows with plane, cylindrical, and spherical waves, induced by the propagation of a strong shock wave in a gas at rest, are studied in [119] by using the method of integral relations and the piston analogy in determining the gas parameters and motion. The application of some versions in using this method is discussed. In one version it is assumed that the pressure and velocity of all gas particles between the shock wave and the piston are identical, i.e., they depend only on time. The equations of conservation of mass, momentum, and energy are used as initial ones, and approximate results obtained show fair agreement with those of an exact solution. In another version, the self-similar solutions are applied by introducing in formulas for mass, momentum, and energy of the moving gas additional constraints which exist between these quantities in self-similar motions under like conditions. The procedure is outlined for determining the gas and shock-wave propagation parameters, which requires much computation. In a third version, the method of a "shock layer" is applied, in which the approximate distribution functions of velocity and pressure are used in the form of expansions in powers of a parameter characterizing the ratio of gas densities ahead of and behind the shock wave. An expression for determining the law of shock-wave propagation is derived. The problem of a detonation with the initial pressure taken into account, and of an unstable source of a gas flow in a compressible gas are discussed. The latter problem is encountered in studying the operation of shock tubes with a divergent nozzle.

Plane and axisymmetric gas flows with strong shock waves having a power-function shape are discussed in [82]. The high-entropy portion of the flow adjacent to the surface of the body carrying the shock is investigated, and it is shown that a correction in thickness of the high-entropy layer is necessary if exact solutions of unsteady self-similar gas motion are to be used in solving the corresponding high-entropy flow problems A method is presented for introducing such a correction, and for constructing the shape of the body for whcih the pressure distribution was determined by means of the small-disturbance theory.

A longitudinal supersonic gas flow past a slender pointed body of arbitrary cross section is investigated in [353], and the location and intensity of the front shock wave are determined by an asymptotic formula

- 11 -

based on methods previously developed by the author (PMM, v. 25, no. 3, 1961); it is assumed that the whole body is within the Mach cone constructed for the undisturbed flow and has its apex at the stagnation point of the body. It is discovered that the bow shock wave is a circular cone, close to the Mach cone, with the axis parallel to the flow direction.

The self-similar reflection of a plane shock wave is discussed and the relative position of the incident, reflected, and Mach waves investigated in [240]. The strength of a Mach wave at the wall is determined, and it is shown that a Mach wave cannot propagate either far ahead of or far behind the incident shock wave. The configuration of waves in the Mach reflection from a rigid wedge is analyzed. An expression for the reflection coefficient is derived, and the regular reflection is compared with the Mach reflection (in a triple point at a certain distance from the wall where the incident, reflected, and Mach waves intersect).

A simultaneous solution of systems of hydrodynamic equations (conservation of mass, momentum, and energy), and equations of state and relaxation is used in determining the distribution of vibrational energy of air molecules N_2 and O_2 behind a normal shock wave in the air [243], assuming that there is an equilibrium distribution of energy in translatory and vibratory degrees of freedom, and disregarding the dissociation, electron excitation, and ionization processes. In discussing the vibrational relaxation, the vibrational energy is related to a unit of mass (one r. le). Results of computation for shock-wave velocities corresponding to M = 5, 9, and 20 are discussed and illustrated by diagrams.

A supersonic flow of a chemically reactive inviscid gas with rectilinear streamlines behind a plane-front oblique shock wave is discussed in [135]. A system of equations describing the flow, equations of kinetics with intital conditions, the equation of state, and relationships between density, velocity, and enthalpy of the gas mixture are used to derive expressions for the locity and temperature variations in the flow direction behind the shoc' in terms of concentrations of the mixture components. The cases when the flow behind the shock wave is subsonic or supersonic are discussed, and the formulas obtained are applied to determining the parameters of shock waves in the air.

5. Minimum-Drag Bodies

The problem of determining the shape of annular bodies of revolution with minimum wave drag on the outer surface is solved in the framework of the linear theory in [267]. A simple explicit formula for a minimum-drag body is obtained under the assumption that the inner and outer flows past the body are independent of each other. It is shown that the drag does not vary substantially with the variation of geometric parameters of the body (in a reasonably practical range) if there are two unchanged initial cross sections (e.g., at the faces). Therefore, the derived drag formula can be accepted as a general law of drag. The drag coefficients of the rear part of a barrel-like body (tail part of a fuselage) are discussed, and numerical values calculated for M = 2.0 and 3.0 are shown in diagrams for bodies of various slenderness.

The problem of determining the shape of a minimum-wave-drag body of revolution is also given in [280] by using a variational approach. The solution of the variational minimum-drag problems is discussed in cases of a turbulent flow past a body of revolution with a given shock-wave shape, and past a plane body.

The problem of designing a generatrix for a body of revolution having minimum wave drag for the given velocity of the oncoming flow and coordinates of two points on the generatrix is presented in [339]. Cases when there is an attached oblique shock wave are discussed, using variational methods. The problem is a degenerate one and is solved by means of the calculus of variations for a particular given velocity of flow and geometric parameters. The computed drag coefficients for various coordinates of points on the generatrix and Mach numbers up to M = 5 are fiven in a table and are illustrated by diagrams.

The determination of the shape of an annular minimum-drag body in a axisymmetrical hypersonic gas flow is discussed in [340], under the condition that the pressure must be non-negative everywhere on the surface. The problem is discussed, using the calculus of variations, and expressions are derived for determining the drag coefficient, the coordinates of two points of the generatrix, and the optimum body contour. Results of numerical calculation of several optimum shapes are presented in a table and in diagrams.

An attempt to formulate and solve the problem of determining the optimal minimum-drag shape of a three-dimensional slender body in a hypersonic gas flow is presented in [218]. The initial expression for the drag coefficient is taken in such a form that the optimum shapes of the meridional section and of the cross section of the body can be determined separately. The first problem was determined long ago, so only the optimum cross-section shape is discussed. A variational problem is formulated, and expressions for determining the shape parameters and the drag coefficient C_x are derived. The optimum cross section determined is star-shaped, as shown in Fig. 1, and the variation of the drag-coefficient ratio C_x/C_x^o with the cross-section S/r^{o2} is plotted in a diagram (Fig. 2) (C_x^o is the drag coefficient determined for an equivalent Newtonian optimum shape of a body of

revolution and n is the number of chines.) The results obtained can be used in determining the minimum-drag shape of a body shown in Fig. 3.

Fig. 1.

Fig. 2.

Fig. 3.

The wave drag of axially asymmetrical bodies in the form of a pyramid with a star-like cross section is discussed in [319]. The faces of the body have the shape of stream surfaces of flows behind the plane shock waves and their edges correspond to the lines of intersection of these shock waves. Formulas are presented for determining the geometric characteristics of these bodies, and the pressure and wave drag for given speeds (each Mach number is associated with a certain shape). In a diagram the pressure coefficients (wave drag) of pyramidal bodies and of equivalent circular cones are compared. The problem discussed in [319] is developed further in [110]. As exact solutions for the configuration of lift-producing bodies, the cutouts from stream surfaces of flows behind one attached plane shock wave, and behind two intersecting plane shock waves are used. Because the pressure on such surfaces is constant and equal to the pressure on a plate behind a plane shock wave, the problem of determining the pressure and lift on a plate in a hypersonic flow is discussed in the first part of the article. In the second part, the exact solutions are given for a V-shaped wing (Fig. 4) formed by two intersecting planes (in the case of one shock wave), and a pyramidal body (Fig. 5) with a V-shaped cross

Fig. 4.

1 - Leading edge; 2 - intersection edge; 3 - undisturbed-flow velocity vector.

Fig. 5.

1 - Intersection edge of the body; 2 - body faces; 3 - wing faces; 4 - wing leading edges; 5 - wing trailing edges; 6 - base-parallel section; 7 - undisturbed flow velocity vector.

section (in the case of two shock waves). Both bodies have a delta shape with leading edges running along shock-wave boundaries. Formulas for the

lift and drag coefficients are derived and the interdependences between the geometry, lift and drag, and shock-wave parameters are discussed and illustrated with a number of diagrams. The wave drag (the surface pressure) of bodies with two plane shock waves can be infinitely reduced by a proper selection of their shape, thus making the whole drag significantly smaller than that of a wedge; the comparison of the drag of proposed shapes with that of a wedge at altitudes of 35, 45, and 55 and M = 6 is presented graphically and is discussed.
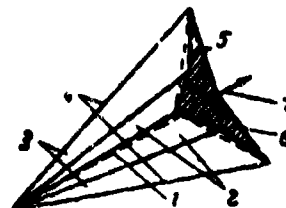
The problem of determining an optimum surface of a body in a gas flow which should either have minimum drag or maximum ability to dissipate the heat (i.e., the amount of heat transferred in a unit of time through the body surface must be a minimum) is considered in [211]. The gas motion satisfies the Navier-Stokes equations of continuity, energy, and state. The amount of heat absorbed by the body surface in a unit of time or the drag of the body is expressed in a general-form surface integral which contains heat-transfer functions depending on the shape of the body surface. Isoperimetric constraints (e.g., concerning the volume of the body, lift or moment of the wing) containing the same functions on the body surface are introduced, and a variational problem of finding the equation of the surface minimizing the surface integral is formulated and solved for both the heat-transfer and minimum-drag problems. A system of equations for determining the shape of a minimum-drag airfoil of a given cross-section area is derived, and its solution by successive approximations is indicated.

The total costs (of construction and operation) are generally used as the criterion of optimality of aircraft construction; the initial total weight can be sometimes taken as an optimality criterion because the changes in this weight are approximately proportional to the total costs. The latter concept of the optimality criterion is used in determining the optimum geometry of aircraft [395], under the assumption that its flight and tactical characteristics, and the useful load will not be affected by a change in the geometric parameters of some member; in other words, in case of such a change, the parameters of other members will be changed in such a way that these characteristics would be maintained; it is also assumed that the law of the aircraft motion with regard to the power consumption is known. Formulas are derived for determining the optimum value of optimized geometric parameters (dependent on or independent of each other), and also of other parameters to which the weight criterion can be applied. The optimum wing loading for a given flight velocity and altitude, and the optimum slenderness ratio of the nose of a fuselage (or of a fairing) are determined as illustrative examples.

6. Experimental Investigation and Equipment

Only a few articles on experimental aerodynamics are included in this report because the content of works in this field is clear from the annotated bibliography. A different approach to experimental investigation is used in [446] where the gas flow in electric-discharge devices is investigated, and formulas for its parameters and the range of application of the device are determined mathematically. The discharge device consists of a rectilinear closed channel of constant cross section filled with gas in which an electric discharge is produced at one end by electric energy continuously supplied; a column of heated gas is formed which expands and displaces the gas at rest. A moving plane shock wave is formed, followed by an impenetrable boundary (a piston) separating the column of heated gas from the disturbed gas which passed through the front of the shock wave. The process of displacing the gas at rest by the piston depends on the initial pressure and density in the channel, and the energy-supply pattern given by a power function of time. The gas which passes through the shock-wave front is assumed to be perfect, inviscid, and non-heat-conducting, and its motion is not accompanied by any physical or chemical changes. The disturbed-gas motion between the shock wave and the piston is regarded as self-similar. Expressions for velocity, density, and pressure in the disturbed region are derived, as well as the Mach number attainable (up to M = 33) and the duration of the process.

A complete description of the supersonic wind tunnel at the Traian Vuia Institute of Applied Mechanics is given with an accompanying diagram and photograph in [445]. The parameters of the flow (up to M = 3.1) are discussed, including the test results of a cone and a sphere at M = 2.2, and illustrated with photographs. The tests for determining the performance of the compressor station are discussed, and the cross-section area of the experimental zone of the tunnel is determined as a function of the Mach number. The arrangement of compressors for a larger supersonic wind tunnel is discussed, and accompanied by illustrative diagrams and tables.

The method of measuring the rate of shock-wave propagation in a shock tube constructed at the Institute of Applied Mechanics of the Academy of Sciences, Rumanian People's Republic, is presented in [180]. The time interval is measured for passage of the wave between two marks placed at a certain distance from each other. The instants of wave passage are registered by special low-inertia capacitance transducers. The time is measured by an electronic chronograph specially developed for this purpose.

Group B. HIGH-SPEED AEROTHERMODYNAMICS

The published material on the aerothermodynamic problems encountered in the study of high-speed gas flows involving thermal radiation, dissociation, ionization, recombination, thermal-boundary-layer and shock-wave formation are inseparably linked with high-speed aerodynamics and have been reported in sections 2, 3, and 4 of group A. This group (B) of published materials deals with aerodynamic heating of flight vehicles and with various means of protection against such heating.

1. Aerodynamic Heating

Aerodynamic heating is the main source of heat developed during entry of a flight vehicle from orbital or space flights into the atmosphere. The phenomenon of kinetic heating of vehicle structures is one of the most widely discussed topics in the Communist World scientific technical literature dealing with the thermal problems encountered in high-speed aircraft design. Gas flows past porous surfaces of plates and bodies with boundary-layer suction or injection of fluid into it, heat exchange between gas and body, heat transfer to aircraft structures, and determination of temperature fields in them — are the most thoroughly investigated problems; the more characteristic ones will be reported. The basic phenomenon which must be examined in discussing the kinetic-heating problem is the skin friction in gas flows. Some works concerning theoretical skin-friction analyses have also been mentioned in group A.

A formula in the form of a power function (obtained by interpolating experimental data) for calculating the surface friction in turbulent flows over a wide range of Reynolds and Mach numbers and temperature drops is given in [569]. A method was developed for direct measurement of local values of surface friction on a flat plate in a supersonic flow, and the measurements were carried out in the presence of intensive heat exchange between the flow and plate. The construction of a surface-friction pickup (for recording the static pressure) is described and possible methodological inaccuracies and errors in measuring are discussed. The range of applicability of relationships obtained, the influence of Reynolds and Mach numbers on the skin-friction coefficient, and comparisons with empirical values obtained by other authors are presented in diagrams.

The aerodynamic heating of a semi-infinite thin plate of finite thickness in a steady flow of a compressible gas with jump-wise increasing temperature is discussed in [556], assuming that the temperature of the plate is the same as that of the gas on the interface between the laminar boundary layer and the plate.

The dependence of the temperature of the leading edge of the plate on time, with consideration of heat flow through the edge, is investigated and exact solutions by means of the operational calculus are obtained for the following conditions of heat flow through the leading edge: 1) there is no heat flow, 2) the edge is artificially heated, and 3) the edge is artificially cooled.

- 17 -

The leading edge of a wing in hypersonic flow can be heated up to temperatures exceeding the melting point of refractory metals (even in cases of large sweepback angles), thus making cooling necessary. But, if the duration of such flights is short (for example, in quick entry and escape from dense layers of the atmosphere), a certain amount of damage to the surface can be tolerated. In this case, it is very important to know the rate of this thermal disintegration. In [660] such failure of the leading edge of a swept-back wing in a steady hypersonic gas flow, with evaporation of the material taken into account, is discussed. The solution of the problem is reduced to the simultaneous solution of a system of nonstationary (due to considering the advancing melting surface) equations of the boundary layer on the molten-material film; and of heat-conductivity equations of the solid remainder. Two cases are discussed in detail: 1) The material of the wing has a certain melting temperature and a number of transformation temperatures at which heat absorption takes place (metals and some ceramic materials disintegrate in this way); and 2) the material does not have a clearly marked melting temperature, the viscosity of the melt being a power function of the temperature (this is a disintegration pattern for various glasses). The behavior of both types of wing material is analyzed in respect to the formation of surfaces of evaporation, melting, and of transformations, and their propagation. Expressions are derived for the parameters of the ablation process and for the rate of disintegration.

The interaction (friction, heat transfer) between the gas flows and bodies on whose surface emission or absorption of a fluid takes place in a natural (for example, evaporation or condensation) or an artificial (suction or injection) way is often discussed in the Soviet technical literature. The effect of such artificial means on the heat and mass exchange in a turbulent boundary layer is analyzed in [562] where a fluid is injected into or a gas is sucked from the gas flow through the porous surface of a plate. A turbulent boundary layer is formed at the leading edge of the plate. An expression which connects the local skin friction coefficient with the suction or injection parameter is derived and its approximate solution is given. The results of a quantitive analysis conducted on the basis of the proposed theory are compared with experimental data obtained by other authors in diagrams which show fairly good agreement.

In many investigations of the effect of gas injection into gas flows past bodies, the variation of pressure in the direction of flow is not taken into account. Reference [225] gives the results of an experimental investigation of the influence of gas injection into a turbulent boundary layer through a porous plate on the dynamic characteristics of the turbulent boundary layer. The plate was placed in a hot-air flow with accelerating and adverse longitudinal pressure gradients. Gases of different molecular weight (air, carbon dioxide, and Freon-12) were injected. The following quantities were measured in the direction of flow (at Reynolds numbers from 10^5 to 5×10^5): dynamic and static pressures, temperatures of the injected gas, temperatures of the gas in the flow (450 to 550°K) and temperatures of the plate (375 to 420°K). The apparatus and the technique used are described. The effect of the physical properties and of the amounts of injected gases (at a certain pressure gradient) on the friction was established for various temperatures and

plotted in diagrams. The data obtained in processing the results were generalized and used in integrating the equation of motion. The procedure developed here for calculating the parameters of a boundary layer with a longitudinal pressure gradient is outlined point-by-point and is recommended for usage.

In previously mentioned works, the gases injected into the boundary layer were inert in respect to gases flowing past the porous surfaces. The case when the injected gas reacts chemically with the gas of the basic flow is of more practical interest. In reference [490], the friction and heat exchange in the turbulent boundary layer of a compressible gas flow are investigated when there are chemical reactions caused by injection of a chemically active fluid. It is assumed that the chemical reactions are instantaneous as compared with the rate of diffusion, which means that the temperature in the boundary layer is high and the thickness of the chemical-reaction layer is an infinitely thin surface as compared with the thickness of the boundary layer. The laminar and turbulent Prandtl and Lewis numbers are taken to be equal to unity. When calculating the characteristics of the boundary layer by the method used here, it is sufficient to know the distribution of concentrations, temperatures, and velocities only in the direction of flow. Expressions are derived for calculating the density distribution, friction, the density of the gas mixture, and the heat flow into the plate.

A similar case of porous cooling, when one side of a porous plate is aerodynamically heated and its other side is exposed to a chemically active cooling fluid under pressure is discussed [560]. Cooling is achieved here by evaporation with chemical reactions, heating of the coolant in the pores, and heat transmission from the gas flow to the coolant. A method of filtration theory is applied in this investigation, assuming that the temperatures and pressures on both sides of the plate are constant and that no evaporation takes place inside the plate. Expressions are derived for the heat flow, diffusion flow, also for the coolant pressure required to maintain its flow through the plate, and the relationships between the criterional parameters of the gas in the flow, of the coolant, and the characteristics of the porous plate.

Approximate methods of determining the temperature distribution in flight-vehicle structures caused by aerodynamic heating have the advantage of simplicity in practical designing. The high surface temperatures and relatively low heat emission coefficient noted in flows at high altitudes and large Mach numbers make thermal radiation an important factor which can not be neglected. In [546], the nonsteady temperature fields in the vehicle structure are analyzed, with thermal radiation taken into account, and a convenient method for practical calculations is presented. The method consists in approximate solution of the heat conductivity equation with initial and boundary conditions by the method of finite differences. The flight is divided into time intervals $\Delta\tau$ and the structure into small finite parallelepipeds whose middle points are dealt with. The following assumptions are made: 1) the temperature gradient between points changes linearly with time; 2) the increase in the heat content of a "point" (parallelepiped) is proportional to its temperature increase; 3) the physical constants of the materials are independent of the temperature; and 4) the adiabatic temperature of the wall, the heat emission

coefficient, and the surface temperature are linear functions of time. A system of linear algebraic heat-balance equations for every "point" in the surface layer and inside the body is derived (the number of equations is equal to the number of "points") from which the variation with time of the heat emission coefficient, the temperature distribution over cross sections, and its variation with time on the surface can be calculated. The estimation of errors and their dependence on $\Delta\tau$ is discussed. The temperature distribution and variation in an aircraft during a 90-second accelerated flight from M = 2 to M = 10 at an altitude of 15,000 m are calculated, and the results are presented in diagrams.

2. Protection Against Aerodynamic Heating

The protection of flight vehicle structures, equipment, and crew against the consequences of aerodynamic heating by selection of proper insulating materials, arrangement of cooling, and use of ablation shielding seems to attract more attention from Soviet scientists working on aerothermodynamic problems than kinetic heating itself. The injection of liquid into the boundary layer (mentioned in the preceding subsection 1) can be used for cooling in cases of moderate kinetic heating. In cases of high velocity, as in atmospheric entry, ablation shielding, the most effective method of dissipating kinetic heat, is widely discussed in the Soviet literature concerned with the thermal protection of flight vehicles.

The basic conditions for any tipe of effective thermal protection are proper insulation of the vehicle skin and designing those shapes of vehicle which will ensure minimum heat transfer from the boundary layer into its structure.

.Fig. 6

One of the solutions of the skin-insulation problem is the three-layer skin construction. The outer surface of the metallic skin is usually covered by a heat resistant (for example, ceramic) layer and inner surface by a layer of fiberglass material. Heat transfer through such a plate, with a flow of hot gas on its outer surface, is discussed in [547], under the assumptions that the plate is infinite (the problem is one-dimensional) and the skin is thin (the temperature is constant along its thickness, Fig. 6), all heat from the boundary layer on the outer surface is used for heating the plate, the inner surface is heat-insulated, and the thermophysical characteristics of all materials are constant. An operational method (using the Laplace transform) is applied to determine the temperature distribution in insulating layers (linear in the outer layer and weakly nonlinear in the inner layer) for the given temperature of the gas in the flow.

The problem of thermal protection by designing that shape of a body in a hot gas flow which will ensure minimum heat transfer into the structure of the body is discussed [506], where that form of a thin airfoil is sought which will have a minimum mean heat transfer coefficient for a given lift, assuming that the upper and lower surfaces of the wing are thermally insulated and that the boundary layer is either laminar or turbulent, not mixed. The problem is reduced to solving the isoperimetric variational problem of determining that function describing the shape of the airfoil camber which will minimize the heat-transfer functional for a given value of the lift functional. The method of Lagrange multipliers is used in

solving the problem, and results of calculations in cases of a laminar and turbulent boundary layers are obtained which show the essential effect of the temperature on the heat-transfer coefficient and the weak effect of the temperature on the optimum shape of the airfoil.

Ablation shielding is the most effective means of protecting the crew and instruments against the heat developed during entry of space vehicles into the dense layers of the earth's atmosphere. Steady ablation is of special interest. Its fundamental problem — that of determining the constant rate of melting of a semi-infinite body heated by a constant heat flow on the boundary under arbitrary initial conditions is discussed in [615]. It is assumed that the molten materials are immediately removed, thus the thin molten film does not affect the melting process. The problem is solved by analyzing the flow of a high-temperature gas near the stagnation point of a blunt body having a melting temperature lower than the stagnation temperature. The equations of heat conductivity and of thermal equilibrium, with initial conditions are solved by the L. I. Rubinstein method (Akademiya nauk SSSR Doklady, v. 58, no. 2, 1947, and Izvestiya vysshikh uchebnykh zavedeniy. Matematika, no. 4, 1958), and a system of integral equations is obtained; from the asymptotic solution of this system, expressions are derived for determining the rate of melting and the process of heat transfer into the solid remainder of the body. The effect of a sudden change in the intensity of heat flow on the melting rate and heat transfer are analyzed, and the course of the melting process in the case when the heat flow varies arbitrarily with time is discussed.

When an axisymmetrical solid body begins to melt in a steady flow of a gas, then, under certain conditions (for example, when the heat-conductivity coefficient of the material of the body is high), a stationary process of ablation will take place and the melting front in the vicinity of the stagnation point advances at a constant rate.

The steady ablation process is discussed in [596] in a general form, and an exact simultaneous solution is obtained for the unsteady Navier-Stokes equations and the equations of the heat inflow (without dissipation) with proper boundary conditions. The steady regime of ablation at the stagnation point of a semi-infinite body in a plane and in axisymmetric flows of an incompressible fluid is discussed. The rotation of the solid about the flow axis is taken into account in the latter type of flow. Systems of nonlinear ordinary differential equations from which single-valued solutions can be obtained are derived in both cases. The possibility of extending these solutions to a compressible gas flow with variable coefficients of viscosity and thermal conductivity of the gas and of the liquid phase of the body material is mentioned.

Soviet authors devote considerable attention to the ablation of material from the surface of a body in radiating gas flow behind a shock wave. The solution of the thermal radiation problem for the boundary layer in the vicinity of the stagnation point of a blunt-nosed body is presented in [614]. The convective and radiative components of the heat flow are considered and the effects of their variation on the ablation rates, temperatures, and heat transfer to the body are examined; formulas for calculating these parameters are given.

The ablation process of a blunt body at the stagnation point (an axisymmetric problem) and along the stagnation line (a plane problem) in a dissociated air flow is investigated in [607], taking account of the evaporation of the molten-material film and the presence of an arbitrary number of endothermic "fronts," for example, sublimation, melting, etc., where absorption of heat can take place. Metals and some ceramic materials disintegrate in this way. Heat transfer in the solid phase, the rate of disintegration with an without evaporation are discussed, and the most typical cases of thermal failure, at low and at high stagnation temperatures, are analyzed in detail. At low temperatures, dissociation of the air is neglected and the boundary layer is treated as a binary mixture of the body-material vapor with air; at high stagnation temperatures, dissociation cannot be disregarded, and the boundary layer is handled as a three-component mixture of atoms of air molecules and particles of the body material. Expressions for determining the rate of ablation are derived in both cases. The solution obtained is generalized to the following cases: when there are heterogeneous chemical reactions between the dissociated air and evaporation products, and when boiling occurs in the melting zone with infinitely strong heat flows from the gas.

An exact solution of the problem of equilibrium and nonequilibrium sublimation of a blunt body at the stagnation point is presented in [610], assuming arbitrary dependence of the physical properties of the body material on time, and disregarding the effects of dissociation and thermal radiation in the gas flow. The variation of coefficients (of viscosity, heat conductivity, diffusion) in molecular transfer, and of criteria (the Prandtl, Lewis, and Schmidt numbers) under given conditions is discussed; the boundary problem is formulated, its numerical solution for the Prandtl number $Pr = 0.7$ and Schmidt number $Sc = 1.0$ is presented, and the results are given in tables; a solution of the problem is derived for arbitrary Prandtl and Schmidt numbers. A necessary and sufficient condition for boiling on the sublimation front is obtained, and expressions for the rate of sublimation are derived in closed form. The temperature profile in the solid is determined in quadratures. It is shown that the solution of any particular problem of sublimation can be reduced under these conditions to a solution of three equations to determine the concentration of gaseous products, the temperature of evaporation, and the rate of sublimation.

An approximate method of determining the law which governs the advance of the ablation front of centrally symmetric bodies in a variable heat flow is presented in [617]. A general qualitative result in the form of a differential equation is obtained first. Its solution is reduced to determining the ablation by only one criterion μ, not depending directly on the melting point. An approximate analytical solution for a plane wall and a constant heat flow is obtained from the basic "qualitative" equation which is reduced to a linear second-order equation that is solved, in turn, in terms of Bessel functions of an imaginary argument; the final solution is obtained in parametric form. The high degree of approximation of this solution is demonstrated in a graph where the curves obtained for various values of μ are compared with those plotted according to numerical calculation data of this particular case (of a plane wall in a constant heat flow) obtained by a method of finite differences.

A very important inverse problem of aerodynamic heating — that of determining in an analytical way the rate of advance of the melting front and the heat transfer into a body by using the data on the variation of the temperature with time at some point inside the body — is discussed in [613]. An approximate solution of this ablation problem is obtained for an infinite plate in a medium with a temperature higher than the melting point of the plate material, in the presence of physicochemical transformations on the surface of the heat exchange, assuming a uniform distribution of the initial temperature in the plate. The concept of the melting front is replaced by the concept of a surface at a certain temperature (of phase change or of disintegration) in the plate with coefficients of thermal conductivity and diffusivity changing in the same way as in the solid remainder of the body. Changes in the boundary conditions are divided into a number of time intervals such that the heat flow can be considered constant in each interval; the thermophysical characteristics are assumed to change step-wise when switching from one interval to another.

Formulas are derived for determining the rate of advance of the phase-change front from the data on the temperature variation in a cross section of the plate, and for determining then the temperature variation over the thickness of the plate from the rate of advance of the phase-change front and associated temperature of the phase-change. The effect of the step-wise treatment on the accuracy of the solution is analyzed in the case when the variation of boundary conditions is linear, and it is shown that the error in this case is directly proportional to the rate of variation in heat flow and to the thickness of the plate; it also depends on the length of the time intervals and on the plate material. Satisfactory agreement is found between the results of analytical calculations by this method and empirical data obtained from heat-exchange experiments involving the melting of a plate surface by electron-beam bombardment in an electric calorimeter with a known heat flow.

3. Experimental Studies

The experimental approach to the solution of ablation problems is very important because in some cases it yields the needed information more quickly and effectively than an analytical solution; very often the empirical results, formulas, and especially, the coefficients of the process are used in analytical investigations, to say nothing of the significance of the experimental verification of theoretical studies. Publication of some typical methods of experimental investigations is reported here.

The oxidation of metals and alloys in air flows at high velocities and temperatures with subsequent disintegration through corrosion, erosion, and burning of the material of the specimen is investigated experimentally in [618]. An installation consisting of a wind tunnel and a heating unit has been designed specially for this purpose (Fig. 7), and the technique of operation has been developed. The installation, specimens, and the methods of measuring and evaluating the disintegration and flow parameters are described in detail, and the dependence of the rate of disintegration on the flow velocity (up to M = 3), the angle of attack (up to 90°), the temperature (up to 1473°K), and the duration of exposure to the air flow (up to 2 minutes) is shown in diagrams for Armco iron and for iron-base and nickel-base alloys. The heat resistance of these materials, and the conditions under which they burn are discussed.

Fig. 7. Schematic diagram

1 - Compressor station; 2 - nozzle chamber; 3 - electric
heating; 4 - wind-tunnel test chamber; 5 - specimen;
6 - area used for calculations.

When a thin film of molten metal moves on the surface of a body in a high-speed air flow, waves are formed on the film and this so-called "liquid roughness" increases the turbulence in the boundary layer, and thus, the heat exchange. An experimental study [612] was carried out in order to obtain a qualitative and quantitative evaluation of the effect of this film on heat transfer. A hollow glass-reinforced textolite cylinder 16 mm in diameter with a flat front face was placed in a supersonic flow. A film of molten tin on the surface of the front face of the cylinder was produced in two ways: by kinetic melting of a tin rod (4 or 8 mm in diameter) protruding to 2 mm and axially movable through a central hole in the face, or by forcing molten tin through a porous chromium plug inserted in the same hole. The experiments were conducted at a stagnation temperature of 580°C and Mach numbers 1.8, 2.3, and 2.7. The two setups of the experiment, the equipment used, and the measurement technique applied are described. The rates at which the rod melted, the consumption of molten metal, the heat-transfer coefficient, and the temperatures are given in tables and diagrams for various parameter of the oncoming flow, and their interrelation is discussed.

Qualitative information on the melting behavior of bodies of certain shapes in supersonic flows can be obtained experimentally by using specimens made of fusible metals. Models made of Wood's alloy are used for this purpose [59]. The low melting point of Wood's alloy made it possible to carry out experiments in flows with relatively low stagnation temperatures (about 88 to 89°C); the flow velocity was M = 1.7. The test specimens were cones with bases 6 to 7 mm in diameter and apex angles measuring 10, 20, 30, and 50°. The melting process was observed and photographed by a IAB-451 apparatus. A device (kimograph) especially designed for the purpose was used for the time-related recording of the melting process. Two photographs of the disintegration of specimens are shown (Fig. 8 and Fig. 9).

Fig. 8. Melting of a cone with a 10° apex angle at 88.8°C and M = 1.7.

The execution of experiments is described and the results obtained are discussed; the constant rate of melting (the decrease Δh of the cone length h with time) for various apex angles α is shown in a diagram (Fig. 10) as a function of time τ.

Fig. 9. Melting of a cone with a 20° apex angle at 88.8°C and M = 1.7.

An experimental investigation of the rate of melting of small cylinders and cones made of lead and of aluminum in a hot supersonic gas flow is described in [589]. The gas flow was obtained by means of a

Fig. 10. Rate of cone melting

1 - Cone with α = 10°;
2 - α = 20°; 3 - α = 30°,
4 - α = 50°.

combustion chamber with a Laval nozzle; three types of specimens were used: 1) specimens for determining the rate of melting, the changes in their shape, and the supersonic flow patterns; they are solid lead and

aluminum cylinders and cones with 10, 20, and 30° apex angles; 2) lead
specimens with protective noses made of materials that melt at high
temperatures for testing the effect of the nose on the melting process;
and 3) specimens with an axial channel through which cooled air is blown
against the hot-gas flow so that a screen of cold air with a pressure
higher than that behind the shock wave is formed around the specimen;
the effectiveness of this method of protection against melting was in-
vestigated. The velocity range of the jet (30 mm in diameter) was
$M = 1.0$ to 2.7, its temperature range — from 500 to 1000°C; the duration
of operation was from 8 to 17 minutes, depending on the pressure and
temperature in the combustion chamber. The arrangement of the unit and
the specimens, the methods applied in measuring, recording, and evaluating
the obtained experimental data are described and explained; the results
of the investigation are discussed and compared in diagrams.

Group C. HIGH-SPEED FLIGHT MECHANICS

No publications directly concerning the mechanism of the atmospheric entry of flight vehicles could be found in Communist-World open scientific and technical literature. Only articles in periodicals on topics more or less associated with atmospheric-entry dynamics can indicate the state of research development in this field and show the means which are available for realization of new ideas. These topics concern the orbital and transfer motions of satellites, flights of winged aircraft at very high altitudes, gliding of lifting bodies from orbital and space flights, processes and phenomena associated with the entry into dense layers of the atmosphere (thermal radiation, dissociation of molecules, ionization and recombination of atoms), space vehicle control, and rocket dynamics, as well as articles concerning the effect of environmental conditions in space (e.g. gravitational fields, cosmic radiation, meteorite hazards).

1. Motion of a Variable-Mass Point

The most general problem of space-flight mechanics is the motion of a mass point in a gravitational field. The solution of nonlinear problems of motion is sometimes simplified by replacing the continuous changes in parameters (e.g. distance, velocity, density) by step-wise ones, by dividing the given range into sections in which the variable parameter under discussion can be regarded as a constant, or by confining the analysis to only one such step properly selected. An approximate solution of the problem of motion of a point of variable mass in a homogeneous central gravitational field given in [790] is based on an assumption that the motion takes place in a relatively narrow cylindrical (or spherical) layer of thickness Δr such that the value of the ratio $\Delta r/r_m$ (r_m - is the distance from the center of gravity to the middle surface of the layer) is so small that it can be neglected if compared with unity, in other words, that the magnitude of the acceleration of gravity in this layer is constant, though of variable direction. Such a field is called a homogeneous plane-parallel field. Differential equations approximately describing the motion of a variable-mass point with a restricted reactive thrust under these conditions are solved with the use of Pontryagin's maximum principle. The optimal programs for the control of thrust and its angle of inclination are obtained by maximizing the corresponding functional and by formulating and minimizing the Hamiltonian. The analysis of these programs leads to the establishing of five regimes for controlling the thrust under the condition that the switching function $\delta \neq 0$. When $\delta = 0$ and the velocity is constant, only a special-purpose control is possible.

The random thrust deviations caused by the errors associated with the realization of an established optimum-thrust program induce disturbances in the calculated trajectory of a body of variable mass. The effect of such variations in thrust on the motion of a variable-mass body in a constant-power flight in a gravitational field is analyzed in [837]. The optimal undisturbed motion of the body is discussed first. Then the errors caused by the thrust variations and by the inaccuracy in realization of initial conditions are examined as well as the induced declinations from the trajectory and the associated optimum corrections necessary to keep up the desirable program of the reactive thrust. A functional ϕ concerning the acceleration due to the thrust in the case of motion with errors and corrections is formed; the minimum mathematical expectation of its increment ($\phi - \phi_{min}$) is determined for the optimum number of corrections and for their optimum distribution, and the effects of both on the motion parameters of the body are discussed. An approximate expression for the minimum total weight of the body (with the source of power and fuel supply) for the given value of ϕ is also derived.

A similar problem of determining the optimum motion parameters of a body of variable mass in a gravitational field, taking into account the random processes of power decrease, is discussed in [641]. Assumptions are made that the source of power consists of a certain number of autonomous sections which are switched off when damaged, thus causing a step-wise reduction of the jet power, and that the weight of the source of power is constant. Two types of random-damage processes are considered: 1) processes stimulated by inhomogeneous external conditions (the probability of damage depends on the radius vector, i.e., is associated with the trajectory); and 2) internal processes and those stimulated by homogeneous external conditions (independent of the trajectory). The limit case when the source of power consists of a large number of sections is also discussed; the step-wise decrease of power in this case is approximately replaced by a continuous one. In all these cases the solution of the problem is reduced to finding the extremals of the acceleration functional ϕ, which is properly transformed for the case in question (e.g. by introducing the acceleration of gravity). Examples of the motion analysis of a variable-mass body with the step-wise power decrease caused by random damage of type (1) and in case of a continuous power decrease are presented. An example of motion with the source of power switched off is also discussed under the assumption that in this case no damage to the source of power can take place.

2. Motion of an Artificial Satellite

It is very important to know the changes in the orbit of a satellite caused by decrease of atmospheric resistance with altitude and by changes in velocity. The problem of determining such deviations of a satellite from an ideal (undisturbed) elliptical orbit (calculated without regard to the braking effect of the atmosphere) with an eccentricity $\varepsilon > 0.01$ is solved in [621], considering only the atmospheric drag X as the disturbing force, and, assuming the effect of X to be small, thus applying the method of small disturbances.

The equation of the undisturbed motion of a satellite in vector form is used, and after certain transformations the equation of a slightly perturbed motion of the satellite is derived from which the expressions describing the changes in the altitude and in the duration of one revolution are obtained, so that from the known elements of an unperturbed elliptical orbit (focal distance ρ and ε), a satellite-construction parameter $\lambda = C_x \cdot S/2m$, and variation of density with altitude, these changes can be calculated. Here C_x is the drag coefficient, S is the cross-section area, and m is the mass of the satellite.

The change of the trajectory of a satellite is of great importance, e.g., in solving the rendezvous and docking problems. Therefore, the problem of changing the plane of a satellite orbit at velocities close to circular orbital ones with a minimum decrease of velocity as discussed in [652] is of interest. This maneuver of a spacecraft at small angles of inclination to the local horizon is treated by means of the calculus of variations as optimal with respect to the loss of velocity. It is shown that under these conditions, the optimum regime is that at a practically constant angle of banking γ and angle of attack α corresponding to the maximum of the hypersonic lift-to-drag ratio $L/D = k$. Finite expressions for the conventional dependence of aerodynamic characteristics on the angle of attack are obtained in a form suitable for optimal programming in a general case by using α and γ as independent variables. The optimum-regime parameters (γ, α, and k) in declination of the plane of an aircraft orbit by a given angle with a minimum deceleration is also discussed in a case when the altitudes at the beginning and at the end of the maneuver are prescribed.

The presence of an atmosphere around a planet is used to decelerate a space vehicle approaching the planet. The degenerate elliptical orbits (braking passes) after which the satellite either lands or is maneuvered into a circular orbit far beyond the "boundary" of the planetary atmosphere are of

a certain interest because there exists a possibility of realizing planetary entry by using a special landing device and leaving the basic vehicle in orbit. The transfer of a space vehicle, which enters the atmosphere at a velocity higher than that of escape, to a circular satellite orbit is discussed in [643]. The magnitude of the additional impulse necessary for transfer of the vehicle from a braking pass to a given circular orbit is investigated and it is shown that a minimum thrust impulse is needed at the instant when the circular orbit is tangent to the braking ellipse in its apastron. A simple formula is obtained for determining the optimum increase in transfer velocity which depends on the altitude of the prescribed circular orbit.

The investigation is based on the assumptions that the gravitational field is a central Newtonian one, the altitude of the circular orbit is much greater than the atmospheric "boundary," the motion of the vehicle takes place in the plane of the prescribed final orbit, and the "atmospheric" portion of the braking passes is so small in comparison to their length that their trajectories can be treated as ellipses.

The deceleration of an artificial satellite in a planetary atmosphere causes secular and short periodical changes in the form and dimensions of its orbit. No studies concerning the short periodical orbit perturbations caused by the resistance of the atmosphere, such as those presented in [624], are known. The general type of the first-order perturbations in elements of a satellite orbit induced only by atmospheric resistance is determined under the assumptions that the Earth's atmosphere has a strictly spherical distribution and its density is a decreasing function of altitude, and that the Earth's gravity can be replaced by that of a mass point in its centroid and having the same mass.

The functions on the right sides of the Lagrange equations describing the perturbations in the plane of an elliptic orbit are expanded in trigonometric series of functions with the average anomaly as the argument. A system of differential equations containing Fourier expansions in terms of M is obtained from which the secular and periodical perturbances can be determined, the latter being either odd or even functions of M (either equal to zero or reaching the extremal values in apogee and perigee respectively). A numerical example of computation is presented, and it shows that the periodical perturbances are small and can be disregarded in evaluation of visual and rough photographic observations.

The motion of an artificial satellite with consideration of the atmospheric resistance in a noncentral gravitational field is a very complicated problem, and its solution is

almost impossible without the use of a high-speed electronic computer. In [620] a method is presented for convenient computer calculation of the motion parameters of a satellite, with the resistance of the atmosphere (rotating together with the Earth) and the deviation of the gravitational field from the central one taken into account; the disturbing action of the Sun and Moon are neglected. A closed system of differential equations in terms of osculating elements supplemented by an equation giving the dependence of the true anomaly on time is used to derive a system of equations completely determining the motion of the satellite; the effect of the noncentrality of the gravitational field is accounted for by introducing the components of the disturbing acceleration induced by this deviation.

The results of a numerical calculation of the orbit parameters of a satellite in a 700-day motion are presented in a diagram and their variation is analyzed.

3. Flight-Vehicle Dynamics

The laws governing the motion of various flight vehicles (airplanes, guided missiles, ballistic rockets, rocket-powered vehicles) under various conditions of motion (steady, unsteady and quasi-steady motions) are discussed, and their paths of flight are analyzed in a monograph [642] under the following basic simplifying assumptions: 1) the medium in which the flight is performed is invariable with time; 2) the vehicle is a body of variable mass with a rigid skin; 3) transient processes inside the vehicle (e.g. motion of fuel in tanks) is neglected; and 4) only the terrestrial gravitational field is considered. In the first part of the book, the possible and optimal trajectories of flight vehicles are discussed only from the kinematic point of view (the laws of variation in velocity, altitude, et cetera, with time) without touching upon the control problems. The vehicle control and the analysis of the stability of its motion will be the content of a future, second part of this monograph.

The equations of motion of a flight vehicle are derived, and mathematical fundamentals and initial data for determining its trajectories are briefly discussed. The steady motion of vehicles, their transient motions in the vertical and horizontal planes, the three-dimensional maneuvers, the range, and the takeoff and landing characteristics are analyzed.

The methods of the calculus of variations are widely applied to finding the optimum regimes of aircraft control because they enable an analyst to select from an infinite variety of possible regimes of motion (usually described by nonlinear differential equations) the narrower classes of motion for which the nonlinear equations can be integrated in quadratures. The motion of an airplane equipped with a liquid-fuel reaction engine on a circular orbit about 60 to 120 km over the earth's surface at speeds on the order of $M > 10$ is analyzed in [651], the aerodynamic forces calculated by Newtonian theory. The optimum angle of attack corresponding to the maximum lift-to-drag ratio is determined by optimizing the function which expresses the L/D ratio analytically. From the equations of motion of the airplane centroid (treated as a variable-mass point) in terms of projections of forces on the tangent and on the normal to the trajectory, expressions for the functionals T and L are derived which determine the duration of the flight and the corresponding distance respectively. By using T and L the solutions of the following variational problems of flight dynamics are given: 1) to determine a law of the mass variation of an orbital airplane during the flight such that a) the power-flight section of the trajectory will be a maximum; b) the power-flight duration will be a maximum for the

given amount of fuel; and c) the power-flight section will be a maximum for a given time of flight. 2) To determine the extremal power-flight times for a given range and for a given amount of fuel.

In problems of determining the optimum regimes of flight under given conditions, the feasibility of controls (their characteristics) must be considered; otherwise, the solutions could not be realized in some cases. The problem boils down to the selection of an optimum control system for an aircraft, which is discussed in [650]. An attempt is made to obtain a more general solution of the problem by supplementing the equations of motion of the aircraft centroid by equations of its motion about the centroid and by utilization of the Pontryagin maximum principle in formulating the optimization criteria. The motion of an aircraft in the vertical plane is analyzed for the case of a power flight in a homogeneous gravitational field assuming that the drag variation and the regime of engine operation are given functions of time. A system of differential equations of motion and kinematic relationships is written whose solution depends on the selection of the time function $\delta(t)$, where δ is the rudder angle, and on the initial values of the velocity components, centroid coordinates, and thrust angle Ψ. The conditions of the optimality of the control system (the values of δ and Ψ) are determined, and it is shown that optimum control can be realized either as a step-wise control (by alternation of δ_{max} and δ_{min}) or as a special-purpose control (Ψ = const., δ = 0). A system of necessary and sufficient conditions (initial, final, and for switching) for the realization of both types of control is given in a table and discussed at length.

At flight speeds close to orbital, a winged space vehicle or a lifting body has a large reserve of kinetic energy which can be used in gliding flight. It is impossible to obtain a closed general solution of the variational problem of determining the optimum trajectory in this case. Therefore, the problem is solved in [635] by an approximate method, where the gliding process is treated as a uniform quasi-steady immersion of the vehicle in the atmosphere at an altitude of 70 to 75 km with overloads not exceeding 4 to 5 G's. It is assumed that terrestrial gravitation does not change with the altitude, that the atmosphere is isothermic, and that the flight is nonpowered. Using the equations of motion in terms of the the projections of forces on the normal and tangent to the path of gliding, the kinematic relationships, and the equation of the L/D-curve, a system of three equations describing the trajectory of gliding is obtained. These equations contain four unknown functions (density ρ, glide angle θ, and lift coefficient C_y), so that a constraint must be imposed

on one of them. Solutions are given for the following cases:
1) gliding range for ρ = const.; 2) gliding with C_y = const.;
and 3) gliding with a constant glide angle relative to the
local horizon. Results of a calculation for an initial speed
of 6 km/sec, initial density of 8.34×10^{-5} kg/sec^2/m^4 (at an
altitude of 49 km), C_y = 0.141, wing loading of 500 kg/m^2, and
drag coefficient at zero angle of attack C_{xo} = 0.02 are pre-
sented in diagrams for lift-to-drag ratio values K = 3.5 to
0, and comparison with the data of an exact numerical solu-
tion shows that the results are almost identical. This
article and the following ones in this group are the few
publications closely associated with the lifting reentry
problem, particularly its final stage—maneuvering in the
earth's atmosphere and landing. Its content can be applied
either to gliding of a winged reentry vehicle or a lifting
body.

The maneuvers of a space vehicle in a gravitational field
can be executed by applying the thrust either in the direction
perpendicular to the radius vector of the vehicle (transverse
thrust) or in the direction parallel to its velocity vector
(tangential thrust). The motion of a spacecraft with a small
transverse thrust in a central gravitational field is dis-
cussed in [647], treating the vehicle as a mass point. As
initial equations, the equations of motion are used in polar
coordinates (r, ϕ) in terms of nondimensional parameters
ρ = r_0/r, z = $r_0\mu/\beta^2$, and $r_0^2 f/\mu$ = ϵ, where r_0 is the radius
of the initial circular orbit, μ is the gravity, β is the
double areal velocity, and f is the acceleration of the trans-
verse thrust. The quantity ϵ—the thrust-to-gravity ratio
on the orbit—is considered as constant and small. The equality

$$\rho = z(1 + 2\epsilon \sin\phi + \epsilon^2 R)$$

containing a new unknown function R is substituted for ρ
in the initial equations of motion. The introduction of a
"correcting term" $\epsilon^2 R$ is a significant peculiarity of the
solution, and contributes to its accuracy. In solving this
modified system of initial equations, an expression for R is
derived in terms of the functions of the argument $x = 4\epsilon\phi$.
A comparison of the trajectory parameters calculated for
various values of x, both with the "correcting term" taken
into account and without it, is presented in tabular form,
and it shows that the results obtained with the consideration
of this term are more accurate.

The maneuvering of a space vehicle into a prescribed cir-
cular orbit around the Earth from some point in space at an
arbitrary value of its velocity vector is a problem encoun-
tered in the return of a vehicle from a space flight. This
problem is discussed as a particular case in solving the

variational problem of a transfer between two points in a
central gravitational field discussed in [648] as a plane
problem of transfer in a minimum time, under the assumption
that a constant acceleration is imparted to the vehicle by its
engine. The distance between the points is given by their
radius vectors. In solving the system of differential equa-
tions of motion, a time functional is obtained whose minimi-
zation gives the solution sought. The Lagrange method is
used, and the final equations obtained are solved by numerical
integration on the BESM-2 computer, considering two problems:
transfer between two circular orbits and placing a vehicle into
a circular orbit from a point in space. In the latter case it
is shown that the time required for transfer by means of thrust
tangential to the trajectory and the time for transfer by thrust
parallel to the velocity vector are practically the same.

The control of the rotary motion of a body in a space
flight by means of a system of reactive torque-producing
nozzles is usually reduced to the selection of their thrust-
regime programming in accordance with the conditions of the
given particular problem. The determination of the optimum
law of operating the reaction-nozzle engines in decelerating
the angular velocity of a rotating symmetrical body which per-
forms a free motion in space around its center of inertia is
discussed in [654]. Two basic regimes of retarding the ro-
tation are discussed: 1) in the shortest time (unlimited
fuel consumption), and 2) with the minimum fuel consumption
(unlimited time). In certain particular cases, they can coin-
cide. This search for a time-optimum regime is based on the
assumptions that the nozzle engines produce control moments of
limited magnitude around the principal axes of inertia of the
body and that the inertia moments of the body and the direc-
tions of its principal axes are invariable. The solutions
obtained in cases (1) and (2) are analyzed, and it is found
that in case (1) all three engines retroact simultaneously
up to the complete cessation of rotation, and in case (2) the
transverse torques act in turn and the longitudial torque
(along the axis of symmetry) acts continuously up to elimination
of the longitudinal component of the angular velocity. As a
particular case of braking the transverse rotation — the
stopping of the precession, i.e., elimination of transverse
angular-velocity components — is discussed as well as the
construction of phase trajectories, i.e., the order in switch-
ing the nozzle engines on and off.

An original discussion of the interesting and important
problem of the free·fall of a mass point in the cabin of a
satellite during a free flight and a flight in the Earth's
atmosphere is presented in [836]. From the equations (in
vector form) of motion of the mass center C of the satellite
(in coordinates with the origin in the Earth's center) and of

the falling mass point M (coordinate center in C) in a free
flight when only gravity forces are acting, a second-order
differential equation for the free fall is obtained whose general solution
contains six constants for which the parameters of the el-
liptical orbit are taken. The derivatives of the radius vector
with respect to these parameters represent the particular
solutions of this differential equation. By means of these
solutions, six radius-vector functions q and their time de-
rivatives $\dot{q}$ are written. The vectors ρ and $\dot{\rho}$ which determine
the position of M in the cabin and its velocity, in a coordinate
system with the origin at C, are determined in the form

$$\rho = \sum_{s=1}^{6} C_s q_s, \qquad \dot{\rho} = \sum_{s=1}^{6} C_s \dot{q}_s,$$

where C_s are constants determined later from the conditions of an
impactless separation of M from the cabin. The separation
processes of M at the instant when the satellite passes its
perigee and when it is in a circular orbit are discussed. The
problem of determining the path and velocity of a mass point
falling in the cabin of a satellite is also examined in the
presence of nongravitational forces which perturb its Keple-
rian motion. The effect of the atmospheric drag, as such a
perturbing force, on the motion of M is analyzed in the case
of a circular orbit.

4. Spaceship Oscillation

The oscillatory processes in the motion of flight vehicles are of great importance for their design and operation. This importance increases with growing flight parameters (e.g., speed, pressure, temperature). In this section, only publications are reported which concern the oscillation of a rigid vehicle as a whole, either about its center of mass or relative to its trajectory, disregarding its deformations. Publications on the vibration of aircraft considering the associated stresses and strains are reported in group D, section 2.

The oscillation of an artificial satellite around its center of mass under the action of gravitational moments during its motion in an elliptic orbit is discussed in detail in [645a], with special attention being paid to the effects of resonance. An investigation of the conditions for the existence and stability of the state of relative equilibrium of a satellite (i.e., equilibrium in an orthogonal coordinate system with its origin in the satellite centroid) and a librational motion around this state was carried out by the author in ISZ, no. 3, 1959, 13-31. In the present article, the small forced plane oscillations of the satellite (induced by the ellipticity of the orbit and described by an equation of the pitch-angle variation) in the plane of its orbit are discussed, and a formula describing the associated forced oscillations of the eccentricity of the orbit is derived. The steady-state oscillations in the case of a parametric resonance are analyzed, and the region and magnitude of resonance values of the natural frequency are determined. A criterional inequality is derived which shows the domain of nonsteady oscillations. The resonance values of oscillation parameters in the case of three-dimensional oscillations are determined by supplementing the equation of the pitch-angle variation with those of the roll and yaw angles.

Solutions are obtained which describe the transverse oscillations of a satellite in an elliptic orbit and in a circular one (by putting the eccentricity of the elliptic orbit equal to zero). The only value of the frequency parameter at which the parametric resonance in transverse oscillation can take place is determined.

The problem of controlling the self-induced plane oscillations of a spaceship relative to its trajectory by an impulse-type automatic control system is discussed in [646] under the assumptions: 1) that the sensors of control system which record the angle of deviation of the vehicle from the prescribed direction have certain dead zones on whose boundaries discrete control impulses of a constant magnitude are produced by the servos; 2) the sensors and servos are of arbitrary nature; 3) the duration of a control impulse is

short, so that during that time the angle of deviation does not change, and thus the angular velocity changes step-wise; and 4) the perturbing moments acting upon the vehicle are constant in magnitude and direction. Assumption (2) permits omitting consideration of the fuel consumption and discussing instead the consumption of energy, which is given for a certain time t by a formula $Q = ngt/T$, where n is the number of impulses in one cycle, g is the known energy consumption in one impulse, and T is the duration of a cycle. The formula shows that for finding the energy consumption the values of T and n must be determined.

The self-induced oscillations in unperturbed motion (i.e., the absence of perturbing moments) and under constant perturbing moments are discussed, and the energy consumption and duration of a cycle are determined in terms of nondimensional parameters of perturbing and controlling moments. The relationship between energy-consumption and disturbance parameters is established and illustrated by diagrams.

The oscillatory motion in the vertical plane of a winged solid-propellant rocket in powered and non-powered flights is studied in [633]. An analytical solution in the form of finite formulas and tabulated functions is obtained for determining the parameters of this oscillatory motion occurring when the steady motion of the rocket is perturbed, e.g., by deflection of elevators, cut-in and cut-off of the engine, or when the thrust becomes eccentric. The following principal assumptions and constraints are used: The incidence angles of wings and control surfaces are fixed, and the eccentricity of thrust is constant; the angles of attack α and of inclination of the vector velocity are small; the drag coefficient is constant and the derivatives of the coefficients of aerodynamic forces and moments with respect to α and to angular velocity are independent of the flight velocity; the mass and centroid of the rocket and the thrust are constant during the burning of the propellant. Linear equations describing the dependence of the lift and of the pitching moment on the angle of attack and angular velocity are used as initial ones, and a second-order linear inhomogeneous differential equation with constant coefficients which describes the motion of the rocket is obtained. In this equation the distance along the trajectory is taken as the argument. The solution of this equation is given, the oscillatory behavior of statically stable and unstable rockets in flights with the engine switched in and shut down is analyzed, and the coordinates of motion of the centroid are determined. The term "statically stable" ("unstable") is applied to a rocket whose $m_z^\alpha < 0$ ($m_z^\alpha > 0$), where m_z^α is the derivative of the pitching-moment coefficient with respect to α.

5. Meteorite Hazard

The encounter of a space vehicle in flight with meteors and meteoric particles (micrometeorites) is very probable, and measures for protecting the vehicles against punctures are developed in two ways: theoretical and experimental investigations of the nature and mechanism of the puncture process at velocities on the order of 10 km/sec or more, and the design and construction of protective means (e.g., increase of the wall thickness, special shielding) to prevent punctures. Results of an experimental observation of the mechanism of impact of two bodies—one of a small mass, the other of a large mass—at velocities of 3 to 7 km/sec, and X-ray photographs of the process of interaction between them at velocities up to 2 km/sec have been used in [672a] for a first-step solution of the impact problem at very high velocities by constructing an impact model which retains the basic features of the phenomenon and permits determining the fundamental parameters of the impact process. The mechanism of impact of a cylinder on a semifinite wall is shown in Fig. 11.

Fig. 11

The cylinder is partly melted in the impact and takes on a mushroom shape $OAA_1A_2B_2B_1B$; KK and nn are are shock waves in the wall and cylinder respectively; the metal between KK and nn is in a liquid phase and is about to be ejected. The impact problem is reduced to the investigation of the motion of this liquid, assumed to be incompressible, and is solved by means of classical methods of hydrodynamics for cases of potential and vortex motions. Formulas for the geometric parameters of a crater in the solid related to the length and diameter of the impacting cylinder and density parameters of the cylinder and wall materials are given. Results of calculations for impact velocities from 11 to 88 km/sec for various geometric and density parameters are given in a table. If less than the whole liquid phase is ejected from the crater during impact, an "inertial" increase of the crater takes place, i.e., the remaining liquid produces a certain additional deepening.

The first logical and simple measure to protect a space vehicle during its flight beyond the Earth's atmosphere against puncture by meteorites is to increase the wall thickness. But, a considerable increase in the weight of the vehicle in this case makes it necessary to search for other means of protection. A protective method proposed by F. Wipple (Astronomical Journal, v. 52, 1947, p. 131) is based on the assumption that in the impact an explosion occurs, and the meteorite and a certain amount of the wall material evaporate; thus the vehicle should be enveloped in a mantle (with a gap between it and the outer surface of the vehicle) which act as a meteor damper, so that the outer surface of the vehicle wall would be exposed only to the weakened action of the explosion products. An approximate method is proposed in [668] for estimating the upper values of the thicknesses l_0 of the mantle and l_w of the wall, and of the magnitude h of the gap, which means that all assumptions and simplifications used in this method are on the safe side, leading to larger dimensions. It is assumed that an oncoming meteorite punctures a hole of radius r_0 in the mantle, evaporates and takes the form of a dense mass of vapor of radius r_0 and length l_0 (the same as the hole and thickness of the mantle); the vapor expands only lengthwise during the passage of the gap h. The wall thickness is determined from the condition that all the kinetic energy of the vapor is spent in vaporization of the wall material. The thickness L of a wall not protected by a mantle is determined and an expression for the ratio $(l_0 + l_w)/L$ is derived for the given h.

The selection of the most rational values of h/L, l_0, and $(l_0 + l_w)$ based on calculations is discussed, and the weight of the cover of a space vehicle in the case of an unprotected wall (L) and a mantle-protected one ($l_0 + l_w$) are compared and the advantages of the latter are pointed out. The method can be made more exact as more knowledge on meteors and their interaction with a wall is acquired.

GROUP D. STRENGTH OF FLIGHT-VEHICLE COMPONENTS
(Thin and sandwich plates and shells)

Thin plates and shells, solid, laminated and of sandwich
construction, are the most frequently used components in the
construction of "light vehicles, machinery, and instruments
of modern des ... Box-type spars of airplane wings, the
fuselage and wing skin; the bodies of rockets, satellites
and space vehicles; the membranes, diaphragms, and bellows
of instruments; the cases and diaphragms of turbomachines,
etc., consist of these elements or of their various combina-
tions. The most significant role in the development of the
design of these constructions is played by the theory of
plates and shells, especially the works of K. Z. Galimov,
A. L. Gol'denveyser, Kh. M. Mushtari, V. V. Novozhilov, V. Z.
Vlasov, and of others on the thin plates and shells which are
well known outside the USSR from their translations, mainly
English. In this report only those publications concerning
the theory of thin plates and shells will be mentioned which
are associated with topics related to high-speed flight
vehicles and their operation: minimum-weight design, load-
carrying capacity, thermal stresses, dynamic stability,
aeroelastic and aerothermodynamic problems, and liquid-filled
shells. All these publications can be divided in two groups:
publications dealing with static and with dynamic stress and
strain analyses.

1. Static Stress and Strain Analyses

Cantilever anisotropic or orthotropic plates are often
used as design models for monolithic cantilever wings or
control surfaces of high-speed aircraft or winged space ve-
hicles. The term "monolithic wing" means a wing with a thick
skin which is able to resist the normal and tangential stresses
varying over the skin thickness. The spars and ribs of such
a wing are designed to resist only the shear forces. This
type of construction is used in high-speed aircraft wings,
tail units and in fins of rockets and missiles. Thin mono-
lithic wings have lower rigidity in bending and especially
in torsion thus creating serious aeroelastic problems.

a. Wing design

The general strength of a sweptback wing of monolithic
construction stiffened with stringers and with ribs parallel
to the fuselage axis is analyzed in [677]. The wing is under
uniform continuous loading (flexural and torsional moments,
and shear forces) and a concentrated load, all applied at
the free end of the wing. A cantilever anisotropic plate is
taken as a design model, and the stress analysis is carried

out under conventional assumptions of the small-deflection
theory. The relationships between the stress and displace-
ment components are established, and the determining of
stresses in the skin is thus reduced to determining the
deflections of its middle surface. The principle of virtual
displacements is applied to derive approximate differential
equations of the four.h order with boundary conditions for
determining the deflections, from the equality $\delta U = \delta A$, where
U is the potential energy of the wing and A is the work of
external forces. The equations derived contain a deflection
function which takes account of the rigidity of the wing, so
that these equations are correct for wings with thin or thick
skins. A simplified solution of these equations is obtained
for "rigid" wings for which an assumption can be made that
the form of the cross section is not distorted by deformation
under loading. The effect of the sweepback angle and the
aspect ratio on the stress distribution along the span and
in the root cross section of such wings is analyzed and the
results are shown in diagrams. A way of obtaining a more
exact solution (with consideration of the distortion of wing
cross sections) by means of the method of successive approxi-
mations is indicated.

The growing speed of flight pressed aircraft designers
to use thin wing profiles, thus reducing the flexural and
(mainly) torsional rigidities of the wing and making its
loading and stresses more dependent on deformations. The
problem of determining the stresses with the effect of de-
formations taken account is considerably complicated by the
fact that the external loading remains unknown until the prob-
lem is completely solved. The strength of a thin elastic wing
of monolithic construction with regard to the effect of de-
formations is analyzed in [689] under conditions and assump-
tions as in [677]. The problem is discussed in a static
formulation, which means that an equilibrium in the process
of changes in deformations and in associated external forces
is considered and that the change in the lift coefficient
caused by deformation is proportional to the change in the
angle of attack. The mass forces are taken into account, and
the interrelated stresses and deformations are determined in
two cases: 1) when the angle of attack at the root cross
section of the wing is prescribed (e.g., flight in gusty air);
and 2) when the load factor is prescribed (flight along a
given curvilinear trajectory). The design formulas for stresses
and deformations are given in matrix form, which is very con-
venient for making calculations, especially on electronic
computers.

The possibility of using these formulas for other pur-
poses, for example, in determining the aerodynamic loads,
lift and moment coefficients of an elastic wing with its de-
formations taken into account, is pointed out, and the diver-
gence and aileron-reversal speeds of an elastic monolithic

wing are determined as examples of such applications.

The solutions obtained in [677] and [689] are generalized in [715] for a monolithic wing with nonparallel stringers and with ribs parallel to the plane of the root cross section. The stiffeners (stringers and ribs) are treated as flexible ropes carrying only axial loads. It is assumed that the wing elements resisting the shear forces (the skin and the webs of ribs and spars) are continuously distributed (along the span and chords respectively). An anisotropic plate is used again as the design model. Two special cases of a monolithic wing design are examined: 1) when sharp changes in loading (e.g., a concentrated load) or in the shape take place in some cross section along the span; and 2) when the wing is of a continuous type (i.e., has a central portion under the fuselage). The changes in equations and boundary conditions involved in cases (1) and (2) are discussed, and in the latter case the simplified general formulas (obtained by assuming a nondistorted cross section of the wing during its deformation as in [677]) are given. The results of computing the stress distribution and the deformation in the root cross section in following triangular wings with a 45° sweep of the leading edge and with the trailing edge perpendicular to the fuselage axis are shown in diagrams and are briefly discussed: three detachable wings with various arrangements of stringers (parallel to the trailing edge, parallel to the leading edge, and parallel to the median of the wing-tip angle); and two continuous wings with different arrangements of the central portion; both with stringers intersecting in the wing-tip corner.

The effect of nonuniformity in strength and spacing of the stringers over the depth of various wings (rectangular, sweptback, and triangular) on the stress distribution in outer fibers of the wing skin is discussed in [722] by presenting the results of theoretical stress analysis by the method given in [677] and [715]. The calculations were carried out for two patterns of stringer arrangement: 1) the effectiveness of the stiffening decreases (stringers are weaker and their spacing grows) along the chord with increasing distance from the leading edge; and 2) the stiffening pattern is inverse to that in case (1). The following types of wings were considered: a) straight wings of rectangular and double-wedge cross section constant along the span; b) sweptback wings of cross sections as in (a); c) triangular wings of rectangular cross section with various directional arrangements of stringers (as described in [715]). The variations of longitudinal stress in the root cross section are shown in diagrams and discussed as well as the displacement of the flexural axis, the additional stresses due to constrained torsion, and the dependence of the stress distribution

on the arrangement of the stringers.

The stress distribution in tapered wings is similar to that in conical shells under similar conditions. The investigation of stress-strain relationships in a sharply tapered thin-walled flattened conical shell having the shape of a tapered (in plan and thickness ratios) wing is presented in [719]. The equations for determining the deformations and stresses in the shell of constant thickness are derived in displacements and are based on the general variational method proposed by V. Z. Vlasov. This approach to the problem permits determining the stresses and strains in the shell in a simple way and with a satisfactory accuracy. The basic assumption used is that the stress distribution is uniform along the thickness of the thin shell. The longitudinal and lateral displacements of a point on the surface of a panel (between spars and adjacent ribs) which are caused by external forces are investigated, and systems of Euler-type differential equations (in terms of generalized displacements) with variable coefficients (containing the distribution functions of displacements) are derived. The extension of these equations to stringer-stiffened shells is briefly discussed.

The application of the proposed method is illustrated by deriving the design formulas for a wing-like cantilever conical shell under a lateral force at the free end and by presenting a numerical sample calculation. The systems of differential equations obtained can be applied to designing one-cell and multicell conical shells under arbitrary loading, and to determining thermal stresses due to constraints in bending and torsion.

b. Minimum-weight design

The problem of designing a structure having a minimum weight under given conditions is associated with the lower and upper estimates of limit loads for this structure by applying the yield conditions for maximum tangential stress and for maximum reduced stress, respectively. In [807] the yield condition for the maximum reduced stress is used for determining the lower limit load in designing a cylindrical shell of minimum weight under continuous uniform internal loading. The shell is of sandwich construction; the faces, of variable thickness, are of a perfectly elastic-plastic material, so that the minimum-weight and minimum-volume problems coincide; the material obeys the yield condition under maximum reduced stress and the associated flow pattern. The core, of constant thickness, is of a lightweight material. The yield behavior of a simply supported cylindrical shell is investigated, and the corresponding deflections, the variation of the face thickness along its axis, and the volume

(i.e., the weight) of the shell are determined and shown in
diagrams. The volume of the variable-thickness shell is com-
pared in a diagram with the volume of a constant-thickness
shell in relation to the length of the shell.

Analogical analysis is carried out for a cylindrical
shell with fixed ends. By the comparison of weights the
author comes to the conclusion that a noticeable economy in
weight can be achieved by using short shells.

The optimum design of a medium-long or a long shell of
given thickness stiffened by annular frames of different
rigidity and acted upon by external pressure is solved in
[795], with the requirement that the shell must have the
same stability against various modes of buckling. The
method of initial parameters in matrix form is used in de-
termining the necessary rigidity of the annular frames. The
shells with one, two, and three frames are analyzed, and the
author comes to the conclusion that equistability can be
ensured by two methods: 1) in a case when identical rigidity
of the frames is prescribed—by the selection of their proper
spacing, and 2) when the spacing of the frames is uniform—by
using frames of various rigidities.

Shells consisting of two layers of different materials
are an important constructional element. Metallic shells
with an inner or outer layer of plastics used either as
thermal insulation or as ablation shielding or a protective
layer against corrosion are often used in aircraft design.
A cylindrical shell with an outer layer of polymeric material
with a filler, exposed to the action of internal pressure and
of a temperature field is discussed in [743] with the purpose
of determining the state of stress in both layers and of
establishing their minimum-weight relationships. The outer
layer is treated as a constructionally orthotropic membrane
shell stiffened by equidistant stringers and uniformly spaced
prestressed rings. The inner layer is treated as a shell
with bending stresses. The interaction between both layers
is investigated assuming their joint deformation, and a
fourth-order differential equation (containing the parameters
of rigidity, pressure, and temperature) of the problem on the
states of stress and strain of the shell is derived; the con-
stants of integration of this equation can be determined from
the boundary conditions and used in finding the stress dis-
tribution at the ends of the shell (the edge effect). These
constants are determined for two arrangements of the bottom
of the shell: 1) plane hinged bottom with a reinforced flange,
and 2) semispherical bottom rigidly connected to the shell.
The minimum-weight problem of this shell is solved under the
assumptions that the whole shell is in a membrane-stress state
(because the edge-effect zones are very narrow, only a few

shell thicknesses) and that the outer layer has only the stiffening rings. The minimum weight is determined under the condition that stresses in the layers should not exceed the prescribed limits; the thicknesses of the layers as well as the initial tension in the outer layer can be determined.

c. Load-carrying capacity

The load-carrying capacity of a structure is understood to be the value of a limit load which the construction can carry without failure or buckling under a certain loading path. The calculation of the load capacity and the investigation of the effect of certain structural parameters on the limit-load variation help to keep the weight of the structure low. In [824] an attempt is made to develop a comparatively simple method for determining the load-carrying capacity of stiffened thin-walled circular cylindrical shells under axial compression. The method is based on the assumption that the longitudinal members of a real shell with manufacturing irregularities and other deviations from the design conditions are subjected to a combination of axial and transverse loadings; the presence of stiffeners (stringers and frames) justifies treating the shell under discussion as "constructionally" orthotropic. The cases of axisymmetrical and of axially asymmetrical initial imperfections of the shell are discussed. In the former case, formulas for the critical (failure) stresses in stringers and frames are derived. Either the buckling stress in certain elements of a stiffener or the yield stress of the material (whichever is lower) is taken as the critical stress. In the axially asymmetrical case, an analogous procedure is used, and similar expressions for critical stresses are obtained. The discussion of the effect of the internal pressure in cases of both symmetrical and asymmetrical initial irregularities on the load-carrying capacity of a constructionally orthotropic cylindrical shell leads to the conclusion that the internal pressure can increase the load capacity in an asymmetrical case when the circular frames are relatively weak or when only stringers are used.

The load-carrying capacity of a plain cylindrical shell under pure flexure is discussed in [826]. An attempt is made to obtain a physically convincing and simple mathematical solution of the failure problem based on geometrically linear theory and to define more exactly certain principles concerning the buckling of the shell. The load-carrying capacity of the shell is determined from the conditions of strength and of buckling of the shell. The strength of a plane cylindrical shell under pure flexure and external uniform radial pressure is analyzed under the assumption that the load capacity will be exhausted when the total stresses at a certain

point exceed the yield stress of the material. The formula
for determining the load-carrying capacity of the shell with
respect to its strength is derived, and the results of cal-
culation are compared in a diagram with experimental data
obtained by other authors. The load capacity of the shell
with respect to local buckling is also analyzed, and it is
shown that the presence of radial pressure decreases the
critical (failure) stress in the shell. A practical formula
for determining the real critical stress is given. Fair
agreement of the theoretical values with experimental data
can be seen in the above mentioned diagram. The coincidence
between theoretical and experimental results in determining
the load capacity with respect to both strength and buckling
as well as the different character of the discrepancies in
the buckling behavior of shells under flexure and under pres-
sure are examined in more detail, and the feasibility of
extending this study to constructionally orthotropic, i.e.,
stiffened, shells is mentioned.

A general solution of the problem of the rigidity of
cylindrical shells having frames at the ends and several
frames arbitrarily spaced between them is presented in [827].
The effect of the spacing of an arbitrary number of inter-
mediate frames on the strength, buckling, and free vibration
of a cylindrical shell is investigated under the assumption
that these frames are elastic in their planes but perfectly
pliable in the out-of-plane direction; the end frames can
be either rigid or elastic. In solving this combined vari-
ational problem, the radial displacements W are taken as
an unknown function and the hoop stresses, bending moments,
shear forces, and the potential of external forces are con-
sidered in writing the energy functional for a section of
the shell between the frames. By minimizing this functional,
a fourth-order differential equation with boundary conditions
is derived from which the general solution (an expression for
W) is obtained. By using proper boundary conditions the
solutions for either the fixed, simply supported, or free
ends of the shell can be derived. The adaptation of the
general solution in the following particular cases is dis-
cussed: 1) the strength under axisymmetrical loading; 2) the
axisymmetrical mode of shell buckling; 3) the shell under
lateral flexure combined with axial compression; and 4) axi-
symmetrical free vibration of the shell.

The buckling behavior of a shallow oblong cylindrical
panel with longitudinal ribs (which are hinged to the shell)
subjected to a uniform normal pressure is investigated in
[794]. The pressure is $q(t) = Mq + \xi(t)$, where the pressure
function $Mq = const$, and $\xi(t)$ is a time function describing
a random stationary process. The presence of disturbances
$\xi(t)$ causes the crossing of the potential barrier of the panel

and thus its premature (from the viewpoint of the classical stability theory of elastic systems) buckling at a certain random instant t. From the numerical characteristics of t one can make a judgement about the load-carrying capacity of the panel. It is assumed that $\zeta(t)$ has a wide-band character, i.e., its correlation time is small in comparison with the natural frequency of the panel, as it is in the case of real disturbances of acoustic or aerodynamic origin. Equations previously derived by the author (under the assumption that the deflection and its first time derivative describe a Markoff process) are used in determining an expression for the mean time of buckling from which a qualitative estimate of the load-carrying capacity can be made.

The problem of the stability of circular cylindrical shells under axial compression forces nonuniformly distributed along the edges of their faces has been studied by many authors with satisfactory results. But the effect of nonuniformity in the distribution of compressive forces on the amplitude of the critical (buckling) stresses is insufficiently known, and considerable discrepancies exist between values of stress factors accounting for this nonuniformity. The linear problem of the local stability of a circular cylindrical shell with its faces abutting on rigid diaphragms and subjected to compressive loading, which varies according to the cosine law, in the middle surface of the shell is investigated in [809] with the purpose of comparing the values of buckling stresses under nonuniformly and uniformly distributed loadings. The procedure in deriving a formula for local deflections is outlined, and the results of the computation of relationships between certain buckling parameters are presented in diagrams. By analyzing these relationships, the author comes to the conclusion that nonuniformity in the distribution of compressive loading has no influence on the magnitude of the buckling stresses. Local buckling is analyzed in the example of a long cylindrical shell placed in a high-temperature field and partly filled with zero-temperature liquid, so that a temperature jump which causes thermal stresses takes place in the circumferential direction. Expressions for the buckling temperature and associated critical compressive stresses are derived, and the calculated values of the buckling stresses are practically the same as those obtained for the same shells under uniformly distributed compressive loading.

d. Thermal stresses and buckling

Temperature changes in the surrounding medium cause volume changes in bodies placed in this medium which result in a state of stress and strain. The magnitude of these stresses and strains must be kept within certain bounds in order to prevent thermal failure of the body. Establishing

temperature-dependent stress-strain relationships and determining thermal stresses and strains is the purpose of many studies published in the Communist World, the most characteristic of which will be mentioned.

The behavior of a heated orthotropic plate is investigated in [758] by taking into account the shear stresses $\tau_{xz} = [f_1(z), \varphi(x, y)]$ and $\tau_{yz} = [f_2(z), \psi(x, y)]$ according to the S. A. Ambartsumyan theory of anisotropic shells, and assuming that the relative deformation over the thickness of the plate e_z is given by the free thermal expansion in that direction $e_z = \beta_z T$, where $\varphi(x, y)$ and $\psi(x, y)$ are the unknown functions, $f_1(z)$ and $f_2(z)$ are the given functions determining the pattern of variation of τ_{xz} and τ_{yz} along the plate thickness, β_z is the coefficient of thermal expansion along z, and T is the temperature. The elasticity and shear moduli, Poisson's ratio, and β are the given functions of T. The origin of the coordinate axes is in a corner of the plate with the z-axis along the plate thickness. Starting with the integration with respect to z of the different_al equation of equilibrium of a plate element, a solving system of five differential equations with variable coefficients is obtained for determining the three displacement components and the functions $\varphi(x, y)$ and $\psi(x, y)$. The application of these equations to the following particular cases is shown: 1) when T varies only along the z-axis; 2) when T varies along the x- and y-axes; and 3) cylindrical flexure of the plate. A sample analysis of stresses in a case when the temperature is zero under the plate and changes linearly from zero to 400°C on the upper surface is carried out for a plate with two opposite sides clamped, and the considerable effect of transverse shear stresses on the magnitude of the resulting forces and moments is pointed out.

The buckling behavior of plates and shells in a supersonic gas flow was examined many times and the determining parameters obtained were mostly established in relation to the initial (prebuckling) state of these structures. But in solving the problem of the thermal buckling of plates and shells in a gas flow, their stability in the buckled state is of most interest. The behavior of plates and shells under the postbuckling conditions is discussed in [741] by using the published data on flight conditions of the V-2 rocket, and it is shown that under these conditions the thermal buckling is a prevalent factor in failure at high temperatures. The equations describing the vibration of plates and shallow cylindrical shells under conventional assumptions (validity of Kirchoff-Love hypothesis, comparability of deflections with the thickness, given temperature fields, etc.) are brought to a nondimensional form, and a system of determining parameters (temperature, pressure, structural damping, velocity,

etc.) are brought to a nondimensional form, and a system of determining parameters (temperature, pressure, structural damping, velocity, etc.) is discussed and selected. Only the temperature parameter θ and velocity parameter μ are considered in the study of the postbuckling behavior of a cylindrical shallow shell of a rectangular planform with supersonic gas flow on the outer surface along the directrix. It is shown that the shell undergoes either thermal buckling or flutter and that the cause of failure depends on the relation between θ and μ. The calculated values of these parameters for various length-to-thickness ratios a/h of the shell are plotted in (θ, μ) coordinates, and the regions of stability, flutter, and thermal buckling are determined (Fig. 12). The conclusion is reached that the problem of thermal buckling of shallow shells in high-speed gas flows deserves perhaps not less, but more attention than the problem of flutter.

Fig. 12

The assumption usually accepted at lower temperatures that the physical properties of materials are independent of the temperature is inadmissible in designing modern flight-vehicle structures, where the gradients of temperature fields are high and grow with the increasing kinetic heating due to increasing speed of flight. The large temperature gradients compel consideration of the dependence of elastic constants and thermal expansion coefficients of materials on the temperature in determining the thermal stress and strain distributions, as well as in solving other thermoelastic problems. An analysis of thermal stress-strain relationships in an orthotropic shell of revolution with consideration of the time-dependent physical properties of its material is presented in [742] in linear formulation, disregarding creep, and assuming the validity of the generalized Hooke's law. The usual assumptions (on preservation of normals, free thermal expansion over thickness, negligibly small thickness-to-radius ratio, etc.) are applied in deriving a system of linear differential equations and of formulas for determining the forces and displacements in the meridional, circumferential, and normal-to-surface directions, as well as the moments in the meridional and transverse planes. The integration of the equations is impossible in the general case; therefore, these equations are rewritten for particular shells of revolution (cylindrical, conical, and spherical) and for a circular plate. There is a detailed discussion of the thermal problem of a cylindrical shell of revolution in the case when the temperature varies linearly along its length, Young's modulus varies linearly with the temperature, and Poisson's ratio is independent of the temperature.

The skin of a stiffened shell moving at high speed in
the air is considerably heated whereas the inner stiffening
members remain cool and hinder the thermal expansion of the
skin, thus creating compression stresses in the skin and ten-
sion stresses in the inner members, so that buckling of the
skin can occur. The thermal stability of an orthotropic cir-
cular cylindrical shell in an external temperature field is
discussed in [804] under the assumption that the induced
thermal stresses in the skin are constant along the length
of the shell and across the thickness of the skin and vary
over the circumference. This simplification of the original
problem reduces the problem of thermal stability of a shell
to that of its static stability under proper boundary condi-
tions.

Fundamental equilibrium equations for an orthotropic
cylindrical shell in terms of displacements are derived in
general form assuming a membrane state of stress prior to
buckling. These equations are used in determining the sta-
bility of a simply supported cylindrical shell by selecting
the corresponding boundary conditions, and an infinite linear
system of algebraic equations is obtained. By equating the
determinant of this system (the stability determinant) to
zero, a general solution can be obtained by a complicated
procedure, which can be greatly simplified for particular
loadings. Simple design formulas for the buckling stresses
in orthotropic and isotropic cylindrical shells under axial
compression and for orthotropic shells under flexure are
derived.

By the nonuniform heating of long cylindrical shells in
the circumferential direction, longitudinal stresses which
can cause their buckling are originated in their middle sur-
face. The clarification of the effect of nonuniformity in
the thermal stress distribution on the magnitude of the
buckling stresses needs supplementary studies. The local
buckling of a circular cylindrical shell under the above
conditions is investigated in [762] as a linear problem.
Starting with the stability equations and taking the unknown
functions in them in the form of trigonometric series, an
infinite system of homogeneous equations is obtained in matrix
form, thus reducing the problem of determining the buckling
stress to determining the maximum eigenvalue of the matrix
(by the iteration method); the eigenvector of the matrix will
determine the deflections. A case of practical importance is
the stability of a cylindrical shell in the horizontal position
partly filled with a zero-temperature liquid and placed in a
medium with a higher (lower) temperature corresponding to
heating (cooling) of the liquid. The buckling behavior of
the shell, the buckling temperature of the medium, and the
effect of the level of liquid in the shell are discussed and

illustrated by diagrams. It is shown that the investigated nonuniformity in stress distribution has practically no effect on the magnitude of the local buckling stress.

e. Sandwich constructions

Plates and shells of sandwich construction are extensively used in aircraft design (lifting surfaces, fuselage) not only for their higher load-to-weight ratio but also for their heat- and sound-insulating and vibration-damping properties. The stress analysis of the sandwich plates and shells under various external loadings and boundary conditions is a topic often discussed in Soviet technical scientific literature; the buckling behavior of sandwich plates and shells is discussed less often. The skin of a wing of sandwich construction is subject to aerodynamic heating in high-speed flight; the outer face of the sandwich skin is heated much more than the inner face, and thermal stresses occur. The effect of thermal stresses on the buckling of a sandwich wing panel of the upper airfoil surface between adjacent spars and ribs is investigated (according to the author, for the first time) in [718]; the panel is compressed in the longitudinal direction by uniformly distributed forces along the ribs and is clamped along all sides. The following assumptions are made: 1) the compressive loading is carried by the face layers only; 2) the hypothesis of straight normals is valid for the face layers; 3) the core layer is free of stresses up to the instant of buckling; and 4) thermal stresses and strains in the core are disregarded because of its low rigidity. The thermal stresses and their distribution in face layers are determined as well as the states of resulting stresses in them, and the equilibrium equations for both face layers are derived. The expressions describing the stress distribution in the core and the joint deformation of all three layers are derived, and from them the expression for the buckling force is deduced. The effect of distribution of thermal stresses on the magnitude of the buckling force is discussed.

The flexure of an unsymmetrical sandwich plate with a rigid isotropic core and unequally thick faces made of different materials subjected to transverse loading combined with nonuniform heating is examined in [797]. It is assumed that the temperature and displacements vary linearly over the thickness of the core (the least heat conductive of all layers), and that the Kirchhoff-Love hypothesis is valid for the face layers; the transverse compressibility of the core is neglected. The differential equations of small deflections with boundary conditions are used in investigating the flexure of a simply supported plate (Fig. 13) under transverse loading q, compression forces P, and thermal loading t linearly distributed along both faces (linear heat source along the x-axis inde-

pendent of the y-axis). The flexure of the plate (by the bending moments distributed along the edges parallel to the x-axis) occurs when the forces in the middle surfaces of the face layers are of opposite signs (tension and compression); an expression for the deflection function under this loading is derived. A formula for deflection in the case when the plate is subjected only to transverse loading is deduced. A solution is also given for the case when two opposite edges are clamped and two others are simply supported.

Fig. 13

2. Dynamic Stress and Strain Analyses

a. Vibration and flutter

Thin plates and shells which are structural components of flight vehicles are exposed to the action of aerodynamic forces which cause such undesired phenomena as buffeting, vibration, and flutter, which can produce, in turn, the buckling and failure of these elements. Because of the increasing speed of flight, the dynamic behavior of plates and shells in a high-speed flow of a compressible gas is a more and more frequently discussed topic in Soviet-Bloc technical scientific literature. Publications dealing with the flutter and vibration will be mentioned.

The dynamic stability of plates and shells has been studied mostly in the linear formulation, and the problems associated with relatively low speeds (e.g. the lower flutter speed of a panel) can be treated by means of linear theory. At higher speeds, the deviations from linearity in relation-

- 55 -

ships between geometric and flow parameters force the investigator to use the concepts of nonlinear theory. The study of the nonlinear flutter of plane and curved panels in very high supersonic flows is presented in [696], with stretching of the middle surface and thermal buckling caused by kinetic heating taken into account; the effect of joint deformation of the panel together with the whole structure (the effect of clamping) on the boundary conditions is considered. The flutter of a double-curvature shallow panel of rectangular planform in a supersonic gas flow (parallel to its longer side) on its convex surface is investigated. The plate is surrounded by a steady temperature field generated by the kinetic heating, with a gradient linear varying over the thickness of the panel, and arbitrarily varying over its middle surface. The basic assumptions of the nonlinear theory of shallow shells (the validity of the Kirchhoff-Love hypothesis, the comparability of deflections with the shell thickness, and their smallness in comparison with its dimensions) are accepted. The flutter motions are assumed to be so slow that the tangential inertia forces can be neglected, and only the normal ones to be considered. A system of differential equations describing the flutter behavior of the panel under the thermal and normal loading (which consists of inertial and damping forces and aerodynamic pressure) is solved by making simplifying assumptions and introducing nondimensional parameters; approximate expressions are derived for determining the flutter speed, and estimating the amplitudes of oscillation and the normal stresses at speeds higher than the speed of flutter. The conditions for the "soft" and "hard" flutter, as well as the interdependence of the flutter speed, amplitudes, and stresses for various thickness-to-length ratios of the panel are discussed and illustrated by diagrams.

In investigations of the oscillatory motion of a wing at high supersonic speeds, the nonlinear interdependence of aerodynamic forces and the angle of attack has to be considered. At high hypersonic speeds of flight the time $\tau = b/v$ (where b is the chord, v, the speed) will be negligibly small in comparison with the oscillation period T, and the ratio τ/T (proportional to the Strouhal number) will be very close to zero. In [756], it is shown that under these conditions the data about flutter obtained by the stationary theory in a case when the angle of attack is constant with respect to time can be applied in a case when the variation of the angle of attack is caused by oscillation. The results of the study of the flexural-torsional flutter of a wing by this simplified method with the aid of an MN-7-type electronic analogue computer are presented. The dependence of the flutter speed on the wing parameters and on the initial disturbances (e.g., wind gusts, atmospheric turbulence) is established; the effect

of the fuselage on the flutter speed is also considered.
The results are discussed and illustrated by diagrams.

The unsteady flutter of plates and shallow shells in a
supersonic gas flow is analyzed in [751]. A method previously
developed by the author is applied in setting up a system of
equations describing the dynamic behavior of plates and shells
in a supersonic gas flow and thus surrounded by a temperature
field; the characteristic temperature of the plate (shell)
and the velocity of the undisturbed flow are described by
parameters θ and μ respectively, so that a point in the (θ, μ)
plane gives an idea of the conditions of the plate (shell)
surroundings in time-variable fields of temperatures, veloc-
ities, and pressures. This fact is used in determining the
character of the transition to flutter and the associated
values of the temperature and velocity parameters. An approx-
imate method, developed by N. N. Bogolyubov and Yu. A. Mitro-
pol'skiy, for investigation of transient processes in nonlinear
systems with many degrees of freedom is used in searching for
nonstationary solutions in cases of simultaneous changes in
parameters of flow velocity, density, and pressure in the
surrounding medium, and in the temperature of the plate (shell).
A (θ, μ) diagram plotted from calculated values which illus-
trates the loss of stability of a plate is shown in Fig. 14.
The crossing of the line AF means the loss of stability
through the flutter, and of the line DF, through the thermal
buckling. Equations for determining the frequency, amplitude,
and phase of a nonstationary flutter are derived, and their
application is discussed. An example of calculating the flut-
ter parameters for a plane nonheated plate is presented, and
the results obtained are examined and illustrated by diagrams.

Fig. 14

Knowledge of the modes of free vibra-
tions of aircraft elements and of their
natural frequencies is necessary in inves-
tigating oscillatory problems. The vibra-
tion parameters of lifting surfaces are of
special importance because of the high
speeds at which they operate when used on
modern airplanes, guided missiles, rockets,
etc. They are usually of monolithic con-
struction (see above, D-1), and a canti-
lever plate is used as a design model for
them. The modes and frequencies of free
vibration of the most general type canti-
lever plate, anisotropic, laminated, swept-back, tapered,
with arbitrarily variable thickness along the span and chord,
are investigated in [684]. The plate simulates a thin mono-
lithic wing or tail unit with a thick skin stiffened by
stringers and rib flanges. The Ritz method is used for de-
termining the modes of free vibration along the span (for a
given vibration mode along the chord) using the equations in

matrix form, so that the problem is reduced to determining the eigenvalues and eigenvectors of a special dynamic matrix whose elements depend on rigidity and inertial characteristics of the construction. The method is very convenient for use on electronic digital computers. The flexural and torsional free vibrations are analysed by using the hypothesis on the nonvariability of the cross sections of the wing under vibration, and the results are compared in a table with the data of investigations where this hypothesis was not used and with experimental data. A fair agreement among all these results is demonstrated. The possibility of replacing the swept-back plate by an equivalent straight plate is discussed.

In solving certain dynamic problems in aircraft design it is sometimes necessary to investigate the vibration of thin-walled structural members of thin-plate and thin-shell types exposed to a high-frequency excitation. .For determining the modes of vibration asymptotic expressions can be derived which can be used in any region except in those adjoining the reinforced contour, at abruptly changing cross sections, etc., where the distortion of the dynamic stress field, the phenomenon called "dynamic edge effect," takes place. It is known from experience that the fatigue failure of vibrating thin-walled structures begins in these "distorted" regions. Therefore, solutions are sought which satisfy the "distorted" boundary conditions and tend to asymptotic expressions for vibration modes in inner regions not too close to the edges. The theory of the dynamic edge effect in the vibration of elastic shells is presented in [707] with an analysis and classification of various types of the edge effect for shells of positive, zero, and negative Gaussian curvatures; methods are given for calculating the edge-effect characteristics in the distorted-stress regions from the known solution for the inner regions. The equations of shell theory (derived by A. L. Gol'denveyzer) describing the modes of vibration in states of stress with a large index of variation (large wave number) are used to derive an expression which completely determines the properties of the dynamic edge effect in the case of vibration

Fig. 15

with given wave numbers. This expression is used in deducing formulas for the dynamic edge effect in plates, shallow shells, and spherical shells, and it is generalized (by introducing nondimensional parameters) to discuss the conditions of existence of an edge effect and its degeneration and to determine its type. The application of the proposed theory to investigating the frequency spectrum and modes of natural vibration of a spherical panel is given; the panel is clamped along a contour bounded by four orthogonal lines of curvature (Fig. 15). It is shown

that the tangential displacements along the lines x_2 = const and x_1 = const do not affect the normal deflections, and the asymptotic estimates of natural frequencies and wave numbers are obtained in a simple way. Results of computations in the case when a = b are given in a table and are compared with those of a very accurate and laborious calculation by S. Iguchi; the results are almost identical.

b. Liquid-filled shells

The solution of problems of dynamic stability of space vehicles during launching and in motion when either the direction or the speed of flight, or both, are changed (e.g., corrections of the orbit, deceleration) boils down to the investigation of the disturbed motion of a solid with cavities partly or completely filled with a liquid. The oscillation of fuel in tanks is excited by vibration of the tank itself and of other structural and control elements of the vehicle, so that the problem of dynamic stability of the body-liquid system arises. These problems are usually solved by variational methods which permit a convenient use of computers. A systematic presentation of variational principles and their substantiation in analyzing the oscillatory behavior of liquid-filled bodies is given in [787]; the body is either rigid, or elastic and obeying the hypothesis of preservation of plain cross sections. The oscillation of the liquid in a fixed open vessel is preliminarily discussed. The application of the Ritz method is described; oscillation of a conservative system of bodies, some of them having cavities filled with a perfect, incompressible liquid without vortices is analyzed; and the static stability of the system is investigated. An approximate method of determining the free oscillation of the body-liquid system is given. The torsional, flexural, and combined free vibrations of an elastic beam with a cavity filled completely or partially by a liquid are discussed, and formulas for natural frequencies are derived. The stability of the beam-liquid system is investigated, and the analytical conditions of stability are formulated. The advantage of the variational method used in this investigation is stressed; it is convenient for the use with electronic computers and makes standardized programming possible.

The dynamic behavior of stiffened thin elastic shells filled with a perfect incompressible liquid is analyzed in [788]. The study is based on A. M. Lyapunov's works on the stability of motion of mechanical systems, and on works by V. V. Bolotin about the dynamic stability of elastic systems, particularly of shells. The works by V. V. Novozhilov, Kh. M. Mushtari, and V. Z. Vlasov on thin shells are also used. The variational equations of motion of the shell-liquid system under the action of arbitrary time-variable forces acting upon

the shell surface are derived under the assumptions that
the stiffeners possess flexural rigidity only in the direc-
tion normal to the shell surface and rigidity in tension
(compression), and that the connection between the skin and
stiffeners is strong enough to.ensure their joint deformation.
From these equations the differential equations which describe
the dynamic stability of the system are derived under the
assumption that the liquid does not separate from the shell
(coincidence of the normal velocity components of both liquid
and shell over the surface of their contact). The following
problems of the stability of a cylindrical shell with liquid
are examined, and the stability parameters (amplitude and
frequency of oscillation, pressure, critical forces and
stresses) are discussed: dynamic stability of a plain closed
shell; quasi-static stability of a completely filled shell
and of a shell stiffened by closely spaced stringers; shells
stiffened by discretely spaced circular frames; dynamic sta-
bility of a closed shell stiffened by stringers. Possible
simplifications of the proposed method are discussed.

When the cavity in a body is almost completely filled
with liquid, a bubble of air of almost spherical shape is
formed, and the dynamic problem consists in determining the
motion of the liquid and that of the bubble in the cavity,
and in describing the motion of the body. The discussion of
this problem is presented in [845] under the assumptions that
the following conditions are fulfilled (and it is so for many
liquids, including water): $va >> \mu/\rho$ and $v^2a >> \sigma/\rho$ (where
a is the radius of the bubble; ρ and μ are the density and
viscosity of the liquid, respectively; σ is the coefficient
of the surface tension on the interface between the liquid
and bubble; and v is a characteristic value of the liquid
velocity relative to the cavity); and that the bubble is a
nondeformable sphere and the liquid is a perfect one. The
equations of motion of the body-liquid-bubble system con-
taining its momentum Q, kinetic energy T, and kinetic moment
K, and the expression for the potential energy $\mathbf{I}$ of the
liquid are used as the initial ones. These equations are
solved first as if the liquid filled the cavity completely
(determining thus the parameters of the motion of the body-
liquid system); then, by integrating the equation of motion
of the bubble, the coordinates and velocities of its center
are determined. By substituting these quantities in the
initial equations of motion, the parameters of the motion
of the body-liquid-bubble system are determined. The fol-
lowing particular cases are examined: 1) the liquid (with-
out a bubble) performs a translatory motion; this can happen
when the body is in translation or if the cavity is a sphere;
and 2) the body with liquid and bubble is subject to an impact
so that all parameters change suddenly and Q, T, and K receive
finite increments. Under these conditions, the deformation

of the bubble is taken into account and it is proven that this consideration has no effect on the increase of the kinetic energy. Formulas for determining the behavior of the system under impact are derived. The instability of the positional equilibrium of the bubble in the steady potential flow of a perfect incompressible liquid is discussed.

The consideration of the surface tension of the liquid in solving the problem of motion of a body with a cavity filled with liquid plays an essential role under conditions of weightlessness. The stability of motion of a liquid-filled solid and of its equilibrium with the surface tension of the liquid taken into account is discussed in [846]. The cavity is completely filled with two homogeneous incompressible, immiscible, perfect liquids possessing surface tension and subjected to mass forces. The cavity has no protruding elements (e.g. ribs) in the neighborhood of the line where the interface of both liquids contacts the wall of the cavity. The formulation of the problem also covers the cases when one liquid is surrounded by the other one and does not touch the wall, and when the cavity is partly filled by only one liquid, with air under pressure or vacuum above it. The equations of motion of the system and the boundary conditions (in which the presence of the surface-tension forces on the interface of both liquids is considered) are derived by applying the principle of least action in the Hamilton-Ostrogradskiy form. It is shown that under the conditions discussed, the total mechanical energy of the system (kinetic energies of the solid and liquid, potential energy of external forces, and surface energy of the liquid) is constant during the motion. Differential equations describing the shape of the interface of liquids in equilibrium or steady motion are derived (assuming a continuity in the motions of the body and of the liquid), and the form of the interface in the cases mentioned above is discussed. The stability of the equilibrium or of the steady motion of a body-liquid system is analyzed and stability criteria for equilibrium, steady motion, and relative equilibrium (in uniform rotation) of the system are derived. The validity of these criteria in cases of a viscous liquid (with and without surface tension) is proven.

The nonlinear problem of the oscillation of a perfect incompressible liquid in a vessel of finite dimensions under the action of gravity and surface-tension forces is presented in [847] in variational formulation, which permits the use of direct methods in its solution. The liquid fills a part of the vessel, and the rest is occupied by gas, so that coefficients of surface tension on the gas-vessel, liquid-vessel, and gas-liquid interfaces are distinguished. The gas over the liquid is assumed to be at rest, and its mass is neglected. The Hamiltonian principle for real motions is applied to the

solution of the problem, using the Lagrangian function
L = T - Π (where T and Π are the kinetic and potential
energies of the vessel-liquid-gas system) and the Hamiltonian
integral of action

$$J = \int_0^t L dt,$$

which assumes a stationary value, i.e., $\delta J = 0$. The problem
of determining the motion parameters of the liquid can thus
have a variational formulation, the problem being to find
among the functions satisfying the boundary conditions those
which also satisfy the condition $\delta J = 0$. It is proven that
this formulation is equivalent to the conventional formulation
of the problem of the motion of a perfect incompressible liquid
in a fixed vessel under the action of gravity and surface-
tension forces. Examples of finding the functions satisfying
the condition $\delta J = 0$ in particular cases of motion and
equilibrium of a liquid in a vessel of finite dimensions
are given.

Concluding Remarks

As can be seen from both the annotated bibliography and
the comprehensive report, the Communist-World scientific
technical literature in the fields closely related to the
reentry problem is very rich. Especially, the aerodynamic
heating, ablation, and ablation shielding of space vehicles,
their flight dynamics and control, and the dynamics of liquid
filled bodies are fields of space science very intensively
studied by Communist-World scientists.

The mathematical methods utilized in the investigations
in these fields are so selected that they can be adapted
easily for calculation on high-speed electronic computers
which are widely used in the USSR.

SPACECRAFT UTILIZING THE LIFTING REENTRY TECHNIQUE

PART II

Section II - Annotated Bibliography

ATD Work Assignment No. 52
(Report no. 1 in this series)

SECTION II

ANNOTATED BIBLIOGRAPHY

TABLE OF CONTENTS

GROUP A   AEROMECHANICS OF HIGH-SPEED FLOWS

    A-1   Aerodynamics, Supersonic and Hypersonic
          Turbulent and Laminar Flow
          Boundary Layer Flow
          Shock Waves
          Rarefied Gas Flows
          Hypersonic Flow Similarity Theory

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1942
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   The phenomenon of the appearance of two waves following each other is described, and the shapes of these waves and the law of the decrease of their intensity are determined. In addition, the propagation of spherical impact waves at large distances from the point of explosion is investigated.

5. Sedov, L. I. Some unsteady motions of a compressible fluid.

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10. Khristyanovich, S. A. Approximate integration
    of supersonic-flow equations.

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    An approximate solution is obtained in a
    simple analytical form for a plane super-
    sonic gas flow.

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    results at $M > 4$. Similarity criteria
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    given.

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Some properties of supersonic flows are discussed which make it possible to establish an analogy with two-dimensional flows, to perform a number of qualitative deductions, and to simplify the calculation of flows past some classes of wings.

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The development and application of the law of plane sections and the equivalence principle to various problems of hypersonic flow over a lifting surface, a cone, and wedge are discussed.

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    region of a velocity hodograph.

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    linearized form.

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    v. 21, no. 2
    303-304

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    boundary layer on a plate with a moving
    shock wave.

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    v. 21, no. 3
    368-374

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    plane stationary shock wave.   v. 21, no. 4
                                                          465-467

    The stability of a plane stationary shock
    wave is studied. Differential equations
    for pressure disturbances and boundary
    conditions, and equations for disturbance
    of the shock-wave surface are derived.

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    the boundary layer on the gas-flow pattern   v. 21, no. 4
    in a tube behind a moving shock wave.   473-477

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    boundary conditions for a motion in extremely   v. 21, no. 5
    rarefied gases at supersonic velocities.   597-605

    On the basis of Prandtl's theory, boundary-
    layer equations are obtained which differ
    from Prandtl's equations by additional
    terms containing higher-order derivatives
    of velocity and temperature. In these
    equations, the normal pressure gradient
    is distinct from zero and is expressed
    through additional terms. The appli-
    cability range of these equations as re-
    lated to velocities and altitudes is given.

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    method of small perturbations to laminar   v. 21, no. 5
    boundary-layer problems.   606-614

    The method of small perturbations is ap-
    plied to problems of the supersonic
    boundary layer on thin bodies or bodies
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                                                 613-641

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    wave front are discussed and their ef-
    fect on the inner structure of the front
    is evaluated.

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     for calculating shock waves.   v. 12, no. 1(73)
                                                   176-177

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    . for an axisymmetrical supersonic gas flow   no. 3
    linearized in relation to the flow from   102-112
    the gas source.

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    flow and boundary conditions is obtained
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    cow). A method of computing the turbulent   v. 27, no. 2
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    gradient.

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    used for determining the value of the local
    friction coefficient and the separation
    point in the first approximation.

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    waves.   v. 27, no. 5
                                                    1126-1135

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35. Vorob'yev, O. S. Approximate analytical rep-   DAN SSSR
    resentation of two-dimensional supersonic   v. 122, no. 5
    gas flows.   778-781

    A procedure is developed for the approx-
    imate analytical representation of two-
    dimensional supersonic gas flows, includ-
    ing solution of specific boundary problems.

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    dary-layer transition from turbulent to   v. 125, no. 4
    laminar.   746-747

    An experimental investigation of boundary-
    layer transition showing the presence of
    reverse transition from turbulent to
    laminar in the case of large negative
    pressure gradients in the supersonic
    nozzle is reported.

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    turbulent flow of an incompressible fluid.   no. 1
                                                    72-78
    A simplified method is proposed for solving
    the plane problem of turbulent flow by the
    method of characteristics. The solution of
    the initial equations by this method is dis-
    cussed for the following cases: in the re-
    gion of a simple centered wave, in the re-
    gion of interaction of two simple centered
    waves, and without any assumption of the
    existence of centered waves.

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    unsteady motions of liquids and gases.   no. 2
                                                    20-28
    The extension of the hydraulic analogy to
    the case of unsteady motions of liquids
    and gases is presented. The theoretical
    results are compared with experimental data;
    the technique and equipment used are de-
    scribed.

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     al supersonic-flow problem.   no. 3
                                                            3-7

         The results of previous investigations on
     determining the shape of minimum-wave-drag
     bodies and the parameters of axisymmetric
     hypersonic flows are generalized to de-
     termine the shape of a body of revolu-
     tion with minimum wave drag in a given
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     (Moscow). Strong point blasts in a com-   v. 22, no. 1
     pressible medium.   3-15

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     1-19

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     strong point detonation are given for three
     new types of equations of state for an ideal
     medium.

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     permeable contours.   v. 22, no. 2
                                                            220-225

         The problem of flow around an arbitrary,
     smooth, closed, uniformly permeable con-
     tour in a potential stream of ideal fluid
     is analyzed.

42. Ryzhov, O. S. Some degenerate transonic   PMMe
     flows.   v. 22, no. 2
                                                            260-264

         Transonic motions of an ideal gas which
     are represented in the velocity hodo-
     graph by a curve or by a surface are
     analyzed. A class of self-similar solu-
     tions representing plane and axially
     symmetric flows is given.

43. Korobeynikov, V. P. (Institute of Mechanics,   PMMe
    AS USSR), and Ye. V. Ryazanov, Ye. V. (Mos-   v. 22, no. 2
    cow State University).   265-268

    Exact discontinuous solutions are derived
    for the equations of one-dimensional un-
    steady motion of an ideal gas in the
    presence of shock waves.

44. Kopylov, G. N. (Leningrad). On similarity of   PMMe
    transonic plane flows.   v. 22, no. 3
                                                     391-395
    A simplification of the basic equations of
    motion is given, based on the assumptions
    that the Mach number of the upstream flow
    is close to unity, velocities of the flow
    are slightly different from the upstream
    velocity, and the direction of the velocity
    vector is only slightly different from the
    direction of flow away from the body.

45. Rozin L. A. (Leningrad). The development of   PMMe
    a laminar boundary layer on a plate with   v. 22, no. 3
    pulsed motion.   407-412

    A study of the laminar boundary layer in
    the case of a semi-infinite flat plate
    moving in an incompressible viscous fluid
    is reported.

46. Kogan, M. N. Equation of motion for rarefied   PMMe
    gases.   v. 22, no. 4
                                                     425-432
    Distribution functions are obtained in any
    desired approximation by simplification of
    the Boltzmann equation. This makes it pos-
    sible to determine the error of any specific
    approximation in rarefied gas flow.

47. **Ryzhov, O. S.**, and **S. A. Khristianovich.** Non-
linear reflection of weak shock waves.

  The exact (partial) solutions for the de-
rived nonlinear differential equations
are used to solve approximately the
problem of nonlinear diffraction in the
case of a rigid wall, and angles of at-
tack near the critical angle.

PMMe
v. 22, no. 5
586-599

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USSR, Moscow). Exact solutions for one-
dimensional gas dynamics equations in the
presence of shocks.

  Solutions of first-order differential equa-
tions of the Ricatti type are given for
arbitrary values of variables.

PMMe
v. 22, no. 5
720

49. **Ginevskiy, A. S.** (Moscow), and **Ye. Ye.
Solodkin.** The effect of transverse surface
curvature on the characteristics of an axi-
symmetric turbulent boundary layer.

  An approximate solution of the problem of an
axisymmetric turbulent boundary layer on
concave and convex surfaces is given, tak-
ing into account the longitudinal pressure
gradient and the transverse surface curva-
ture.

PMMe
v. 22, no. 6
819-825

50. **Rozin, L. A.** (Leningrad). An approximate me-
thod for calculating nonstationary turbulent
boundary layer in an incompressible fluid.

  The development of an approximate method for
calculating the unsteady turbulent boundary
layer, based on the analogy between laminar
and turbulent unsteady layers is presented.

PMMe
v. 22, no. 6
842-847

51. Barglazan, A., and O. Popa. A contribution to the theory of turbulence over a thin profile.   StuCeMaAp Jan-Jun 58 57-71

A method is developed for determining vortex distribution over a thin profile, applicable to the case of an arbitrary thin profile, without introducing any limitations on curvature or angle of attack.

52. Golitsyn, G. S. (Institute of Atmospheric Physics, AS USSR), and K. P. Stanyukovich (Moscow State University). Some remarks on the structure of shock waves.   ZhETF v. 35, no. 3 828-830

A qualitative investigation of some aspects of the physical structure of a normal shock wave in magnetohydrodynamics is presented.

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The development of a method used to reduce the calculation of boundary layers described by partial nonlinear differential equations to the solution of boundary problems for ordinary linear differential equations is given.

54. Biybosunov, I. An example of plane-parallel transonic gas flow with a curved shock wave ending in a flow with a stream function of the form $\phi_{2/3} = \rho^{2/3} f_{2/3}(\theta/\rho)$.   DAN SSSR v. 126, no. 5 951-952

An example of transonic gas flow with a shock wave, with supersonic speed being converted to subsonic and ending in the stream function cited in the title is presented. This example is an extension of an example previously cited by F. I. Frankl' (Frankl', F. I., IVUZ, Matematika, no. 2, 1959). The solution is obtained by the method of characteristics and gives the coordinates of the shock, of the zero flow line from the end of the shock downstream, and the sonic line.

55. Ryazanov, Ye. V. Examples of exact solutions for the propagation of explosion waves in a gravitating gas with zero temperature gradient.

The work presented in this article is a continuation of the formulations of self-similar problems and exact solutions of equations describing unsteady adiabatic motions of gas stellar models (explosions and dynamic disruption of equilibrium) previously given by L. I. Sedov. Analogous exact solutions are given here for the propagation of explosion waves in a perfect gas with its own gravitational field (with spherical symmetry) under the assumption of absence of temperature gradients.

56. Galin, G. Ya. Shock wave theory.

This article deals with the problem of whether the equation of motion used in theoretical studies of the structure and width of a shock front, with viscosity and heat conductivity taken into account, has a continuous solution in the case of media with an arbitrary equation of state and the consequences stemming from regarding shock transitions as the limit of these solutions.

57. Lyubimov, G. A. High supersonic flows of a ron-ideal gas around bodies.

The small-parameter method developed for an ideal gas is extended to the case of non-ideal gas flows around plane contours and bodies of revolution when the internal energy of the gas is an arbitrary function of the pressure and the temperature. The application of this method to flow of air around a cone is used as an example.

58. Lyakhov, G. M. (Moscow), and N. I. Polyakova
(Moscow). An approximate method for analysis
of shock waves and their interactions.

IzAN MeMa
no. 2
13-18

The method proposed is based on replacing
the pressure-volume curve by a broken line
consisting of linear segments. Expressions
are derived which determine the motion of
the wave front and the flow behind the wave
in these sections. The application of the
method to incident and reflected shock waves
is discussed.

59. Churikov, F. S. On a form of supersonic gas-
flow equations.

IzAN MeMa
no. 3
204-207

It is shown that various linearized gas-
dynamics and other equations of mathe-
matical physics can be transformed into
"compact" equations (partial differen-
tial equations having only one mixed
derivative) if the initial and boundary
conditions are transformed accordingly. The ad-
vantages associated with integration of
"compact" equations are pointed out.

60. Regirer, S. A. (Vorkuta). The unsteady asymp-
totic boundary layer over an infinite porous
plate.

IzAN MeMa
no. 4
136-139

The parameters of the asymptotic boundary
layer on an infinite porous plate in an
unsteady compressible flow with uniform suc-
tion over the whole plate is discussed.

61. Frankl', F. I. (Kabardino-Balkarskiy
University). A new example of a plane-
parallel transonic flow with a straight
compressibility jump terminating in the
flow.

IzVUZ M
no. 2
244-246

62. Pol'skiy, N. I. Self-similar solutions of   IzVUZ AvT
    equations for the laminar boundary layer   no. 3
    in an incompressible liquid with heat   13-15
    exchange.

    The results of finding all the self-
    similar solutions by direct application
    of methods elaborated by Pol'skiy,
    A. Sh. Dorfman, and P. N. Romanenko are
    presented.

63. Adamskiy, V. B., and N. A. Popov. A gas   PMMe
    motion caused by pressure on the piston   v. 23, no. 3
    varying according to a power law.   564-573

    An integro-differential equation is
    derived for plane motion of a gas
    produced by a power-law-variable
    pressure on the piston. The same
    equation describes the motion caused
    by a short impact. An expansion is
    found which serves as a good approximate
    solution of this problem. Self-similar
    solutions of the problem and the behavior
    of hydrodynamic variables close to
    the piston are discussed.

64. Pashchenko, N. T. Flow of a highly rare-   PMMe
    fied gas past oscillating surface.   v. 23, no. 4
                                                  760-765

    The total force acting on a unit of a
    surface of a body in a translational
    motion and performing small transient
    movements is determined as well as the
    pressure, friction, et cetera, caused by
    the components of this force. The
    application of the free-molecule-flow
    method to analyze the flow past surfaces
    with concavities is discussed and limita-
    tions on the shape and motion of such
    surfaces are obtained.

65. Zhigulev, V. N., and Yu. L. Zhilin.   PMMe
       Bodies with minimal wave drag.   v. 23, no. 6
                                                             1019-1029
       Some variational problems for bodies
       with minimum drag at supersonic velo-
       cities are investigated. A method
       proposed by A. A. Nikol'skiy is used
       for determining optimum body shape.

66. Zysina-Molozhen, L. M. (Central Sci-   ZhETF
       entific Research Institute of Boilers   v. 29, no. 4
       and Turbines, Leningrad.). A study   637-639
       of a longitudinal pressure gradient
       on the development of a boundary
       layer.

       An experimental investigation for
       positive and negative values of the
       longitudinal pressure gradient is
       reported. Studies were made for ten
       pressure patterns along the surface
       over which the flow occurred.

67. Zel'dovich, Ya. B. Converging cylindri-   ZhETF
       cal detonation wave.   v. 36, no. 3
                                                             782-792
       The properties of detonation waves
       close to the normal detonation wave are
       considered. A theory of the amplifica-
       tion of a converging cylindrical detona-
       tion wave is proposed which exactly des-
       cribes the amplification at the start of
       the process. The theory gives satisfactory
       results even for small radii and consider-
       able amplification of the wave.

68. **Kucherov, R. Ya., and L. Rikenglaz. Slip-velocity and temperature jumps at the boundary of a gas mixture.**

    The development of a method for finding the boundary conditions for the hydrodynamic transfer equations of a binary nonhomogeneous gas mixture on a nonabsorbing solid surface is given. The conditions take into account slip-velocity and the gas interface.

    ZhETF
    v. 36, no. 6
    1758-1761

69. **Petukhov, I. V. Numerical integration of laminar boundary layer equations.**

    A method is presented for the exact integration of the equations of a boundary layer with arbitrary boundary conditions. The method can be generalized for the case of a laminar compressible boundary layer.

    1960
    DAN SSSR
    v. 132, no. 2
    307-310

70. **Petukhov, I. V. (Moscow). Integration of boundary layer equations using asymptotic solutions.**

    InSb
    v. 30
    149-169

71. **Avduyevskiy, V. S., and R. M. Kopyatkevich. Calculating the laminar boundary layer in a compressible gas in the presence of heat transfer and with arbitrary pressure distribution over the surface.**

    An approximate method is given for calculating laminar boundary layer with heat transfer in hypersonic compressible gas flows with a high pressure gradient. Temperature variation on the wall and integral energy correlation are taken into account. Flows around plane, axisymmetrical blunt bodies and bodies with sharp leading edges are considered.

    IzAN MeMa
    no. 1
    3-11

72. Bogdanova, V. V. A laminar three-
    dimensional boundary layer with
    longitudinal and transverse tempera-
    ture gradients.

    IzAN MeMa
    no. 1
    12-19

    The problem is reduced to the solution
    of ordinary differential equations with
    variable coefficients. Longitudinal
    and transverse velocity profiles in the
    boundary layer, the lines of the flow,
    and the magnitude of friction on the
    surface are determined.

73. Ruminskiy, A. N. Boundary layer in
    radiating and absorbing media.

    IzAN MeMa
    no. 2
    47-53

    A system of approximate partial dif-
    ferential equations is derived with-
    out any unknown integral radiant
    characteristics. A solution is obtained
    for a laminar boundary layer on a plate
    in the form of a series in two variables
    whose terms are determined by means of
    quadratures. The results are true for
    gray and selective radiations.

74. Kuptsov, V. M. The method of characteristics
    for an axisymmetrical equilibrium flow of
    real gas.

    IzAN MeMa
    no. 2
    138-144

    An equilibrium flow of gas is studied at
    very high temperatures and high pressures.
    It is assumed that the flow is in equili-
    brium, without heat transfer and friction,
    and that the flow is uniform in the initial
    cross section.

75. Larish, E. Aerodynamic interaction in free molecule flow.

Free molecule flow around several bodies of any shape (not only convex) is considered under the assumption that the dimensions of the entire system are smaller than the free molecular path. It is shown that the problem may be reduced to solving one linear integral equation. Since the form of this equation coincides with that of the equation of illumination theory, a method exists for simulating its solution which amounts to making photometric measurements.

76. Bunimovich, A. I. (Moscow). The effect of slip on the separation of a boundary layer.

The effect of rarefaction on velocity profiles above the detachment point in flows around curved surfaces is discussed. Critical pressure gradient is considered.

77. Mezhirov, I. I. Turbulent boundary layer of a real compressible gas.

Equations for perfect gases are derived from equations of motion, continuity, and energy. The equations are generalized and applied to real gases (for example, dissociated air), with the enthalpies substituted for the temperatures.

79. Chernyy, G. G. (Moscow). The application of integral relationships in problems of strong shock waves.

    PMMe
    v. 24, no. 1
    121-125

    An expression is derived for determining the parameters of propagation of explosion shock waves by using an integral relation on the total energy of the shock and the piston theory.

7 . Shidlovskiy, V. P. (Moscow). The laminar boundary layer on an infinite disk rotating in a gas.

    PMMe
    v. 24, no. 1
    161-164

    The laminar boundary layer on an infinite disk rotating at a constant angular velocity in a viscous gas is calculated.

80. Pavlov, K. B. (Bauman Higher Technical Institute). Theory of Prandtl-Meyer motion.

    PMMe
    v. 24, no. 1
    165-166

    The development of the theory for two-dimensional motion of the Prandtl-Meyer type is given. The particular case of flow in the presence of a shock wave ahead of the body, whose intensity decreases with increasing distance from the body, is covered.

81. Dem'yanov, Yu. A., and V. N. Shmanenkov. (Moscow). On investigating inverse flows in the region of a turbulent-boundary-layer separation.

    PMMe
    v. 24, no. 2
    237-239

    The free-turbulence pattern is used for analysis of flows in the region of

a turbulent-boundary-layer separation.
Inverse flows in the stagnation region
are taken into account. Plane and
axisymmetrical problems (supersonic
flow past a step and a blunt body with
a needle nose, respectively) are dis-
cussed.

82. Sychev, V. V. On the theory of hyper-
sonic gas flows with shock waves
described by power functions.

Plane and axisymmetrical hypersonic
gas flows with strong shocks whose
shape is given by power functions are
discussed. It is shown that a cor-
rection is necessary if utilizing the
exact solutions for solving the
corresponding self-similar gas-flow
problems.

83. Lunev, V. V. Self-similar case of hyper-
sonic flow of a viscous, heat-conduct-
ing gas past an axisymmetrical body.

An example of the flow past a slender,
axisymmetrical body at $M \gg 1$ is discus-
sed for the case in which the boundary
layer has a substantial effect on the
outer flow. It is shown that the
solution of this interaction problem
is self-similar.

84. Polyanskiy, O. Yu. Decay of shock waves
in a moving medium having variable
density and temperature.

The propagation and decay of shock
waves are studied under the assumption
that they are weak and that their

length is much smaller than the characteristic dimensions in the problem. Asymptotic formulas are derived for the excess pressure in wave fronts having a pressure profile.

Mikhaylova, M. P. (Moscow). Motion of a spherical piston at constant velocity through an inhomogeneous medium.

PMMe
v. 24, no. 5
919-922

The motion of gas behind a spherical piston moving at constant velocity through an inhomogeneous medium is studied. The shock wave formed ahead of the piston is considered.

Chuskhin, P. I. (Computing Center, Academy of Sciences USSR, Moscow) Blunted bodies of simple shape in a supersonic gas flow.

PMMe
v. 24, no. 5
927-930

A method of characteristics adapted to computer calculation of a supersonic gas flow around blunt bodies of simple shapes is presented. The results of calculation made by this method are given for several blunt cones and wedges.

Sandulescu, S. (Institute of Applied Mechanics, Rumanian Academy of Sciences, Bucharest). A method is presented for the characteristics of a three-dimensional boundary layer.

StuCeMeAp
v. 11, no. 1
61-77

Frankl', F. I., and Voyshel', V. V. Turbulent friction in the boundary layer of a flat plate in a two-dimensional compressible flow at high speed.

1937
TsAeGiI Report
no. 321

TSAGI Report No. 321 (Transl. as NACA
TM No. 1053 (1943)

89. **Galanova, Z. S.** The laminar boundary layer
      on a plate in the presence of dissociation.

VeLUMMeAs
no. 1
95-99

Second-approximation solutions are pres-
ented of laminar-boundary-layer equations
derived by M. Ye. Shvets (PMM, v. 13, no. 3,
1949) for a thermally insulated plate and
for a plate with a given wall temperature.
Results of numerical calculations for a
thermally insulated plate at Mach numbers
10, 20, and 30 are given.

90. **Dorodnitsyn, A. A.** A method for solving
      laminar boundary-layer equations.

ZhPMeTF
no. 3
111-118

A method suitable for computers is
described which gives exact values of
laminar boundary-layer parameters.

91. **Koldobskaya, T. G.** The problem of un-
      steady, nearly self-similar motion.

VeLUMMeAs
no. 1
111-122

A method of linearization nearly
identical with a self-similar
solution is used. The method can
be applied to plane shock waves in
flow past wedges and cones.

92. **Kutateladze, S. S., and A. I. Leont'yev.**
      Turbulent friction on a flat plate in
      supersonic flow.

ZhPMeTF
no. 4
43-48

It is shown that limiting solutions for turbulent boundary layers of compressible gases may be obtained by Prandtl's semi-empirical theory of turbulence.

93. Kosterin, S. I., and Yu. A. Koshmarov. (Institute of Mechanics, AS USSR, Moscow). Turbulent boundary layer on a flat plate in a uniform stream of a compressible fluid.

ZhTF
v. 29, no. 7
906-915

Translation: in Sov. Phys. Tech. Phys., Jan. 1960, 819-828.

An analysis is given of the effect of gas density variation on the distribution of velocities, temperatures, and densities in the boundary layer, and consequently, on friction and heat exchange for a plate in a gas stream.

94. Lun'kin, Yu. P. (Leningrad Physico-technical Institute, Academy of Sciences USSR). Variation of gas parameters caused by nonequilibrium dissociation behind a shock wave.

ZhTF
v. 30, no. 6
622-626

An approximate method is presented for the solution of a system of equations which describes the non-equilibrium dissociation of monatomic and diatomic gases behind a shock wave. In deriving an expression for the temperature distribution, it is assumed that the heat capacities of the gases are constant.

95. **Alekseyev, V. M.   On the theory of perturbed motion.**

A system of differential equations describing the relative motion of two bodies acted upon by perturbations of any nature combined with Newtonian gravitation is replaced by an equivalent system of integral equations on the basis of which various estimates are made concerning the perturbed Keplerian motion, the hyperbolic approach of two bodies, and convergence of the method of successive approximations.

96. **Charnyy, I. A., D. S. Vil'ker (deceased), B. I. Mitel'man, and G. D. Rozenberg. On two-phase supersonic flows.**

The supposition that a liquid introduced in a supersonic gas flow (freezing temperature of liquid is considerably higher than that of the gas) freezes, thus forming a two-phase flow, was verified by an experiment (water and gas at M = 1.2 and 3). This phenomenon can be utilized in cooling of bodies in high-speed gas flows. A quantitative theory will be given in future work.

97. **Kochina, N. N., and N. N. Mel'nikova. The theory of point explosions.**

The problem of a point explosion in a compressible medium, as studied in the Steklov Institute of Mathematics, Academy of Sciences USSR, is presented theoretically in this article, which was recommended for publication by L. I. Sedov. References are given to studies devoted to various aspects of the point-explosion problem.

98. Pressman, A. Ya. On the flow of a rare-
       fied gas from a point source into a
       vacuum.

                                                DAN SSSR
                                                v. 138, no. 6
                                                1305-1308

   A practically collision-free flow of
   particles of a sufficiently rarefied
   gas from a point source into a vacuum
   is considered from the standpoint of
   solving the Einstein-Fokker equations
   with a time-dependent "diffusion coef-
   ficient" and with boundary conditions.

99. Bazhenova, T. V. The gas-flow velocity
       behind the shock wave in a shock tube.

                                                EnI AN SSSR
                                                FGaTp
                                                31-35

   The evolution of heat in a gas flow in
   a shock tube is analyzed in order to
   establish the degree of uniformity in
   the interval between the shock wave and
   the interface and to verify the law of
   velocity changes in the shock wave region.
   Tests were made at M = 2 to 6.

100. Morozov, M. G., V. M. Yeroshenko, and
        Yu. P. Petrov. Flow in stagnation
        zones on surfaces in supersonic flow.

                                                EnI AN SSSR
                                                FGaTp
                                                60-65

   Experiments were carried out in an aero-
   dynamic tunnel, with an air velocity of
   M = 1.69, to determine the direction and
   magnitude of flow velocity in stagnation
   zones and to study the general pattern
   of the flow and the distribution of
   static pressures on the periphery of
   stagnation pockets.

101. **Naboko, I. M.** Deflagration in the stagnation region over an obstacle in supersonic flow.

EnI AN SSSR
FGaTp
42-45

The shape of the shock wave and the direction of the flow behind it are discussed on the assumption that the detonation front is an infinitely thin surface and that an instantaneous reaction takes place in the front with some heat generation. Tests were made in a shock tube with a mixture of hydrogen and oxygen at a flow velocity of $M \leq 1.25$, which corresponds to a wave velocity of $M \leq 2.65$.

102. **Murzinov, I. N.** The influence of the boundary layer on flow past slender, blunted cones at high supersonic velocities.

IzAN MeMa
no. 1
152-153

The influence of a laminar boundary layer on the distribution of pressures along the generatrices of a cone is evaluated approximately by using the small disturbance method.

103. **Larish, E.** Equations of free molecular flow.

IzAN MeMa
no. 2
70-77

Equations describing steady and unsteady free-molecule flows past bodies are derived with rebound of gas particles taken into account. Flows with a slight variation of parameters about their mean values are considered.

104. **Stulov, V. P.** (Moscow). Boundary layer on a plate with nonequilibrium dissociation taken into account.

    Viscous compressible gas flow past a plate under conditions making possible the dissociation and recombination of a diatomic gas is discussed.

<div align="right">IzAN MeMa
no. 3
5-12</div>

105. **Tagirov, R. K.** Determining the base pressure and temperature in sudden expansions of sonic or supersonic flows.

    A method for determining the base pressure and temperature in sudden expansions of plane or axisymmetric flows is discussed. The method is based on H. Korst's well known method, but it also takes account of nonisothermicity of mixing and propagation in the case of sudden expansion of an axisymmetric flow toward its axis of symmetry.

<div align="right">IzAN MeMa
no. 5
30-37</div>

106. **Kolodochkin, V. P.** Calculation of a supersonic flow about cones at angles of attack.

    The calculation consists of numerical integration of gasdynamics equations in three meridional planes. The results are compared with other calculation methods and with experimental data.

<div align="right">IzAN MeMa
no. 5
38-43</div>

107. **Murzinov, I. N.** Flow of gas near the stagnation point of a blunted body at a finite excitation velocity of vibrational degrees of freedom.

<div align="right">IzAN MeMa
no. 6
33-36</div>

An approximate solution is sought by
determining the gas parameters between
a shock wave and a body at M ≈ 7. The
influence of relaxation on the shock
wave during motion of a sphere in air
considered as a mixture of highly
rarefied oxygen and nitrogen is calcula-
ted.

108. Kosterin, S. I., Yu. A. Koshmarov, and
     Yu. V. Osipov. Shock-wave position in
     a supersonic nozzle.

An experimental study was made on the
effect of the divergence angle in the
supersonic section of a nozzle on the
position of a shock wave at a given
pressure ratio, with account taken of the
e   ot of heat transfer. The study was
conducted within the ranges of R_e and M
numbers representing the actual operat-
ing conditions of the nozzle with the
divergence angle varying from 0° to 50°.

109. Golubev, V. A. A study of a high-
     temperature gas stream.

A theoretical study is presented on a
high-temperature plane-parallel gas
stream. A purely turbulent stream is
assumed, that is, the molecular viscosity,
heat conductivity, and radiation energy
are neglected. Discrete solutions for
the differential equations of motion of
the boundary layer are used, taking into
account gas dissociation and ionization.
The formulas derived permit rapid calcula-
tion of the gas-stream parameters at all
points for any degree of initial pre-
heating.

110. Keldysh, V. V. Exact solutions [in geometry]   InZh
     of lift-producing systems with one and two   v. 1, no. 3
     attached plane shock waves.   22-39

     The shapes of lift-producing bodies in
     hypersonic air flows are discussed. The
     geometry of these bodies is taken from
     flow patterns behind one attached plane
     shock wave or two such intersecting shock
     waves. The geometric and aerodynamic
     characteristics of these bodies are
     determined for certain flight conditions.

111. Proshnikov, R. S. On almost free-molecule   InZh
     flow of rarefied gas around bodies.   v. 1, no. 3
                                                       60-64

     The correction to values of aerodynamic
     characteristics obtained by free-molecule
     theory to obtain corresponding values
     for higher Knudsen numbers is discussed,
     and the significance of secondary col-
     lisions is pointed out. The applicabi-
     lity range of this correction is pointed
     out.

112. Bakulev, V. I. Calculation of the turbu-   InZh
     lent mixing flow of a real gas.   v. 1, no. 3
                                                       65-74

     The solutions of the problem of the boun-
     dary layer in the initial portion of a
     plane-parallel, low-temperature real-gas
     (with solid and liquid phases eliminated)
     jet is presented. The investigation is
     based on Prandtl's theory of free turbu-
     lence, with the additional assumption
     that the mixing lengths are larger for
     scalar quantities (heat, density) than
     for vector quantities (momentum), that
     is, taking into account the rotation of
     the particles.

113. **Keringaziyev, E.** Investigation of   InZh
     transonic flow past a body for the   v. 1, no. 3
     purpose of designing an airfoil.   75-85

     High-speed subsonic flow around a body
     of arbitrary shape, with a shock wave
     at the rear of the supersonic region is
     investigated. Transonic symmetrical flow
     past a symmetrical airfoil is constructed
     by an approximate method. By applying
     equations for velocity, potential, and
     stream function, a flow pattern is obtained
     which suggests the shape of a double-
     wedge airfoil.

114. **Galkin, V. S.** Applicability limits of   InZh
     relaxation models of Boltzmann's kinetic   v. 1, no. 3
     equation [in the aerodynamics of rare-   153-156
     fied gases].

     Boltzmann's equation is simplified by
     using assumptions concerning the collision
     of molecules. The solution of the system
     of " model" equations is compared with the
     solution of an exact system of kinetic
     momentum equations of an ideal monatomic
     gas, and the limits of applicability for
     the models are established.

115. **Nikol'skiy, A. A.** One class of exact   InZh
     solutions of three-dimensional gas-   v. 1, no. 4
     dynamics equations.   11-17

     The calculation is simplified by intro-
     ducing cylindrical coordinates in the
     area of the velocity hodograph, and partial
     solutions are made possible by the method
     of separating the Fourier variables. These
     partial solutions lead to an exact solution
     of three-dimensional gas dynamics equations.
     The method is useful in the analysis of
     supersonic flow over fuselage-type bodies.

116. Fadeyev, S. I. Gas flow in a discharge
        tube.

        One-dimensional unsteady flow of a per-
        fect gas in a discharge tube is analyzed
        for the case where the energy release
        in the discharge gap is a function of
        time and is a determining factor of the
        process. A relationship between the
        energy release law and the law of the
        motion of a shock wave is derived.

117. Kostychev, G. I. (Kazan' Aviation Insti-
        tute). On optimal body shape in unsteady
        flowS.

        The determination of optimal body shape
        and the effect of unsteadiness on
        optimal shape are discussed.

118. Stanyukovich, K. P., and V. P. Shalimov.
        On the motion of meteor bodies in ter-
        restrial atmosphere.

        Two stages of meteor motion in the earth's
        atmosphere are discussed: 1) in the upper
        layers of the atmosphere where the free
        path of the air molecules is larger than
        the diameter of the meteor body and 2) in
        the lower layers where a strong shock
        wave is formed in front of the body.

119. Chernyy, G. G. (Moscow). A method of in-
        tegral relations for analyzing gas flows
        with strong shock waves.

        A general approach to utilization of
        integral relations in the solution of
        problems related to flows with strong
        shock waves is presented. Some parti-
        cular sample problems concerning the
        detonation waves, and waves in shock
        tubes are discussed.

120.. Arkhimov, V. N. Plane-parallel flow of compressible fluid in the wake of a body.

Equations of motion, continuity, and energy are formulated for the following conditions: at a given distance from the body, the pressure is approximately constant in the cross section of the wake, the transverse velocity is small as compared with the longitudinal velocity, the rate of change in longitudinal velocity, along the axis of the wake is small as compared with the rate of its transverse change, and the rate of pressure change along the wake is negligible.

121. Pal'kcvich, S. V. (Saratov). Near-sonic plane laminar gas flow with singular points on the sonic line.

Near-sonic plane laminar flows with singular points on the sonic line were studied. Solutions with a singular point on the sonic line of Tricomi's equation and solutions of Chaplygin's equation are used to obtain solutions in the form of an infinite series, the first term of which is the corresponding "self-simulating" solution of Tricomi's equation. The cases of wedge-shaped profiles and flat plates are considered as illustrative examples.

122. Medukhovskiy, I. B. (Moscow). The flow at an angle of attack past a finned body of revolution.

The regularity patterns of a flow past a body of revolution are discussed using general assumptions on the relation between

aerodynamic flow parameters and orienta-
tion of the velocity vector of the oncoming
flow relative to the meridians. Dependence
of aerodynamic forces on the angle of
attack of a longitudinally finned body of
revolution is discussed as well as the
number of fins, assuming that there is
no aerodynamic interference between them.

123. Sychev, T. V. (Moscow). Hypersonic gas
flow of a viscous, heat conducting gas.

PMMe
v. 25, no. 4
600-610

Motion of a body in hypersonic flow of a
viscous heat conducting gas is studied
and equations characterizing the gas flow
around the body are derived on the basis
of the Navier-Stokes equation for an in-
finite Mach number. General common
properties of steady hypersonic flow
around bodies with formation of a strong
shock wave, and self-similar unsteady
flows with $t^{\circ} = 0$ in the undisturbed
region x are discussed.

124. Galkin, V. S., and A. A. Gladkov (Moscow).
Lift at hypersonic speeds.

PMMe
v. 25, no. 6
1138-1139

Presents a study demonstrating that the
lift for a large class of bodies (wedge,
cone, et cetera, but not a cylinder or
plate) in a free-molecule hypersonic
flow at any value of Knudsen number and
in a continuum hypersonic flow is negative
for any angle of attack in the range from
zero to 90°.

125. Dorodnitsyn, A. A. Solution of boundary
layer equations.

IPMMe, ANSSSR
Sib. O. Sb.
77-83

A short presentation is made of one method
for the exact solution (with any degree

of accuracy) of equations of a laminar
boundary layer of a noncompressible liquid.
Two examples are presented which show the
rate of convergence of the method. It is
noted that although setting up the system
of differential equation is a tedious
process, the solution of the system on high-
speed computers is simple.

126. Ginzburg, I. P. (Leningrad State University).   VeLUMMeAs
     Turbulent boundary layer on a plate in a   no. 1
     compressible flow.   75

     The skin friction and heat transfer on a
     flat plate in a turbulent hypersonic flow
     at arbitrary Prandtl numbers are determined
     with dissociation and diffusion taken into
     account.

127. Kulonen, L. A. Calculating the parameters   VeLUMMeAs
     of a laminar boundary layer on a flat   no. 1
     plate in dissociating gas.   128-132

     Equations for a laminar boundary layer
     on a flat plate are solved with the
     chemical nonequilibrium dissociation of
     a diatomic gas under conditions of in-
     complete thermodynamic equilibrium taken
     into account, under the assumption that
     the specific enthalpies of atomic and
     molecular components are arbitrary
     functions of gas temperatures.

128. Belova, A. V., and S. V. Vallander. Integral   VeLUMMeAs
     kinetic equations in the theory of monatomic   no. 2
     gases in an external field of body forces.   75-80

The system of equations derived is intended to describe a gas flow subjected to a constant external field of body forces. It is shown that the equations can be used for a variable external field with negligible variations. In deriving the equations, the fact was taken into account that the trajectories of atoms in the external field of body forces are curvilinear.

129. Vallander, S. V., and A. V. Belova.
Integral kinetic equations for gas
mixtures with internal degrees of
freedom.

VeLUMMeAs
no. 2
81-86

A system of integral kinetic equations
is presented for a mixture of polyatomic
gases flowing in a constant external
field of body forces in the presence of
chemical reactions. The system of equa-
tions can be solved by the method of
successive approximations. It is as-
sumed that for gas motion only molecular
collisions in pairs are essential and
that the gas particles formed by the
chemical reactions are electrically
neutral.

130. Kulonen, L. A. A method for analyzing a
laminar boundary layer on a porous sur-
face.

VeLUMMeAs
no. 2
123-135

The laminar boundary-layer problem of the
motion of a binary mixture of gases with
different physical properties is considered
for the general case of a variable free-
stream velocity, a variable surface tempera-
ture, and an arbitrary relationship
between the mass-transfer coefficients,
temperature, and concentration. The
method can also be used for solving the
problem of gas-mixture motion on a boun-
dary layer with injection through the
porous surface.

131. **Koldobskaya**, T. G., and I. A. Sychev. Irregular reflection of a shock wave from a curvilinear wall.

The problem is solved by Paper's method with some additional assumptions. A series of experimental investigations was made to compare data for reflection from curvilinear profiles and wedges.

132. **Ryzhov**, O. S. Decay of shock waves in inhomogeneous media.

Physical phenomena associated with the propagation of small-amplitude waves in a nonuniform medium are explained. The interaction of two shock waves is analyzed for the case in which one overtakes the other.

133. **Lunev**, V. V., and I. N. Murzinov. Effect of radiation on the flow in the stagnation point region of a blunt body.

The effect of thermal radiation of a gas on its flow parameters near the stagnation point of a blunt body is discussed, disregarding the radiation pressure, the interaction between radiation and oncoming flow in the shock layer, and the effect of the thin boundary layer.

134. **Ryzhov**, O. S. The decay of shock waves in steady flows.

The basic characteristics of the development of shock waves of small amplitude in nonhomogeneous steady supersonic flows are studied for the case where the width

of the disturbed-flow region is assumed
to be small compared with the radius of
curvature of the shock waves and the
distance at which the parameters of the
initial medium change appreciably.

135. Sayasov, Yu. S. Structure of an oblique   ZhPMeTF
     shock wave in a chemically reactive   no. 6
     gas.   172-174

     The system of equations describing the
     flow or a chemically reactive inviscid
     gas behind an oblique shock is used in
     analysis of flow parameters behind the
     shock wave. Assumptions are made that
     the front of the shock wave is plane
     and that the flow lines behind the shock
     wave are rectilinear.

136. Grebenshchikov, S. Ye., M. D. Rayzer, A. A.   ZhTF
     Rukhadze, and A. G. Frank.   v. 31, no. 5
                                                        529-538

     In an experimental study of the inter-
     action of converging ring-type shock
     waves with a " magnetic wall," shock
     waves were produced in a vacuum chamber
     at a frequency of 360 kc by discharging
     two parallel-connected 0.2-µf capacitors
     through a copper ring surrounding the
     chamber. Comparison of the experimental
     results with those obtained theoretically
     for plane shock waves interacting with a
     magnetic wall showed close agreement.

137. Lun'kin, Yu. P., and F. D. Popov. Non-   ZhTF
     equilibrium dissociation of a gas mixture   v. 31, no. 6
     behind a shock wave.   726-730

     Nonequilibrium dissociation of a mixture

of two diatomic, or of one monatomic gas
and one diatomic gas behind a normal
shock wave is investigated. An approxi-
mate method of solving the equations (of
conservation of state and of relaxation)
which describe such dissociation is pre-
sented.

138. Gvozdeva, L. G. (Laboratory of Combustion
Physics, Krzhizhanovskiy Institute of
Power Engineering, Moscow). Refraction
of detonation waves by incidence on the
boundaries between two gaseous mixtures.

ZhTF
v. 31, no. 6
731-739

A motion picture investigation of rare-
faction of a shock wave moving in a
reacting medium as it passes through
a boundary between this medium and an
explosive or inert medium is presented.

139. Lun'kin, Yu. P. (Ioffe Physicotechnical
Institute, Leningrad). Measurement of
entropy in the relaxation of a gas
mixture behind a shock wave.

ZhTF
v. 31, no. 9
1112-1118

The relaxation of a mixture of a diatomic
gas and a monatomic gas behind a shock
wave is analyzed. The excitation of
degrees of freedom and entropy changes
behind weak and strong shock waves are
discussed.

140. Koryavov, P. P. Numerical calculation of
laminar flows.

ZhVychMMF
v. 1, no. 5
856-868

The problem of jet mixing of two steady
laminar semi-infinite flows of compressible
viscous gases of different velocities and
temperatures is considered. A method is
presented for numerical calculation of

velocity and temperature profiles in
the mixing zone on the basis of the
general boundary layer theory, under the
assumption that parameters of gas density—
viscosity, heat transfer, and specific
heat at constant pressure are known
functions of temperature.

141. Shchennikov, V. V. (Moscow). An analysis   ZhVychMMF
       of a laminar boundary layer over a sub-   v. 1, no. 5
       liming surface.   869-883

       Equations are derived and boundary
       conditions are established for analysis
       of the laminar boundary layer over a
       subliming, axisymmetric, blunted body in
       a high supersonic flow, taking the chemical
       reactions into account.

142. Godunov, S. K., A. V. Zabrodin, and G. P.   ZhVychMMF
       Prokapov. A difference scheme for two-   v. 1, no. 6
       dimensional gas dynamics problems.   1020-1050

       A method was developed for the numerical
       solution of two-dimensional gas dynamics
       problems. The difference computational
       scheme for gas dynamics equations and the
       formulas for approximate calculation of
       the decomposition of discontinuity were
       worked out and are presented in detail.
       The stability of the difference scheme
       was studied only for the case of a
       linearized system of gas dynamics equations
       with constant coefficients; necessary and
       sufficient stability conditions of the
       scheme for this sytem were derived. The
       difference method is also applied to the
       case of a homogeneous supersonic flow of
       an ideal gas around a sphere.

143. **Babenko, K. I., and G. P. Voskresenskiy.**
A numerical method for calculating the
flow of gas around bodies.

A method for numerical calculation of the
three-dimensional supersonic flow of an
ideal gas around pointed bodies has been
developed. Programs are worked out for
electronic digital computers, and calcula-
tions are made of the flow around a
circular cone and a body of revolution for
various values of Mach number and of angle
of attack.

144. **Dorodnitsyn, A. A.** Numerical methods for
solution of laminar boundary-layer
equations.

A general method of integral relations
used at the Computing Center of the
Academy of Sciences USSR for the solution
of complicated boundary-layer problems
by means of high-speed computers is
described. General expressions are
derived for integral relations for a
boundary layer in a "classical" compres-
sible fluid (that is, without chemical
reactions and radiation) which can easily
be adapted to incompressible fluids.

145. **Lubonski, J.** Hypersonic plane couette
flow in rarefied gas.

Hypersonic plane Couette flow in a rare-
fied gas is considered in terms of a
certain approximation method which is of
more general use than conventional ones
and can be applied to other hypersonic
flows. A flow between two walls which
reflect molecules diffusely is considered
because of its simplicity. Fields of
macroscopic values, such as density, mean
velocity, and temperature are investigated.
The molecules are grouped into three
classes according to their motion origin.
The gas is regarded as a mixture of the
three classes and the molecules are con-
sidered as rigid spheres.

146. Goz'kov, L. P., and L. P. Pitayevskiy.   DAN SSSR
        The origin of a shock wave caused by   v. 144, no. 2
        reflection of a weak discontinuity   293-296
        from the sonic line.

        The reflection of the weak discontinuity
        (the discontinuity of the first deriva-
        tives of velocity) from the sonic line
        was studied with the aid of the Euler-
        Tricomi equation describing the sonic
        flow of gas. Formulas describing the
        change of parameters on a shock wave are
        derived.

147. Bazhenova, T. V., and O. A. Predvoditeleva.   EnI AN SSSR
        A comparison of air parameters behind   FGaTp
        shock waves.   15-24

        Thermodynamic and gas dynamic parameters
        behind normal, incident, and reflected
        shock waves are compared under certain
        assumptions on equilibrium dissociation
        of air; the excitation of degrees of
        freedom of particle is considered.

148. Anfimov, N. A. The laminar boundary   IzAN MeMa
        layer in a multicomponent mixture of   no. 1
        gases.   25-31

        The equations of a laminar multicomponent
        boundary layer are solved in the neighbor-
        hood of the stagnation point of a blunt
        body in a flow of dissociated air. It is
        assumed that the chemical reactions inside
        the boundary layer are frozen and that the
        state of the gas at the wall and in the
        outer boundary of the layer is in equili-
        brium.

149. Avduyevskiy, V. S. (Moscow). Analysis of   IzAN MeMa
      a three-dimensional laminar boundary   no. 1
      layer along geodesics in the flow.   32-41

      Differential equations are derived for
      flows in the regions of the geodesics on
      a cone under an angle of attack, slip
      flow past an infinite cylinder, and at
      the forward stagnation point. Formulas
      are given for calculating the parameters
      of heat transfer, friction, and boundary
      layer.

150. Shidlovskiy, V. P. Flow of slightly rare-   IzAN MeMa
      fied gas about a sphere.   no. 2
                                                         17-24

      Slip flow about the forward part of a
      sphere is considered. This flow cor-
      responds to Knudsen numbers K from 0.1 to
      0.01. It is assumed that the Mach
      number is of the order of 1/K.

151. Mel'nikov, D. A. Shock wave reflection in   IzAN MeMa
      a supersonic gas flow.   no. 3
                                                         24-30

      The problem is studied of a gas flow
      through the region of an incident shock
      wave reflected from the axis of symmetry,
      where a normal shock wave is formed.
      A method is developed for determining
      a subsonic flow beyond the normal shock
      wave. Shadow photographs are given of
      flows from four axisymmetrical nozzles
      of different shapes, with uniform and
      nonuniform velocity fields and Mach
      numbers from 2.8 to 3.2 and 2.67 to 3.37.

152. Anfimov, N. A. The laminar boundary layer   IzAN MeMa
      on a chemically active surface.   no. 3
                                                         46-52
      The burning of a blunted semi-infinite

body (consisting of various carbon, oxygen, and hydrogen compounds) in a flow of high-temperature air is discussed. The boundary layer in an eight-component gas mixture in the presence of chemical reactions and mass exchanges on the body surface is examined. A method is given for determining the rate of burning and the surface temperature is given.

153. Shkadov, V. Ya. A solution of the boundary layer problem.

IzAN MeMa
no. 3
173-175

The flow of a viscous incompressible fluid in a boundary layer is studied and equations with solutions which satisfy particular boundary conditions are analyzed. Analytical series are employed to derive two satisfactory solutions, for boundary layers starting at the boundary edge and at the critical point and for bodies with sharp and blunt edges.

154. Vulis, L. A. An interpolation formula for a transient region of flow.

IzAN MeMa
no. 3
180-182

An interpolation formula is presented, based on phenomenological treatment of the process of transition from a steady laminar regime to a turbulent one, which is applicable to integral (drag, heat transfer, et cetera) and local (effective viscosity and temperature conductivity in a turbulent boundary layer) governing laws.

155. Avduyevskiy, V. S. A method for analyzing a three-dimensional turbulent boundary layer in compressible flow.

IzAN MeMa
no. 4
3-12

A method is developed for calculating a turbulent boundary layer in a compressible

two- or three-dimensional hypersonic flow
on an arbitrary curvilinear surface. The
formulas for a flat plate are applied at
every point of the body, and in place of
the true length along the surface of the
body, a certain effective length which
satisfies the basic integral correlations
is considered. The expressions for the
parameters of a turbulent boundary layer,
are obtained by analyzing experimental
data on turbulent boundary layers. Calcula-
tion of the friction drag at Mach 6 on an
axisymmetrical ideal nozzle is presented,
as are sample calculations of the heat ex-
change for a Mach 10 three-dimensional flow
around a cylinder of infinite length, and
around sharp- and blunt-nosed cones.
The effect of the shock-wave curvature
is taken into account and discussed.

156. Dorfman, L. A. The boundary layer on bodies
     rotating at high velocities.

An approximate method is presented for
calculating the boundary layer on axisym-
metrical bodies (turbine wheels, propellers,
rotors, and projectiles) rotating at high
velocities in axial flows. The inflow
("ventilating") effect of rotation on the
flow in the boundary layer is taken into
account. A comparison of the results with
those obtained by the method set forth
by E. Truckenbrodt in 1954 indicates that
the present method gives values closer to
experimental data.

157. Cherkez, A. Ya. Averaging of supersonic
     gas-flow parameters.

The possibility of using the relations
and methods of one-dimensional gas
dynamics in the study of highly irregular
supersonic flows is considered. It is
demonstrated that for irregular super-
sonic flows in which the stagnation
temperature is constant, it is possible
to find average parameters which will
satisfy the flow conditions.

158. Avduyevskiy, V. S., and Ye. I. Obroskova.
Laminar boundary layer on a porous plate
in the presence of chemical reactions on
its surface.

A laminar boundary layer with chemical
reactions on a porous plate through
which a gas is injected is discussed.
Approximate formulas are derived for
determining the boundary-layer para-
meters, with carbon and hydrogen
burning on the plate surface and binary
diffusion in the boundary layer.

159. Cherkez, A. Ya. One-dimensional theory
of supersonic gas jets.

The one-dimensional theory is shown
to give quantitative results conforming
with experimental data, to determine
qualitative flow laws, and to disclose
the physical meaning of some character-
istics of the initial portion of the
jet.

160. Kireyev, V. T. Shock wave propagation in
a shock tube.

A flow pattern is presented for deter-
mining the variations in shock wave
velocity and flow parameters of the
driving and driven gases during dia-
phragm opening. Results of numerical
calculation of the shock wave velocity
and cross-section area variation of
the opening are presented in graphs.

161. Lunev, V. V. (Moscow). A shock layer
method in problems of hypersonic flow
over thin blunted bodies.

The method proposed by H. Cheng, T. Hall,
T. Gollian, and A. Hertzberg for approximate
calculations of a flow over thin blunt
bodies is analyzed. It is shown that the
solution obtained for any isentropic
exponent not equal to unity contradicts
the results obtained by G. G. Chernyy,
who used another method, which gives,
in general, more accurate results.

162.   Kutateladze, S. S., and A. I. Leont'yev.   InFZh
        Calculating turbulent boundary layer   v. 5, no. 1
        parameters under essentially positive   33-41
        pressure gradients.

        A new successive-approximation method for
        calculating the parameters of a turbulent
        boundary layer was developed. The analysis
        is based on the limiting laws of friction
        and heat exchange in the diffusion region
        of gas flow. Equations for determining
        the velocity profile within the turbulent
        layer, the drag distribution, and the limit-
        velocity profile at the point of separation
        are also derived and show good agreement
        with experimental data.

163.   Romishevskiy, Ye. A. (Moscow). Boundary   InFZh
        layer and steady gas discharge diffusion-   v. 2, no. 1
        pattern radiation.   170-174

        The process of the interaction of a
        viscous radiating gas-flow at reentry
        velocities with the surface of a body in
        a thin layer which has a boundary-layer
        pattern is discussed, as well as phenomena
        in a steady gas discharge under high
        pressure which are of the same character.
        It is assumed that the radiation range
        is small and has a diffusion pattern.

164. Slezenko, Z. F. The velocity profile of   InFZh
     the boundary layer on a nonuniformly   v. 5, no. 10
     heated plate.   47-52

     A method was devised for direct measure-
     ment, with an accuracy of 0.01 to 0.005 cm/sec,
     of local values of the small-velocity profiles
     in the boundary layer on a nonuniformly
     heated plate. Based on the photoelectric
     principle, the method is applicable to weakly
     rarefied and nonrarefied gases. A circuit
     diagram of the device used in the measure-
     ments is given, along with the method of
     calculating velocities from a nomogram.

165. Kostychev, G. I., and V. I. Polkovnikov.   IzVUZ AvT
     Variational problems of gas dynamics.   no. 1
                                                      11-18
     The effect of flight conditions on the
     optimum form of an aircraft and its
     vertical motion are studied.

166. Dulov, V. G. An approximate method for   IzVUZ AvT
     calculating slightly divergent supersonic   no. 2
     axial flows.   8-14

     For the calculation of slightly divergent
     supersonic isentropic gas flow, the Lenin-
     grad Institute of Mechanics has developed
     an approximate method which combines and
     to some extent is based on two classical
     methods, that of characteristics and that
     of the linearization of equations and
     boundary conditions.

167. Dulov, V. G. Shock-wave propagation in a   IzVUZ AvT
     variable-cross-section channel.   no. 3
                                                      17-24
     The propagation of a shock wave formed in
     a gas duct of constant cross section and
     moving through a short divergent channel is
     analyzed and the dependence of shock wave
     parameters on the area of the cross section
     of the channel is established.

168. Tolstykh, A. I. A turbulent boundary layer   InZh
     with pressure gradients on a porous surface.   v. 2, no. 1
                                                       79-86

     The problem is analyzed for incompressible
     gases, and the results are generalized
     for compressible gases. The equations may
     be used for calculating any general case
     of a turbulent boundary layer with diffusion
     and heat transfer.

169. Nikol'skiy, A. A., and B. A. Smirnov. Action   InZh
     of a shock wave on an obstacle.   v. 2, no. 1
                                                       181-188

     Some specific obstacles, both two- and
     three-dimensional, are considered. The
     overall impulses and moments and also
     the distribution of pressure impulses on
     the surface of the body are determined.
     It is shown that when the velocity is
     sufficiently low and vorticity may be
     neglected, the problem can be reduced to
     the case of incompressible-fluid flow.

170. Stanyukovich, K. P. Variation of arbitrary   InZh
     constants in self-similar solutions.   v. 2, no. 2
                                                       355-358

     An approximate method for calculating the
     variation of arbitrary constants in the
     propagation of moving shock waves is
     presented. The new solutions are based
     on the principle that any motion of
     gases in small volumes for short time
     intervals may be considered self-similar.

171. Neyland, V. Ya., and G. I. Taganov. The   InZh
     flow pattern in the separation region.   v. 2, no. 3
                                                       36-42

     A general solution of the problem of
     the flow in the boundary-layer separation
     region with a return flow is presented.

The study is restricted to the plane
flow of an incompressible fluid within
the plane flow of an incompressible
fluid within the stagnation zone, and
to a supersonic flow past a body with
a needle fixed at its front. The
formation of separation zones, the zone
angles, and the velocity profiles are
discussed in both flows.

172. Petukhov, I. V., and A. L. Ankudinov. The   InZh
      effect of flow vorticity and body curva-   v. 2, no. 4
      ture on boundary layer.   262-268

      The effects of flow vorticity outside
      the boundary layer, as well as of the
      curvature of body contour, on the
      structure of the boundary layer are
      analyzed by using a strict formulation
      of boundary conditions for the secondary
      streams in the layer. The results of this
      analysis were used as a correction of
      the known solution of this problem (with-
      out outer-flow vorticity) by Blasius.

173. Shcherbina, Yu. A. The effect of initial   MoFTI
      turbulence on the boundaries of a mixed   no. 7
      jet.   152-157

      Results are presented of an experimental
      investigation of a two-dimensional mixed
      jet in its initial region, where the
      structure of the jet is disrupted due to
      high turbulence. Turbulence measurements
      were made by the optical-diffusion method
      at the same distance from the nozzle
      grid in all cases. Initial velocity was
      kept constant in all of the experiments.
      The schematic diagram of an experimental
      device is given, as well as graphs of
      velocity distribution and relative
      boundaries of the mixing region.

174. Ladyzhenskiy, M. D. An analysis of hyper-
     sonic flow equations and the solution of
     the Cauchy problem.

     General equations of hypersonic vortex
     flows are investigated. The approximate
     solution of the Cauchy problem is compared
     with exact analytical and numerical
     solutions. The results can be used for
     studying internal hypersonic flow.

175. Zhilin, Yu. L. Similitude parameters at
     high hypersonic velocities.

     Similarity conditions established by
     W. D. Hayes and R. F. Probstein for
     intermediate hypersonic velocities
     are extended to high hypersonic
     velocities. Analytical expressions
     are given.

176. Kogan, M. N. Hypersonic flows of a rare-
     fied gas.

     The basic theoretical concepts and the
     criteria and conditions for the existence
     of near-free-molecular hypersonic flows
     are discussed. Flow past a plate perpen-
     dicular to the flow direction is considered
     for various Mach numbers and collision
     cross sections. It is assumed that re-
     flection of molecules from the plate is
     diffusive with a Maxwellian velocity
     distribution.

177. Galkin, V. S. On the lift in a free
     molecule flow.

     It is shown that the lift of certain
     finite-length bodies in a free -molecule
     flow can be negative at any angle of
     attack between 0 and 90° and with forces
     acting on bases of such-bodies taken
     into account.

178. Kulkovskiy, A. G. On shock-wave structure.

Solutions of general gas-flow equations which can be used in gas-dynamics and magneto hydrodynamics and analyzed and the structure and behavior of shock waves are discussed.

PMMe
v. 26, no. 4
631-641

179. Ladyzhenskiy, M. D. Flow of viscous gas into vacuum.

Viscous, heat-conducting gas flows from two-and three-dimensional sources were studied by using Navier-Stokes equations with the assumptions that the coefficients of viscosity and heat condictivity are power functions of temperature and that the Prandtl number is constant. An asymptotic solution is sought for the case of the flow of gas into a vacuum when the pressure at infinity approaches zero.

PMMe
v. 26, no. 4
642-649

180. Jakob, I. A., A. Zaharescu, and L. Dumit-rescu. A method for measuring the velocity of shock-wave propagation.

A method for measuring the velocity of shock-wave propagation is discussed. The measurements by a simple and compact unit with circuit components of original design are accurate to 0.2 to 0.5% for Mach numbers from 1 to 4. The arrangement of the system is described and shown in a diagram; a concise description of the characteristics of the component blocks is given.

RevMeAp
v. 7, no. 1
173-183

181. Losev, S. A., and Osipov, A. I. An investigation of nonequilibrium pheno-mena in shock waves.

UaFN
v. 74
393-434

The following nonequilibrium phenomena
were investigated in shock waves: 1)
equalizing processes based on the ki-
netic theory of gases (qualitative study);
2) the state of the gas in a shock wave
(experimental study). The operation of
a shock tube was also studied.

182. **Filippov, B. V.** A variant of unsteady
kinetic equations in rarefied-gas aero-
dynamics.

VeLUMMeAs
no. 1
142-146

Unsteady gas flow is described by a system
of kinetic integral equations derived for
the case in which the initial value of
the distribution function is given.

183. **Taibarov, V. A.** Relationship between
equations of the kinetic gas theory.

VeLUMMeAs
no. 1
147-151

The connection between the solutions of
integral-differential and integral-
kinetic equations derived by Vallander,
Fenner, and Sinter is established.

184. **Vallander, S. V., E. A. Gurmuzova, and B. V.
Filippov.** Kinetic integral equations for
an arbitrary conservative field of external
forces.

VeLUMMeAs
no. 3
87-89

A system of kinetic integral equations is
presented which describes the motion of
a gas consisting of particles with
internal degrees of freedom moving in an
arbitrary field of mass forces changing
so slowly that they can be considered
constant within the limits of a molecule.

185. Aleksenko, I. I., R. G. Barantsev, and I. N. Panteleyeva. The method of transversal approximation in hypersonic flow.

The method of transversal approximation is used for establishing the relation for the variation of flow parameters across the layer between the shock wave and the body along the normal to the shock wave. The basic features of the method are analyzed through quadratic approximation of the stream function; a detailed and complete study is carried out for the case of linear approximation.

186. Lugovtsov, B. A. (Novosibirsk). The propagation of a shock wave from a distant explosion in a water reservoir of constant depth.

The site of the explosion is located at a distance (comparable to the depth of the reservoir) such that the disturbances caused by the passage of the shock wave are quite small, thus permitting one to consider the motion caused by this passage as short-wave propagation.

187. Mezhirov, I. I. One-dimensional gas flow in a channel of varying cross section in the presence of friction and heat exchange.

The problem of calculating one-dimensional gas flow in a channel with varying cross section in the presence of friction forces and heat exchange between the gas and the external medium is considered. The effect of these factors on the total gas pressure is determined, and the problem of determining the channel-area variation necessary to obtain a designated Mach-number distribution for a given heat exchange law is solved.

188. Leonas, V. B. A study of interaction between free-molecule   flow and a wall.

ZhPMeTF
no. 6
39-44

A method of experimental laboratory measurement of the coefficient of impulse transmission in the flow of a rarefied gas against a surface is discussed. An installation for producing a high-speed molecular beam from a supersonic jet of rarefied gas is described, and the results of a study on the angular distribution of recoil molecules are given. Measurements of the velocities of recoil particles are also presented.

189. Korobeynikov, V. P. An analogy between a cylindrical explosion and hypersonic gas flow past bodies.

ZhPMeTF
no. 6
45-49

An approximate analytical method for determining the law for the motion of an explosion wave and the pressure in the center of the blast is presented. The procedure used in this method is compared with that employed in the analysis of an inviscid hypersonic flow past blunted bodies. It is shown that with an increased Mach number, the shape of the shock wave in the flow approaches that of an explosion wave.

190. Lapin, Yu. V. (Leningrad Polytechnical Institute). A turbulent boundary layer in dissociating gas.

ZhTF
v.32, no. 4
473-479

The influence of equilibrium dissociation of an "ideal dissociating gas" on friction and heat transfer in a turbulent boundary layer of a plane plate is studied.

191. Kulonen, G. A. Application of the Kochin-
      Loytsyanskiy method to analysis of a
      laminar boundary layer with an interface.

The flow parameters of a two-dimensional
boundary layer at the stagnation point are
discussed. It is assumed that a film is
formed on the surface of a body from a
substance which is in a different phase
(gaseous or liquid) than that of the on-
coming flow, so that an interface is formed;
The densities of both phases are constant,
and their physical properties independent
of the temperature. The surface-tension
forces are neglected.

192. Lozgachev, V. I. The theory of free mole
      cule flow. II. Passage through chambers
      of arbitrary shape.

The general problem of free-molecule
flow through a chamber with arbitrary
location of the inlet orifice and the
outlet orifice is considered, that is,
the probability of a molecule passing
through the chamber is sought. It is
assumed that the mean free path of a
single molecule is greater than any
dimension of the chamber, that there is
no interaction between molecules, and
that the chamber walls reflect all
incident molecules according to a specific
law.

193. Belotserkovskiy, O. M. (Computing Center,
      Academy of Sciences USSR). Supersonic
      flow of perfect and real gases around
      blunt-nosed bodies.

The method of integral correlation is
applied to the problem of hypersonic flow
around blunt bodies at Mach numbers
$M_\infty = 4$ to $M_\infty \to \infty$.

194. **Hess, H.** (Physikalisch-Technisches Institut, Bereich Strahlungsquellen, der deutschen Akademie der Wissenschaften). Discontinuity conditions in the front of an ionizing shock wave.

The gasdynamic parameters upstream from an ionizing shock wave propagating in helium at 25 mm Hg, at velocities of less than 20 M, were calculated by means of the Rankine-Hugoniot equations, equations of state, and the Saha equation for ionization. The density, pressure, temperature, gas velocity, and degree of ionization were plotted for ionizing and non-ionizing waves as functions of M up to M = 18.

195. **Mikhaylova, M. P.** Motion of gas behind an asymmetrical piston.

The motion of piston in a homogeneous gas is investigated under the assumption that the gas in front of the piston is at rest. The solution is sought for self-similar motion of the gas behind a piston moving at a constant speed.

196. **Korobeynikov, V. P., and V. P. Karlikov.** The parameters and shape of a shock wave front produced by an intense explosion.

An approximate method is presented for calculating the parameters and shape of a shock wave produced by a point explosion in an inhomogeneous medium. Analytical relationships permitting determination of the shape are given, together with the law of its change with time. The method can be applied to the problem of explosions in a nonisothermic atmosphere.

197. Kuksenko, B. V. (Moscow State University).   DAN SSSR
A method of rarefied-gas-flow analysis.   v. 151, no. 5
1040-1045

A method is outlined for setting up
systems of equations for many functions
of a small number of independent vari-
bles which are sufficient for obtaining
an approximate solution of aerodynamic
problems of rarefied gases.

198. Struminskiy, V. V. (Corr. member, AN SSSR).   DAN SSSR
On the nonlinear theory of aerodynamic   v. 151, no. 5
stability.   1046-1049

The successive-approximation (small-
parameter) method is applied to the
study of the aerodynamic stability of
disturbed viscous incompressible fluid
flows between two parallel walls and in
the boundary layer. The bounds of sta-
bility and the development of disturbances
with time are discussed.

199. Petrosyan, L. G.   On the solution of the   IzAN ArmSSR
boundary-layer equation.   FM
       v. 16, no. 5
A solution of the boundary-layer dif-   91-98
ferential equation is presented in the
case when the pressure gradient is zero
and the equation of the potential-flow
velocity are given. Expressions for the
flow parameters and shear stresses on a
plane surface are derived.

200. Ginevskiy, A. S., and Ye Ye. Solodkin. The   IzAN MeMa
effect of transverse surface curvature on
characteristics of an axisymmetric, non-   no.1
isothermal, compressible turbulent boundary   99-110
layer.

A theoretical investigation of the above-mentioned problem in a high supersonic flow is presented. Flows past convex (cylindrical) and concave (channel) surfaces are discussed for various Reynolds and Mach numbers, and various values of a temperature parameter are discussed.

201. D'yakonov, Yu. N., and N. A. Zaytseva.   IzAN MeMa
    Supersonic flow of an ideal gas about   no. 1
    a blunted body.   118-123

    The axisymmetrical supersonic flow field
    around a blunt body is investigated. The
    results of calculations for flows at
    M = 3, 4, 6, 10 and past a sphere and past
    spherically blunted cones are presented.

202. Shkadov, V. Ya. The boundary layer with   IzAN MeMa
    pressure gradient in compressible fluid   no. 2
    flow.   28-32

    A boundary layer problem in a compressible
    fluid flow under the assumption that the
    viscosity varies linearly with temperature
    and that the Prandtl number is constant.

203. Motulevich, V. P. Evaluating terms of   InFZh
    boundary layer equations.   no. 5
                                                86-91

    An attempt is made to obtain quantitative
    criteria for evaluation of various phenomena
    and their corresponding terms in a complete
    system of differential boundary layer
    equations, taking into account all the
    factors resulting from the molecular-kinetic
    theory of matter. Diffusion and energy
    equations are considered. The expression
    for the reference term is established and
    its selection procedure outlined for both
    equations. An approximate method is developed
    for calculating the dimensionless para-
    meters of both equations, which makes it pos-
    sible to determine the relative role of
    every separate term.

204. Kozlov, L. F. Optimum boundary-layer bleed   InFZh
       on a porous plate in an incompressible   v. 6, no. 10
       fluid.   88-92

       The optimum suction of an incompressible
       fluid from the boundary layer on a porous
       plate is investigated theoretically.
       Laminar friction coefficients, and local
       and total amounts of removed fluid are
       determined.

205. Galkin, V. S. The effects of slip in hyper-   InZh
       sonic slightly rarefied gas flow past bodies.   v. 3, no. 1
                                                        27-36

       The effects of slip on aerodynamic para-
       meters of bodies in a hypersonic rarefied-
       gas flow and the limits of applicability of
       laminar boundary layer theory to the
       description of a viscous disturbed flow
       past plane and axisymmetric bodies are
       discussed. Expressions for slip-
       velocity and temperature jumps are
       derived and the terms of the Burnett
       equation along the wall are evaluated
       by using the local similarity method and
       self-similar solutions of the boundary
       layer equations.

206. Neyland, V. Ya., and G. I. Taganov. Super-   InZh
       sonic separated flows.   v. 3, no. 2

       A detailed study on the configurations of
       forward separated flow regions in super-
       sonic flow past symmetric bodies is presented.
       The angle of flow separation is determined,
       and its dependence on Mach number is estab-
       lished for the case when the ratio of the
       viscous boundary-layer thickness on the
       interface of the conical separated region
       near the reattachment point to the radius
       of body curvature in the meridional cross
       section tends to zero.

207. Bukovshin, V. G., and G. I. Taganov.
    Determination of the aerodynamic forces
    acting on bodies with separation regions
    in hypersonic flows.

                                                                InZh
                                                                v. 3, no. 2
                                                                215-221

    A theoretical method is outlined for
    calculating the aerodynamic forces acting
    on bodies of arbitrary shape in hypersonic
    flows in the presence of separated flow
    regions of given configurations. The method
    is applied to the calculation of lift and
    drag for a sphere and a cone, both with
    a spike at an angle of attack.

208. Koshmarov, Yu. A. (Moscow). Rarefied gas
    flow along a wall suddenly set in motion.

                                                                InZh
                                                                v. 3, no. 3
                                                                433-441

    The dynamic behavior of a gas set in motion
    by a sudden movement of the gas-confining
    infinite plane is investigated on the basis
    of molecular theory and under the assumption
    that the velocity of the plane is smaller
    than the velocity of sound in the gas. An
    equivalent system of equations of moments
    is used instead of the Maxwell-Boltzmann
    equation for determining the function
    of molecular velocity distribution.

209. Badyagin, A. A. The maximum lift-drag ratio
    of an aircraft.

                                                                IzVUZ AvT
                                                                no. 1
                                                                3-9

    The effect of balancing (static stability)
    on the lift-drag ratio of a conventional
    and of a "canard" type supersonic air-
    craft is investigated.

210. Khaldeyev, V. M. The selection of optimal
    parameters of aircraft mechanisms.

                                                                IzVUZ AvT
                                                                no. 1
                                                                66-79

    An engineering method is described for
    the design of aircraft mechanisms which
    are to be set within a strictly limited
    contour. The particular case of a land-
    ing-gear mechanism is considered.

211. **Sirazetdinov, T. K. Optimal problems of gasdynamics.**

A system of equations is derived for determining an optimum body surface having minimum drag or maximum heat dissipation (minimum heat flow into the body). The equation of a minimum-drag airfoil in supersonic flow is discussed in detail.

212. **Vinogradov, B. S., and Z. G. Shaykutdinov. An approximate method for calculating the detached bow shock wave in supersonic flow past blunt bodies.**

An approximate method is outlined for rapid evaluation of the basic parameters of a detached bow shock wave and of flow behind it. It may be applied with sufficient practical accuracy to either plane or axisymmetric flows.

213. **Dolomanov, Ye. G. The calculation of air parameters behind a normal shock with stagnation-temperature inversion taken into account.**

The flow parameters in the region of the stagnation point are calculated, taking the effect of temperature inversion into account. A graph-analytical method is used for calculating the gasdynamic and thermodynamic parameters of air; the effects of ionization, dissociation, NO-molecule formation, and variable specific heat are considered.

214. **Sidorov, O. P. A certain class of vortex flows.**

Hydrodynamic effects on flows which

exclude the formation of shock waves
(specially selected vortex fields have
this property) are investigated to the
first approximation. A nonlinear system
of gas dynamic equations describing a
plane, steady flow of an inviscid, compres-
sible gas is considered and after certain
analytical transformations reduced to a
linear system.

215. **Vallander, S. V.** (Editor). Soviet studies
     of rarefied gases (I), (II), and (III).

LU
NIIMMe
no. 1
1-267

216. **Varzhanskaya, I. ., Ye. I. Obroskova, and
     Ye. N. Starov..** Boundary layer in the
     vicinity of a stagnation point.

MoUVychTs, Sb
no. 2
135-145

An analytical investigation is presented
of a compressible laminar air boundary
layer near the stagnation point of a flat
porous plate through which hydrogen is
uniformly injected.

217. **Golitsyn, G. S.** Correlations in local
     isotropic turbulence.

PMMe
v. 27, no. 1
61-74

A study of velocity correlations and
pressure distributions is made on the
basis of Kolmogorov's theory of locally
isotropic turbulence. The statistical
characteristics of the turbulence in
the whole equilibrium range are
calculated with the use of a spectral
density mode which at high wave
numbers decays like a Gaussian function.
Where possible, these characteristics are
compared with results obtained on the
basis of other turbulence models, for
example, models with constant asymmetry
and Heisenberg modes.

218. Gonor, A. L. Three-dimensional minimum-
     drag bodies at high supersonic speeds.

PMMc
v. 27, no. 1
185-189

   Supersonic flow around a conical body
   is analyzed and expressions for pressure
   and drag coefficients are derived. The
   drag coefficient formula is used to reduce
   the problem to the separate determination
   of optimal shapes for meridional and
   transverse sections. The calculations
   show that the optimal cross section is
   star-shaped. The possibility of determin-
   ing the optimal transverse section of a
   body having one of its sides a plane
   parallel to the flow is indicated.

219. Kreyko, A. N. (Moscow). On the determina-
     tion of minimum-drag bodies by use of the
     Newton and Buseman pressure coefficient
     laws.

PMMe
v. 27, no. 3
484-495

   After reviewing a series of studies on
   determining the shape of bodies having
   minimum drag under certain types of
   restrictions, the author analyzes the
   same problem with various arbitrary
   restrictions.

220. Savulescu, S. N., and V. Toma. An ex-
     perimental investigation of the inter-
     action of a low-intensity jet with an
     incompressible boundary layer on a flat
     plate.

StuCeMeAp
v. 14, no. 5
1037-1063

   The principal results of an experimental
   investigation of the transition of an
   incompressible boundary layer on a flat
   plate initiated by a low-intensity jet
   are presented. A brief description of
   the experimental setup is given.

221. Solou*khin, R. I. Detonation waves in gases.

This review of 125 articles (88 Soviet) published in 1959-1963 on detonation waves in gases deals with: experimental methods for studying gas parameters behind a detonation front, characteristics of gas ignition behind a shock wave, transition from deflagration to detonation in gases, gas pulsations behind the detonation front, detonations in steady gas flows. Unsolved problems and prospective research are briefly discussed.

222. Baush, G. The small-parameter method in the hypersonic flow of an ideal gas past pointed bodies.

The method of a small parameter is used for determining the hypersonic characteristics of flow of a perfect gas past plane and axisymmetrical pointed bodies. The method does not lead to a singularity at the zero-contour-pressure point.

223. Grib, A. A., G. Baush, and L. M. Vyaz'-menskaya. Some special features of hypersonic gas motion.

Flow past bodies of revolution and flat contours with arbitrary dependence of internal energy on pressure and temperature is determined by a procedure based on the methods of G. G. Chernyy and G. A. Lyubimov. Some special features connected with the solution of the Mises equations in the form of a series are discussed.

224. Onufriyev, A. T.   A model of nonequilibrium   ZhPMeTF
      processes in continuum mechanics.   no. 1
                                                            47-56

      An attempt is made to construct a model
      of the transfer processes in some linear
      problems with one-dimensional transfer,
      considering the free-molecule flow. The
      concept of the mean free path is reviewed,
      and the flow of a rarefied gas past a semi-
      infinite plate is analyzed.

225. Romanenko, P. N., and V. N. Kharchenko.   ZhPMeTF
      The effect of gas injection into a turbu-   no. 1
      lent boundary layer on skin friction.   77-83

      The boundary layer on a flat porous plate
      is experimentally studied in respect to
      the effect on its dynamic characteristics
      of injecting freon, CO_2, and air into it.
      A flow of heated gas with increasing and
      decreasing pressure gradients is considered.
      A detailed description of the experimental
      facilities and test procedure is presented.
      An approximate procedure is suggested for
      calculating the dynamic boundary layer in
      the case of turbulent gas flow with a longi-
      tudinal pressure gradient and transverse
      mass transfer.

226. Korobeynikov, V. P. (Moscow), P. I. Chushkin,   ZhPMeTF
      (Moscow). Calculation of the initial   no. 4
      stage of a point explosion in various gases.   48-57

      A numerical solution of a linearized point-
      explosion problem with back pressure taken
      into account is considered in the cases
      of plane, cylindrical, and spherical waves
      in gases within a wide range of adiabatic
      exponent. A method is outlined for the
      solution of linearized . blast-wave problems
      which is very convenient for computer
      calculations.

227. Adushkin, V. V. (Moscow), I. V. Nemchinov (Moscow). Approximate determination of gas parameters behind a shock-wave front for the prescribed law of shock propagation.

ZhPMeTF no. 4 58-67

A method is outlined for approximate determination of gas parameters behind a shock-wave front from the given law of shock-wave propagation. The method is based on calculation of basic derivatives of gasdynamic parameters at the shock-wave front in Lagrange's coordinate system and consists of the linear extrapolation of pressure along the mass of gas in motion with respect to a known value of the pressure derivative at the wave front. The other parameters are calculated from gasdynamic equations.

228. Shidlovskiy, V. P. (Moscow). A problem of gas point-mass escape and its solution by means of the kinetic theory.

ZhPMeTF no. 4 74-77

An unsteady motion of a monatomic gas, corresponding to the escape of a point mass into vacuum, was studied by means of the kinetic theory of flows on the basis of the solution of the Boltzmann equation in the case of nonequilibrium initial distribution. Collisions among the molecules themselves were neglected. The more general case of escape in the presence of a steady potential power field was also considered.

229. Adushkin, V. V. (Moscow). Formation of a shock wave and dispersion of explosion products into the air.

ZhPMeTF no. 5 107-114

The law of motion of a shock-wave front and the explosion products from detonation of spherical charges of certain explosives in the air were investigated experimentally. The dependence of the shock-front basic parameters on the shock-front velocity is

established near the source point and at distances at which the Sadovskiy formulas are satisfied. The dependence of shock-layer thickness on distance is derived in the region of detonation-product action. A set of photographs of data obtained by a piezoelectric sensor is given. The pressure and density distribution in the region between the shock front and contact surface is obtained on the basis of experimental data by a method similar to the thin-layer method used by Chernyy.

230. Zaydel', R. M. (Moscow), and Ya. B. Zel'-dovich (Moscow). One-dimensional instability and attenuation of a detonation.   ZhPMeTF no. 6 59-65

Instabilities associated with perturbations causing distortion of the shock front were analyzed. In this detonation wave in-stability different temperatures are estab-lished in individual sections of the shock front and amplification of the perturbation results in the occurrence of ignition steps and collisions which in turn cause spinning detonation. In the present study, the stability of a detonation wave is considered with respect to the changes in the dist~ce between the shock front and the chemical reaction zone.

231. Shugayev, P. V. Interaction of a supersonic stream with an obstacle.   ZhPMeTF no. 6 101-103

An experimental investigation of the motion of a shock wave caused by the interaction of a supersonic stream (M = 1.5 to 1.65) in a shock tube with a cylinder. The shock wave velocity is determined and the duration of the transient motion is measured.

232. Anisimov, S. I., and Yu. V. Khodyko. Gas
flow about the forward stagnation point
of a blunt body with retarded excitation
of vibrations.

    The gas flow near the stagnation point
of a blunt body is studied in the velocity
range where there is no appreciable dis-
sociation behind a detached shock wave,
in the presence of retarded excitation of
vibrations.

ZhTF
v. 33, no. 11
1333-1337

233. Telenin, G. F., and G. P. Tinyakov. A
method for three-dimensional analysis
of flows around bodies with detached
shock wave.

    A numerical method developed by the authors
for integrating gas-dynamics equations
to analyze supersonic flows around bodies
with detached shock wave is extended to
the case of three-dimensional flows with
a detached shock wave. Some results of
the calculations for ellipsoids of
revolution are presented.

1964
DAN SSSR
v. 154, no. 5
1057-1058

234. Generalov, N. A., S. A. Loscu, and A. I.
Osipov.

    The distribution of vibrational energy
of molecules of N_2 and O_2 and tempera-
tures behind the front of a normal shock
wave are determined with and without
effects of vibrational quanta taken into
account, by using a simultaneous system
of equations of conservation of mass,
impulse, and energy, also of equations
of state and relaxation. The shock-
wave velocities M = 5, 9, and 20 at an
initial pressure of 1 mm Hg are consi-
dered.

DAN SSSR
v. 156, no. 5
1057-1060

235. Koshmarov, Ya. A. (Institute of Mechanics, Academy of Sciences USSR). On the rarefaction effect on gasdynamics surface friction when gas is injected or sucked through a wall.

InFZh
v. 7, no. 6
48-54

The problem of steady flow of a rarefied Maxwellian gas between two permeable surfaces moving relatively to each other at a low speed is discussed on the basis of molecular motion.

236. Gozdovskiy, G. L. Yu. N. Ivanov, and V. V. Tokarev. The mechanics of low-thrust space flight. III

InZh
v. 4, no. 1
168-196

This third part contains a discussion of the problems associated with limited-power propulsion systems — their optimum control, reliability in operation, and weight. Propulsion systems related to those of low thrust are also examined.

237. Pudoveyev, A. P. The supersonic analogy method for calculating one-dimensional unsteady gas flows.

IzVUZ AvT
no. 2
81-87

The supersonic analogy method is extended to determining the quantitative relationships and calculating unsteady flows. A self-similar unsteady flow is compared with the Prandtl-Meyer flow. The relations obtained here can be used for determining the gas flow parameters for arbitrary boundary conditions up to the formation of a shock wave.

238. Romanenko, P. N., and V. N. Kharchenko. The effect of gas injection into a turbulent boundary layer with a longitudinal pressure gradient on skin friction.

ZhPMeTF
no. 1
77-83

The results of an experimental investigation of basic dynamic characteristics of a turbulent boundary layer on a porous plate in a longitudinal hot-air flow with accelerating and adverse pressure gradients in the direction of flow are presented.

239. Pavlova, L. M. (Moscow), and Yu. D. Shmyglevskiy (Moscow). Boundary layer in radiating gas.

ZhPMeTF
no. 1
109-113

Plane and axisymmetrical flows of radiating gas in the boundary layer over plane surfaces (for example, a double-wedge airfoil, the plane front portion of bodies of revolution, et cetera) are discussed. The simplifications of the expressions for the flux of radiant energy (essentially facilitating the computations) are studied, and a criterional inequality for determining the validity of such simplifications is derived.

240. Korotkov, P. F. (Moscow). On Mach reflection of shock waves.

ZhPMeTF
no. 1
114-116

The self-similar problem of determining the configuration of shock waves in Mach reflection of a normal shock from a plane rigid wall (wedge) is discussed. The location of the Mach wave (relative to the incident shock) and its intensity at the wall are determined, as well as the reflection coefficient.

241. Gladkov, A. A. (Moscow). The effect of relaxation entropy layer.

ZhPMeTF
no. 1
116-117

Relaxation processes in a hypersonic flow of a inviscid, heat-nonconducting gas past a blunt-nosed body are examined, assuming that relaxation processes occur in the gas behind the normal shock wave.

The relaxation entropy layer parameters
(pressure gradient density, gas velocity)
are briefly discussed.

242. Zhilin, Yu. L. (Moscow). On the theory
     of an entropy layer.

The formation of an entropy layer ac-
companied with a distortion of the shock
in a hypersonic flow of an ideal gas
around slender pointed bodies is dis-
cussed. The point of origin of the
entropy layer, the intensity of its
growth, and its thickness are examined.

243. Belotserkovskiy, S. M., V. S. Sukhorukikh,
     and V. S. Tatarenchik. Determining
     the density distribution in three-
     dimensional gasdynamic flows by means
     of optical methods.

A method is proposed for investigations
of three-dimensional gas flows by means
of quantitative optical methods. Approxi-
mating functions which describe the
density field, including the form of
a shock wave front, are selected on
basis of empirical data obtained by
optical measurements. A system of
linear equations is derived from which
the density distribution around the
obstacle and the shock-wave form can
be determined.

244. Soloukhin, R. I. On detonation in a gas
     heated by a shock wave.

Experimental shock-tube data on the
formation of detonation waves in
mixtures of adiabatically heated
inert gases, are given. The process
of development of self-ignition in
a shock-tube is discussed. Analytical

and experimental values of detonation-
wave parameters are compared in graphs
and diagrams.

245. Zaytsev, S. G., Ye. V. Lazareva, and
    A. P. Shatilov. Investigating the
    normal shock-wave reflection in a
    shock tube.

The apparatus and the method for
investigating the normal reflection
of a shock wave from a rigid wall are
described. The state of gas behind the
shock wave is determined for various
Mach numbers (2 to 6) in carbon dioxide,
nitrogen, and argon. The density field
behind a reflected shock wave is studied.

GROUP   A   AEROMECHANICS OF HIGH-SPEED FLOWS

    A-2   Aerodynamics of Bodies
          Plates and Cylinders
          Wedges
          Wings
          Airfoils
          Wing-Body Systems
          Blunt and Pointed Bodies
          Slender Bodies
          Lift-Drag Ratio

246. Donov, A. E. A flat wing with sharp edge in a supersonic stream.

Translation: NACA Tech. Mem. No. 1394 (1956)

1939
IZAN MeMa no. 3
603-626

247. Gurevich, M. (Institute of Mechanics, Academy of Sciences USSR, Moscow). The lift of a swept-back wing.

Translation: NACA Tech. Mem. No. 1245 (1949)

1946
PMM
v. 10, no. 4
513-520

248. Krasil'shchikova, Ye. A. The effect of the wing-edges at supersonic speeds.

Vibration of a thin, deformable finite-span wing moving at supersonic speed is discussed. The method described here for determining the velocity potential at any point of the wing and the normal-velocity component due to vibration is applicable to wing edges of arbitrary shape.

1947
DAN SSSR
v. 58, no. 4
543-546

249. Krasil'shchikova, Ye. A. The effect of the wing edges of a vibrating wing moving at supersonic speeds.

A supplement to the author's preceding article [248], is presented, and the solution is obtained in the form of an absolutely converging series.

DAN SSSR
v. 58, no. 5
761-762

250. Sedov, L. I., M. P. Mikhaylova, and G. G. Chernyy. The effect of gas viscosity and heat conductivity on the flow behind a

1953
VELUMMeAs
no. 3
95-100

large curvature shock wave.

Supersonic gas flow past a body of revolution with a strong shock wave is discussed with the effect of viscosity and heat conductivity taken into account.

251.   Aslanov, S. K.   Low-supersonic flow of an ideal gas past a thin wedge.

1954
PMM
v. 18, no. 5
561-572

A simplified method of determining the drag of a thin wedge in a supersonic flow with a detached shock wave is presented. The sonic similarity law is used to derive formulas for the drag coefficient of a wedge and of a double-wedge airfoil in cases of a detached and attached shocks.

252.   Aslanov, S. K.   Magnitude of a local supersonic zone in a supersonic flow of compressible gas past a wedge.

1955
PMM
v. 19, no. 3
359-362

The influence of the wedge apex angle and of the flow velocity is shown.

253.   Yur'yev, I. M.   On the linearized theory of supersonic gas flows past bodies of revolution.

PMM
v. 19, no. 3
363-367

An approximate final form solution of the linearized equation for axisymmetric supersonic gas flows is proposed. This proposed method is suitable for calculating parameters of flows around annular bodies of revolution and around the outer parts of such bodies.

254. Kogan, M. N. Theory of flow past bodies of relatively small aspect ratio.

The possibility of adapting conformal mapping to the solution of three-dimensional problems of flow past wings is studied in a more precise setting than the thin-wing theory.

255. Lunev, V. V. Laminar boundary layer of a compressible gas with large temperature gradients on a plate.

The temperature range considered includes the temperature of air dissociation. A method of successive approximations for determining the flow parameters is given for steady boundary conditions.

256. Aslanov, S. K. Drag of a curvilinear profile in a sonic flow.

Sonic flows past a wedgelike body at a zero angle of attack are studied. Various methods of solution are reviewed.

257. Belotserkovskiy, O. M. (Computing Center Academy of Sciences USSR, Moscow). Flow past a circular cylinder with detached shock wave.

Translation: M. D. Friedman, NoB-131

258. Chernyy, G. G. (Moscow). Hypersonic flow past an airfoil with a slightly blunted leading edge.

Translation: M. D. Friedman, No. C-112

259. Chernyy, G. G. (Moscow). Hypersonic Flow around a slender blunt cone.

DAN SSSR v. 115, no. 4 681-683

Translation: M. D. Friedman, No. C-113

An approximate solution for hypersonic flow past a slender blunted cone is derived, and results are compared with experimental data. Mass concentration in the perturbed region is assumed to be located on the generated shock wave and moving with it.

260. Krasil'shchikova, Ye. A. Unsteady motion of a finite-span wing in a compressible fluid.

DAN SSSR v. 117, no. 5 777-780

Three-dimensional motion of a compressible fluid due to unsteady motion of a finite-span wing immersed in an unbounded fluid, at rest at infinity, is investigated. The motion of the wing is assumed to be only slightly disturbed. The problem is linearized and the generally accepted assumptions of thin-wing theory are used.

261. Chernyy, G. G. Flow of an ideal gas around a body at hypersonic speeds.

IzAN OTN no. 6 77-85

An analytical method is presented for calculating steady hypersonic flows around plane contours and axisymmetric bodies. The method is based on expanding gas dynamics equations in a special series in powers of a parameter $\varepsilon = (\gamma - 1)(\gamma + 1)$, where γ is the ratio of heat capacities, and is analogous, in principle, to the method of solving the equations of motion of a viscous fluid in boundary layer theory by expansion in series of powers of $N_{Re}^{-1/2}$, where N_{Re} is the Reynolds number.

262. Gonor, A. L., and G. G. Chernyy. Minimum-drag bodies at high supersonic speeds.

IzAN OTN
no. 7
89-93

Numerical quadrature is used to solve the variational problem of finding the minimum-drag body in an axisymmetrical flow. Two limiting cases are considered: 1) the angle between the tangent to the contour of the body and the direction of the incident flow is small (the pressure is very low), and 2) the pressure on the surface of the body is infinite; the transition from a cone to the optimal shape was found to decrease the drag by about 30 per cent.

263. Kadyrov, S. Motion of a finite-span wing at supersonic speed.

IzAN OTN
no. 8
35-40

The motion of a wing of arbitrary shape in a three-dimensional flow of an ideal compressible fluid moving faster than the critical speed is discussed. The Mach number is assumbed to be high enough for formation of a shock wave at the leading edge of the wing and the gas flow behind the shock wave is supersonic everywhere.

264. Kopzon, G. I. Unstable motion of a wing in a supersonic flow.

PMMa
v. 21, no. 1
136-141

The application of the Laplace transformation to the velocity potential makes possible the analysis of a general case of boundary conditions on the wing, with an arbitrary dependence on time.

265. Kogan, M. N. Minimum-drag bodies in a supersonic gas flow.

PMMa
v. 21, no. 2
207-212

The problem of determining the minimum

drag of wings and bodies in a supersonic
gas flow is studied under the assumption
of the linear theory. It is shown that
there are surfaces for which the forces
acting on bodies inside these surfaces
can be expressed by values of the velocity
potential on that surface.

266. Chushkin, P. I. The calculation of some
sonic gas flows.

PMM
v. 21, no. 2
353-360

The application of ⌂. approximate
method to the problem of symmetric
sonic gas flow around the nose of an
ellipse or an ellipsoid of revolution
is given, and its extension to the case
of an arbitrary profile is presented.

267. Nikol'skiy, A. A. Annular bodies of
revolution with minimum external
wave drag in supersonic flow.

TsAeGII, Sb
56-63

The problem of determining the shape
of an annular body of revolution with
minimum wave drag on the outer surface
is solved in linear formulation, and
explicit drag formulas for minimum-
drag bodies are obtained.

268. Dorodnitsyn, A. A. Relationship between
the curvatures of a shock wave and the
outer surface of an annular body of
revolution.

TsAeGII, Sb
64-73

Supersonic flow past a barrel with a co-
axial cylindrical hole is analyzed,
and the curvature of the shock wave is
determined in relation to the curvature
of the outer surface. The shock-
curvature value is necessary in determin-
ing the pressure distribution over the
outer surface of the body of revolution.

269. Dorodnitsyn, A. A. Pressure-distribution   TsAeGiI, Sb
     analysis for bodies of revolution in a   116-126
     supersonic gas flow.

     A method for determining the pressure
     distribution over bodies of revolution
     based on approximate integration of
     equations of axisymmetric-flow character-
     istics is presented. In practical ap-
     plications, this method is even simpler
     than the method based on linearization
     of equations of motion, and shows
     satisfactory accuracy in comparison with
     known exact solutions.

270. Aksenov, A. P. Laminar boundary on a cone   VeLUMMe As
     in a supersonic flow.
                                                  no. 3
     Skin friction and surface temperature   13-28
     are determined by using integral momen-
     tum and energy equations, with heat
     radiation either neglected or taken
     into account. The Prandtl number is
     assumed to be a function of temperature
     only, and the viscosity is assumed to
     vary according to Sutherland's formula.

271. Aksenov, A. P. Turbulent boundary layer   VeLUMMe As
     in supersonic flow past a cone with heat   MMA
     radiation taken into account.   no. 4
                                                  112-128
     The surface temperature is determined
     and a general formula for the skin
     friction in an axisymmetrical steady
     supersonic flow of gas past a cone is
     given.

                                                  1958
272. Krasil'shchikova, Ye. A. Unsteady motion   IzAN OTN
     of a finite-span wing in a compressible   no. 3
     medium.   25-32

     This article deals with disturbed motion

of a compressible fluid caused by unsteady motion of a thin wing of finite span moving according to a given law. The boundary value problems are solved by a previously published method for unsteady plane-parallel motions of a fluid (Izvestiya AN SSSR, OTN MM, no. 2, 1954). Quadratures are employed here for solving problems involving all types of unsteady motion of a wing in which the speed of motion of the wing is essentially supersonic, neglecting the end effect and the effect of the vertex system behind the wing.

273. Shidlovksiy, V. P. Approximate method of calculating high-Mach number flow past two-dimensional forebodies.

IzAN OTN
no. 3
156-162

The two-dimensional problem of supersonic flow of an ideal gas about a sharp-nosed semiairfoil at zero angle of attack is treated. It is assumed that the flow is adiabatic and that the entropy changes are due to the presence of a shock wave.

274. Chernyy, G. G. The effect of slight bluntness of a body on high hypersonic flow around it.

IzAN OTN
no. 4
54-66

An attempt is made to extend the theory of high hypersonic flows around slender pointed bodies to cases in which the nose or leading edge of the body is slightly blunted. The study is limited to flow around profiles and bodies of revolution.

275. Gonor, A. L. (Moscow State University). Hypersonic flow around a cone at an angle of attack.

IzAN OTN
no. 7
102-107

A study of hypersonic gas flow around
a circular cone is considered. The
method of G. G. Chernyy for solving
two-dimensional axisymmetrical flow is
applied, introducing a spherical co-
ordinate system with transformation of
the system of equations into series in
a stream function expression.

276. Zheludev, P. I. Supersonic flow past
     slender bodies of revolution with
     fins and without fins.

     IzAN OTN
     no. 9
     74-82

Supersonic flows past slender bodies of
revolution with fins at an angle of
attack are considered in accordance with
slender body theory and a second-approxima-
tion solution is constructed for super-
sonic flow past arbitrary bodies of revolu-
tion. The second approximation produced
results which were closer to experimental
values than the first approximation in
the case of cones with vertex angles less
than 15 degrees.

277. Monakhov, N. M. Determining the circula-
     tion around a high-aspect wing in a
     sideslip.

     IzVUZ AvT
     no. 1
     19-26

An integral equation for determining
the spanwise distribution of the circula-
tion around a high-aspect wing in a side-
slip at any angle is derived on the basis
of the Biot-Savart formula.

278. Ostoslavskiy, I. V., and T. A. Grumondz.
     (Moscow Aviation Institute). The con-
     nection between the generation of lift-
     ing force of a wing and the nature of
     the flow in the boundary layer.

     IzVUZ AvT
     no. 1
     27-36

The determination of the relationship
between the generation of lifting forces
of a wing and the nature of the boundary
layer flow is given. Some experimental
results are presented.

279. Sirazetdinov, T. K. (Kazan' Aviation
     Institute). Vibrations of a wing of high
     aspect ratio in a subsonic flow.

     IzVUZ AvT
     no. 1
     43-52

     The derivation of integral differential
     equations for a wing of high aspect ratio
     oscillating in a subsonic flow is given.
     The solution is presented for small
     frequencies of oscillation.

280. Kostychev, G. I. On shapes of bodies with
     minimum wave drag.

     IzVUZ AvT
     no. 2
     9-15

     The shape of minimum-wave-drag bodies is
     determined for given flow parameters
     in cases of supersonic potential flow, a
     flow with an oblique shock wave, and a
     plane flow. In the latter case, the optimal
     form is a wedge.

281. Keldysh, V. V. (Moscow). The application
     of slender-body theory to the calculation
     of aerodynamic characteristics of small-
     span wings with wingtip tanks.

     PMMe
     v. 22, no. 1
     126-132

     The application of the theory of slender
     bodies to the calculation of the aero-
     dynamic characteristics of small-span
     wings with wingtip tanks is discussed.

282. Belotserkovskiy, O. M. Flow past a
     symmetrical airfoil with a detached
     shock wave.

     PMMe
     v. 22, no. 2
     206-219

     Translation: J. Appl. Math. and
     Mechanics, v. 22, no. 1, 1958, 274-296.

     A critical survey of previous studies
     and various approaches used in calcula-
     ting flows past a symmetrical profile
     with a detached shock wave is presented.

A method is given for computing the pressure distribution over the body, the sonic line, and other parameters. An analogous procedure based on Dorodnitsyn's method is used for analyzing the flow around an axisymmetric body with a detached shock wave.

283. Shmyglevskiy, Yu. D. On supersonic minimum-drag airfoils.

The problem of finding an airfoil with minimum wave drag in a supersonic gas flow is considered. It is shown that concave airfoils of minimum drag practically coincide with a wedge.

284. Bulakh, B. M. Nonlinear conical gas flow.

Quasi-linear differential equations describing the gas motion are reduced to canonical form to yield a second approximation for the nonlinearized vortex-free steady conical flow of a gas. The method is applied to a gas flow around a cone.

285. Khaskind, M. D., and V. S. Khomenko. Constrained supersonic flow past an airfoil.

A nonlinear two-dimensional problem of a steady, constrained supersonic flow of an isentropic gas past an airfoil with a sharp leading edge is studied. The boundaries of the flow are assumed to be straight and parallel and the airfoil is positioned asymmetrically relative to them.

286. Bulygina, Ye. V. (Novosibirsk Electrical Engineering Institute). Problem of a wing of given volume with minimum wave drag.

    PMMe
    v. 22, no. 6
    826-828

The derivation of a solution for the problem of an airfoil with minimum wave drag, based on the linearized theory and using the variational method, is presented.

287. Carafoli, E. and M. Ionescu. (Institute of Applied Mechanics Rumanian Academy of Sciences, Bucharest). A general theory of triangular wings with a given pressure distribution is presented.

    StuCeMeAp
    v. 9, no. 2
    267-284

288. Carafoli, E. and B. Horovitz. (Institute of Applied Mechanics, Rumanian Academy of Sciences, Bucharest). Mixed problems of triangular wings provided with a normal plate (cruciform wings) in a supersonic flow.

    StuCeMeAp
    v. 9, no. 4
    819-832

Certain mixed problems in the case of high-speed homogeneous flow around cruciform wings were studied.

289. Carafoli, E. and A. Nastase. (Institute of Applied Mechanics, Rumanian Academy of Sciences, Bucharest). A study of thin triangular wings of forced symmetry in a supersonic flow.

    StuCeMeAp
    v. 9, no. 4
    833-853

Thin triangular wings of forced symmetry governing the variation of incidence and, consequently, the vertical velocity over the wing were studied. The derived formula can be used to determine the aerodynamic characteristics for wings of natural symmetry.

290. Kulonen, L. A. Interaction between a
      shock wave and the boundary layer in
      the vicinity of the leading edge of a
      flat plate at high supersonic velocities
      with radiation taken into account.

      An approximate solution is obtained for
      uniform velocity at zero angle of attack
      for the case when the heat transfer
      between the plate and the surrounding
      medium is determined by the Stefan-
      Boltzmann Law.

VeLUMMeAs

no. 2
172-188

291. Marenkova, A. F. A slender wing in a super-
      sonic flow confined by a wall.

      The linearized problem is solved by Ye. A.
      Krasil'shchikova's method and by the
      special procedure of mirror reflection.
      Calculations of flow past a flat infinite-
      span wing and a rectagular wing confined
      by a wall are given as examples.

VeLUMMeAs

no. 4
125-138

292. Belotserkovskiy, O. M. Computer Center,
      Academy of Sciences USSR). Flow past
      a circular cylinder with a detached
      shock wave.

      Translation: AVCO Research and Develop-
      ment Div Report RAD-9-TM-66, 1959.

      Dorodnitsyn's general method for inte-
      grating first-order partial differen-
      tial equations of the mixed type is
      applied to calculating the flow of a
      uniform supersonic or hypersonic stream
      past a circular cylinder.

Vych M
no. 3
149-185

293. Lyubimov, G. A. (Moscow State University).
      Steady flow of an infinitely conducting
      gas around a wedge.

      A study of the problem of steady,
      infinite, conducting gas flow around

1959
DAN SSSR
v. 126, no. 4
733-735

a wedge for an arbitrary distribution
of the magnetic field in relation to
the flow is reported.

294. Shmyglevskiy, Yu. D.   Bodies of revolution   DAN SSSR
     offering minimum drag at supersonic   v. 126, no. 5
     speeds.   958-960

     The problem of finding a contour which
     offers minimum wave drag for a given
     speed (supersonic) of the incident gas
     flow is considered for cases in which
     the shock wave is attached. It is shown
     that the variational problem can be solved
     if the conditions on the shock wave are
     utilized, which prmits reformulation of
     the variational problem.

295. Dolapchiyev, B., and B. Sendov. (Insti-   DAN SSSR
     tute of Mathematics, University of Sofia,   v. 128, no. 1
     Bulgaria).   Symmetrical flow about a   53-56
     circular cylinder with two trailing
     vortices. Vortex trajectory and drag
     of the cylinder.

     An exact solution is obtained for the
     hydrodynamic problem of symmetric flow
     about a circular cylinder with two trail-
     ing vortices, including determination of
     the vortex tr sctory and drag of the
     cylinder.

296. Gonor, A. L.   High supersonic gas flows   IzAN MeMa
     around conical bodies.   no. 1
                                                     34-40
     A supersonic flow with an attached shock
     wave past a conical body of a given sur-
     face is examined. A method is developed
     for solving the equations of motion in
     the form of series in powers of a small
     parameter $\varepsilon = (\gamma - 1)(\gamma + 1)$, where γ
     is the ratio of heat capacities. The
     method is applied to analyses of flows
     past a triangular wing and an elliptical
     cone.

297. Grigoryan, S. S. On the motion of a
       slender body under the action of a
       strong shock wave.

       The motion of a body struck by a strong
       shock wave is discussed, neglecting the
       disturbances caused by reflection and
       diffraction behind the shock front.

IzAN MeMa
no. 1
165-166

298. Vorob'yev, N. F. Unsteady motion of a
       finite-span wing in a supersonic flow
       in the case of a sudden change in
       velocity.

       The motion of a thin wing at a small
       angle of attack in an infinite volume of
       gas is investigated in linear formulation
       under conventional assumptions of the
       thin-wing theory. A vertical wind gust
       is mentioned as a particular case.

IzAN MeMa
no. 1
167-170

299. Grodzovskiy, G. L. Favorable wing-
       fuselage interference at hypersonic
       speeds.

       Configurations of a wedge-shaped fuselage
       with a triangular or a swept wing, a
       semiconical fuselage with a triangular
       wing, and a power-law shaped fuselage
       with a suitable wing are discussed.
       Systems were considered at $M\to\infty$ as
       slender bodies. The results obtained
       can be used for bodies of similar shape
       at high supersonic speeds on the basis
       of hypersonic similarity and stabilization
       of aerodynamic coefficients.

IzAN MeMa
no. 1
170-173

300. Slezkin, N. A. (Moscow). On the theory
       of gas flow between a shock-wave front
       and the surface of a blunted body of
       revolution.

       Previous articles by the author (DAN
       SSSR, v. 54. no. 2 and no. 7, 1946) on

IzAN MeMa
no. 2
3-12

flow analysis between the shock wave
and body are extended here to a body of
revolution. Two ideas are utilized:
to divide the flow not only into longi-
tudinal layers, but also into trans erse
sections and to distinguish the Reynolds,
Oseen, and Prandtl layers, and use linear-
ized equations in passing from one section
to another.

301.   Zheludev, P. I. On supersonic flow past   IzAN MeMa
        plane quasi-triangular wings of low   no. 3
        aspect ratio.   202-203

        An approximate method of investigating
        the above problem by finding the velocity
        potential (in the second approximation)
        close to the wing surface. An expression
        for the pressure coefficient over the
        surface is derived.

302.   Lunev, V. V. Motion in the atmosphere   IzAN MeMa
        of a slender blunted body at high   no. 4
        supersonic velocities.   131-133

        The effect of a strong entropy increase
        of the gas in a detached shock wave on
        the pressure distribution over a slender,
        blunted body is analyzed. It is shown
        that at Mach numbers larger than 20, the
        entropy increase has a marked effect on
        the pressure distribution, even far down-
        stream from the body.

303.   Gonor, A. L. The pattern of a bow wave   IzAN MeMa
        in an asymmetrical high-supersonic gas   no. 5
        flow around a pointed body.   117-118

        The variation of the bow shock-wave
        angles (on the windward and leeward
        sides of a circular cone), depending
        on the angle of attack, the apex angle
        of the cone, and the Mach number of the

oncoming flow is calculated and experimentally verified. The analytical and empirical data, as well as the technique of the experiment are discussed.

304. Zheludev, P. I. (Moscow). Supersonic flow past winged bodies of revolution.

IzAN MeMa
no. 5
118-121

A study of supersonic flow past slender pointed bodies of revolution equipped with low aspect ratio wings is reported. An iteration method is used to determine the velocity potential in the second approximation, using the solution of the slender-body theory for the first approximation.

305. Myasnikov, V. P. Laminar boundary layer on a plate in a supersonic flow of a slightly rarefied gas

Iz AN MeMa
no. 5
127-130

An investigation of the laminar boundary layer on a flat plate in the region of slip flow is presented, taking into account the interaction between the external flow and the boundary layer.

306. Bondarev, Ye. N., and M. Ya. Yudelovich. On the possibility of an increase in the base pressure behind a wedge in flight at supersonic speeds.

IzAN MeMa
no. 5
186

The method of H. Korst for the approximate calculation of the pressure at the base of a wedge is discussed. As the pressure at the base increases as the square of the Mach number, it rises to a level above that in the oncoming flow. This "base drag" has little effect on the total drag of the wedge, but may affect the heat flow in the vicinity of the base.

307. Myasnikov, V. P. Laminar boundary layer
on a plate in a supersonic flow of a
rarefied gas.

IzAN MeMa
no. 5
127-130

The flow is investigated in its slip
region, where the interaction between
the outer layer and boundary levels is
taken into account. Calculations show
strong influence of rarefaction on
surface friction and heat flux. In the
case of heat insulation of the plate,
the rarefaction of air does not affect
the value of surface friction.

308. Bulygina, Ye. V. (Novosibirsk Electrical
Engineering Institute). Minimum-drag
supersonic wings with a given degree of
stability.

IzVUZ, AvT
no. 1
3-9

The problem of determining the shape of
a three-dimensional wing with minimum drag
(for given lift and stability) is reduced
to the problem of minimum drag for the
given moment at zero lift. Triangular
and tapered wings are discussed in
linear formulation.

309. Kiselev, O. M. (Kazan' State University).
Construction of a body of revolution on
the basis of a given velocity distribu-
tion.

IzVUZ, AvT
no. 2
20-24

A study to determine the shape of a body
of revolution in an infinite axisymmetric
potential flow of incompressible fluid,
on the basis of a given velocity distribu-
tion, is reported.

310. Strashinina, K. P. Flow of compressible
fluids past bodies of revolution.

IzVUZ, AvT
no. 2
33-38

Gas parameters are determined on the

surface of a body of revolution on the
basis of fundamental physical laws and
some physical considerations. The
method may be used to determine pres-
sure on the surface of the body by
taking friction into account.

311. Sidorov, O. P. (Moscow Aviation Institute).   IzVUZ, AvT
     Calculation of hypersonic flow past a   no. 2
     cone.   144-146

     Steady axisymmetric flow around an in-
     finite cone is studied. The velocity of
     the flow is assumed to be hypersonic;
     the solution is given in closed form,
     using the approximate equation for the
     velocity potential.

312. Bobrov, G. Ye. (Military Aviation Engine-   IzVUZ, AvT
     ering Academy, Leningrad). Theory of   no. 3
     annular wings in supersonic flow.   3-8

     The lifting force and the aerodynamic
     moments are determined for the internal
     surface of an annular wing in a super-
     sonic gas flow in a linear formulation,
     using the distribution of pressures
     over the inner surface of the annular
     wing.

313. Mugalev, V. P. (Moscow Physicotechnical   IzVUZ, AvT
     Institute). An experimental investiga-   no. 3
     tion of a subsonic turbulent boundary   72-79
     layer over a plate with injection.

     An experimental investigation of the
     subsonic turbulent boundary layer over
     a porous plate with gas injection is
     reported. The boundary layer flow was
     found to be analogous to flow over an
     impermeable surface in the case of a
     positive pressure gradient; a parameter
     determining the effect of injection
     on the boundary layer is discussed.

314. Vil'nit, L. N. (Novosibirsk Electrical Engineering Institute). The shape of a tapered wing which yields minimum wave drag for a given volume.

IzVUZ, AvT
no. 3
135-142

Procedures for determining the shape of a wing of trapezoidal plan form which will produce minimum wave drag for a given volume are studied.

315. Aleksakhin, B. N. Coefficients of lift and pitch moment for a combination of two slender bodies of revolution.

IzVUZ, AvT
no. 4
3-13

Aerodynamic coefficients of this combination of bodies are determined by the W. R. Sears' theory of slender bodies and by the method of conformal mapping. Applications of the method to calculating a combination of cone-nosed bodies are given.

316. Korobeynikov, N. P. Refinement of the slender-body theory for supersonic flow past bodies of revolution at an angle of attack.

IzVUZ, AvT
no. 4
26-31

An attempt is made to make G. N. Ward's slender body theory more exact by taking into account the effect of the Mach number. Relatively simple formulas are derived for calculating the Mach-number-dependent aerodynamic characteristics of slender bodies in a supersonic flow at an angle of attack.

317. Fomina, M. I. Characteristics of a geometrically twisted rectangular wing at supersonic speeds.

IzVUZ, AvT
no. 4
139-150

Coefficients of lift, drag, and moment of the wing in relation to its aspect ratio and geometric twist parameters are determined.

318. Kvashnina, S. S. and G. G. Chernyy. (Moscow), PMMe
     Steady flow of detonating gas around a   v. 23, no. 1
     cone.   182-186

     Discussion of a symmetrical steady flow
     of a detonating gas around a cone,
     based on the work of J. Ruthkowski and
     J. A. Nicholls, is presented.

319. Maykapar, G. I. (Moscow). Wave drag of   PMMe
     a nonaxisymmetric bodies in a super-   v. 23, no. 2
     sonic flow.   376-378

     Translation: J. App. M.M, v. 23, no. 2,
     1959, 528-531.

     Exact solutions are presented for cone
     shaped bodies of polygonal cross section
     and the effect of geometric parameters
     on the wave drag of such bodies in super-
     sonic flow is determined.

320. Biryukov, Ye. A. (Moscow). Downwash   PMMe
     behind a swept back wing of finite   v. 23, no. 3
     span during nonsteady motion.   583-584

     Formulas leading to a method for cal-
     culating the downwash in an ideal in-
     compressible fluid behind a wing having
     a high aspect ratio and a small angle of
     sweepback are derived. The study covers
     the case when the circulation varying
     with span also varies harmonically with
     time.

321. Lunev, V. V.   Flow of a viscous heat-   PMMe
     conducting gas past a cone at high   v. 23, no. 6
     supersonic velocities.   1006-1018

     Flow past a circular cone at a zero
     angle of attack is analyzed. The
     flow conditions are studied at a
     sufficient distance from the nose
     of the cone so that the method of
     small perturbations may be applied.

322. Kovaleva, V. A. (Dnepropetrovsk). Unsteady motion of a rectangular plane wing.

The results from an investigation of the unsteady motion of a thin rigid wing of finite span and rectangular planform in supersonic flow, arbitrarily varying with time, including gust- or shock-wave-dependent unsteady motion, are presented.

323. Fedyayevskiy, K. K., and A. S. Ginevskiy. (Moscow). An unsteady turbulent boundary layer on an airfoil and on a body of revolution.

The development of an approximate single-parameter method for determining the parameters of a turbulent boundary layer and the position of the separation point during acceleration of forward motion is discussed.

324. Ladyzhenskiy, M. D. On high supersonic gas flows.

General equations of a steady high supersonic flow of a perfect gas are simplified (by giving various values to a certain velocity-vector parameter) for the flow past a slender body, and in solving the Cauchy problem for which the domain of definition of the solution is discussed.

325. Carafoli, E. (Institute of Applied Mechanics, Rumanian Academy of Sciences, Bucharest). Theory of simple and cruciform triangular wings in a supersonic stream. Part I.

Triangular wing systems are investi-
gated — isolated wing and combinations
of horizontal and vertical surfaces
(such as the tail unit). The direct
problem (determining the flight para-
meters of a given system) and the
inverse problem (tailoring the shape
of a system to given flight parameters)
are discussed in parts I and II, respec-
tively.

326. Krasil'shchikova, Ye. A. (Institute
    of Mechanics, Academy of Sciences
    USSR). Wings of finite span with a
    symmetrical profile in subsonic and
    supersonic flows.

    InSb
    v. 27
    29-37

    Some boundary value problems of a thin
    wing of finite span with a symmetrical
    profile in supersonic flow at an angle
    of attack are solved by the method pro-
    posed by the author.

327. Yur'yev, I. M. (Moscow). The calculation
    of bodies of revolution in a supersonic
    flow.

    InSb
    v. 27
    38-44

    Problems which are solved by means of
    linear second-order ordinary differential
    equations are discussed. These calcula-
    tions are in agreement with calculations
    based on the theorems of Dorodnitsyn
    and Nikol'skiy.

328. Carafoli, E. (Head of Institute of Applied
    Mechanics, Rumanian Academy of Sciences,
    Bucharest).

    InSb
    v. 28
    3-25

    Part 2 of the article presents a theory
    of conical flow of a higher order, giving
    further development to include cruciform
    wings. It also deals with the problem of
    determining wing form as a function of a
    given distribution of pressure coefficients.

329. Iordanskiy, S. V., and Yu. D. Shmyglevskiy.   InSb
     (Computing Center, Academy of Sciences   v. 28
     USSR, Moscow). Sublimation of an axi-   26-35
     symmetrical blunt body near the stagna-
     tion point of an oncoming flow.

     Laminar boundary-layer equations for a
     subliming body are derived. A method
     for calculating the flow parameters and
     the sublimation rate is presented.

330. Yermolenko, S. D., and N. F. Vorob'yev   InSb
     (Novosibirsk). A comparison of finite   v. 30
     span wing characteristics obtained   131-138
     experimentally with those calculated
     by using the linear theory of super-
     sonic speeds.

     A study concerned with comparison of
     experimental results and those calcu-
     lated on the basis of the linear theory
     of finite span wings is presented.

331. Bam-Zelikovich, G. M., A. I. Bunimovich,   IzAN MeMa
     and M. P. Mikhaylova. (Moscow State   no. 1
     University). Motion of slender bodies   33-40
     at hypersonic speeds.

     The results obtained by Tsien Hsueh-shen
     for the case of three-dimensional flow
     in the presence of shock waves and
     vortices are generalized. A comparison
     of the results obtained with available
     exact solutions determined the limits of
     applicability of this method.

332. Lunev, V. V., I. N. Murzinov (Moscow),   IzAN MeMa
     and O. N. Ostapovich. Hypersonic flow   no. 3
     around blunted cones at small angles of   121-125
     attack.

The effect of bluntness on the pressure
distribution over the generatrix of thin,
blunted cones at large Mach numbers is
discussed.

333. Korobeynikov, N. P. Supersonic flow at   IzVUZ, AvT
     an angle of attack past triangular   no. 1
     wings and elliptical cones with a sub-   28-34
     sonic leading edge.

     A conformal mapping analysis is made of
     the flow past pointed, low-aspect-ratio
     lifting wings with a curved leading edge
     and past elliptical cones. The procedure
     is based on the solution of an arbitrary-
     generatrix body of revolution, obtained
     by employing the refined slender-body
     theory.

334. Bu gina, Ye. V. Self-balancing of super-   IzVUZ, AvT
     onic wings having a variable-sweep   no. 4
     leading edge.   10-17

     Self-balancing achieved by imparting a
     cylindrical curvature and geometrical
     twist to the median surface of the wing
     is analyzed.

335. Bobrov, G. Ye. On the feasibility of using   IzVUZ, AvT
     aerodynamic interference to reduce the   no. 4
     wave drag of annular wings in a super-   3-9
     sonic flow.

     The feasibility of using aerodynamic
     interference to reduce the wave drag
     of annular wings in a supersonic
     flow at zero angle attack is studied.
     The obtained solution, which is true
     for any values of the ring parameters
     and any values of the flow that satisfy
     the linear theory of supersonic flows,

represents a generalization of the results
obtained by Utkin for the special case
in which the trailing edge of an annular
wing is not completely within the plane
of the small-perturbation cone having its
apex upon the leading edge.

336. Sychev, V. V. (Moscow). Two-dimension-
al hypersonic gas flows past slender
bodies at large angles of attack.

PMM
v. 24, no. 2
205-212

Two-dimensional hypersonic flow about
slender bodies is investigated. Ap-
proximate formulas are derived for cal-
culating the aerodynamic characteristics
of bodies at large angles of attack.
Results can be applied to the case of
wings of low aspect ratio and small
relative thickness in hypersonic flow.

337. Belotserkovskiy, O. M. (Computing Center,
Academy of Sciences USSR, Moscow).
Machine computation of flow around axi-
symmetric bodies with a detached shock
wave.

PMM
v. 24, no. 3
511-517

The development of a method for computer
calculation of flow around axisymmetric
bodies with a detached shock wave is
presented. Results are given for certain
simple bodies such as ellipsoids, spheres,
and disks at various adiabatic exponents
and Mach numbers $(1 < M - < -)$.

338. Prituio, M. F. (Moscow). Streamline wings
flying in presence of slip.

PMM
v. 24, no. 5
873-878

A method of determining the additional
load on wings due to the presence of
slip is presented. The technique is
based on analysis of the linear equation

of the velocity potential. The case
is considered in which, for M > 1, the
small-parameter method leads in the
second approximation to a solution with
infinitely large first derivatives.
Several problems involving streamline
slip flow are solved as examples.

339. Shmyglevskiy, Yu. D. On a class of bodies
of revolution with minimum wave drag.

PMMe
v. 24, no. 5
923-926

The shape of a generatrix of a body of
revolution with a minimal wave drag is
determined for a given velocity of the
oncoming flow. The case of an attached
shock wave is considered. Sample calcula-
tions for various M- are presented.

340. Gonor, A. L. (Moscow). Determining the
shape of minimum-drag bodies for hyper-
sonic speeds.

PMMe
v. 24, no. 6
1073-1078

A variational method for determining the
shape of minimum-drag bodies in high
supersonic plane and axisymmetric flows
with a supplementary condition that the
pressure at any point of the body contour
must be non-negative.

341. Carafoli, E. and A. Nastase. Calculation
of the surface of a supersonic wing
furnished with a rib separating regions
of different pressure distribution.

Rev MeAp
no. 1
5-20

The surface of a thin supersonic wing
of triangular planform equipped with
a rib which separates the two regions
of different pressure distributions is
determined. The cases of an arbitrarily
and of a centrally located rib are
considered.

342. Carafoli, E., and D. Mateescu. (Institute of Applied Mechanics, Rumanian Academy of Sciences, Bucharest). A general method of determining wing-fuselage interference in supersonic flight.

StuCeMeAp
v. 11, no. 1
11-48

343. Murgulescu, E. (Institute of Applied Mechanics, Bucharest). On the theory of conical flows in the case of a thin wing of given cross section.

StuCeMeAp
v. 11, no. 1
61-94

A unique method is developed for studying conical flows in the case of thin conical wings with given cross section. A brief survey of research done on the theory of conical flows is given. The boundary problems can be reduced to those of Dirichlet or Volterra. The case of conical wings with subsonic trailing edges is considered, taking account of the separation of a turbulent layer at the trailing edges.

344. Carafoli, E., and D. Mateescu (Institute of Applied Mechanics, Rumanian Academy of Sciences, Bucharest). Supersonic flow around a cruciform wing-conical fuselage system.

StuCeMeAp
v. 11, no. 2
325-337

A study was made of the flow around a wing-conical fuselage system equipped with a normal plate for the case of subsonic leading edges of the wing and plate, where the incidence of the fuselage differs from that of the wing and the normal plate. The study is based on the small perturbations hypothesis and it is considered that the dimensions of the fuselage are sufficiently small relative to the Mach cone and that the angle of incidence of the wing, the normal plate, and the fuselage are also sufficiently small.

345. Carafoli, E., and A. Nastase. A thin tri-
angular wing with minimum drag in super-
sonic flow.

The planform of a minimum-drag, thin,
asymmetric triangular wing equipped
with a ridge separating the distribution
w, which can be considered as the hinge
of the leading edge slot is determined.
Suction forces are included in the calcula-
tion of drag. The study is made within
the limits of higher-order conical flows
and uses a variational method of calcula-
tion.

346. Lunev, V. V. Hypersonic flow of a radiating
gas past a wedge.

Hypersonic flow past an infinite wedge
is investigated under assumptions that
the influence of radiation is small,
and that it has no influence on the gas
motion in front of the shock wave.

347. Yeletskiy, A. V. Flow of a gas with part-
ial internal energy lag past a wedge.

Works in this field are reviewed, and
fundamental relationships are established
for supersonic flows below 2000°K.

348. Grigor'yan, S. S. (Moscow State University),
and V. Vani (Peking). Hypersonic flow of
a perfect gas around an axisymmetrical
body at small angle of attack.

Chernyy's analytical method is applied
to calculations of flows at small angle
of attack. The method permits the lineari-
zation of the problem and its solution.

349. Karpenko, P. D. Determination of the
        pressure distribution over an airfoil
        in an incompressible fluid flow.

      A method of determining the parameters
      of flow of an incompressible fluid past
      a given airfoil with a salient point
      at the trailing edge by means of suc-
      cessive conformal mapping is discussed.

1961
Dop An UkrSSR
no. 12
1560-1566

350. Ionov, V. P. Gas parameters at the surface
        of a cone.

      Approximate methods are presented for
      determining the parameters of a high-
      velocity gas flow at the surface of a
      cone. The flow is assumed to be axisym-
      metric, isentropic, and in thermodynamic
      equilibrium. At high velocities the
      oblique shock wave is very near the sur-
      face of the cone, thus there is only
      a small change of air-flow parameters
      between the cone and the shock wave.

EnI. AN SSSR
FGaTp
M. 1961
25-30

351. Petrov, Yu. N. Supersonic flow about a
        plate in the presence of a boundary
        gas film.

      Results are given of an experimental
      study of phenomena connected with
      longitudinal supersonic flow about a
      heat-insulated plate on whose surface a
      film of various cooling gases (air,
      nitrogen, hydrogen, and argon) was formed
      by tangential injection through a thin
      slit. Temperatures were measured by
      thermocouples, with errors not exceeding
      0.3°C.

EnI. AN SSSR
FGaTp
81-88

352. Nikol'skiy, A. A. Forces acting on a
        slender body in the vicinity of a blunted
        surface in supersonic flow under con-
        ditions of gas radiation.

InZh
v. 1, no. 3
40-45

Hypersonic heating of a blunted slender body (plate or bar) is analyzed. The flow is divided into three regions: 1) stagnation H, where high temperatures are generated; 2) immediate vicinity of the body K, where all the streamlines have passed through H; and 3) turbulent region L, between K and the shock wave.

353. Bulakh, B. M. On the position of the bow shock wave in a supersonic gas flow past an arbitrarily shaped slender body.

InZh
v. 1, no. 3
158-160

By an asymptotic formula based on the author's previous work the position (and strength) of a forward shock wave formed in a supersonic gas flow past a slender body of arbitrary shape is determined.

354. Krasil'nikov, Yu. I. Aerodynamic characteristics of wings in supersonic flow in the presence of slip.

InZh
v. 1, no. 4
18-26

A study is made of plane, symmetrical wings at a small angle of attack and a given angle relative to the direction of the supersonic flow. It is assumed that the disturbance caused by the wing is small and that the flow satisfies all requirements of the linearized theory.

355. Kogan, M. N. Symmetry of load on minimum-drag wings.

InZh
v. 1, no. 4
132

A simplified calculation of a minimum-drag supersonic wing is presented. The load distribution on the entire wing is derived from the pattern of load distribution on the frontal area of the wing.

356. Ladyzhenskiy, M. D. Hypersonic flow past
     slender, blunted bodies.

IzAN MeMa
no. 1
150-151

The bodies are of an arbitrary cross
section, and it is assumed that the
whole mass of gas is concentrated in
an infinitely thin layer behind the
shock wave. The problem of the flow
past the body is reduced to the equiva-
lent problem of the unsteady motion of
a gas displaced by a piston.

357. Fursov, M. K. Calculation of rotary deriva-
     tive coefficients for wings at supersonic
     speeds.

IzAN MeMa
no. 2
89-96

The linear problem of vibration of a thin,
flat wing in a supersonic potential flow
is considered. The basic motion of the
wing is rectilinear translational.
Harmonic vibrations of infinitely small
amplitude are superposed on this basic
motion.

358. Telenin, G. F., and G. P. Tinyakov.
     Unsteady supersonic flow around a
     blunt conical body.

IzAN MeMa
no. 2
97-105

A comprehensive theoretical analysis is
presented of unsteady supersonic flow of
gas around a body composed of spherical
and conical surfaces and subjected to
plane angular oscillations about its
center. On the assumption that the
conjugation points of the spherical and
conical surfaces are located in the super-
sonic region at all times, the flow
around each surface is considered as a
separate case, that is, a flow around a
sphere and a flow around a cone.

359. Galkin, V. S. Investigation of a hypersonic
     flow of weakly rarefied, viscous gas past
     a flat plate.

IzAN MeMa
no. 3
18-21

The drag coefficient is established for
a flat, semi-infinite, heat-insulated
plate in a hypersonic flow. It is as-
sumed that the region between the attached
strong shook wave and the plate is
formed by a nonviscous zone and a laminar
boundary layer. The strong interaction
of the shock wave and the layer is analyzed.
The slip velocity is taken into account.

360. Minyatov, A. V. Calculating the base
     pressure in a supersonic flow past
     a body of revolution.

IzAN MeMa
no. 3
32-39

The theory of base pressure in the
supersonic flow past flat plates is
generalized to cover flow past bodies
of revolution. Methods are given for
the calculation of pressures in the
cases of turbulent and laminar flows.
Experimental and theoretical data are
compared.

361. Shveyko, Yu. Yu. Influence of a supersonic
     gas flow on the lower critical force of a
     cylindrical panel.

IzAN MeMa
no. 4
14-19

The velocity effect of a supersonic flow
of a compressible gas along the directrices
of a shallow rectangular cylindrical
panel under compression on its lower buck-
ling force is investigated. The upper
critical force is also determined and
the relationship between the stream
velocity and the buckling stress, as well
as stability criteria for the panel are
established.

362. Zheludev, P. I. Thin-wing theory.

IzAN MeMa
no. 6
172-176

Supersonic flow past slender, sharp-
nosed bodies of revolution is analyzed
from the point of view of the thin-
wing theory.

363. Korobeynikov, N. P. The calculation of the aerodynamic characteristics of thin, curved bodies and cambered wings.

<div style="text-align: right">IzVUZ, AvT
no. 2
35-46</div>

Initial relationships for flow around slender cambered bodies obtained from previously published data (Korobeynikov, N. P. Supersonic flow around slender bodies with a curved axis. GKAT, Collected Articles, no. 15, 1959) are used to derive formulas for calculating the aerodynamic characteristics of cambered, low-aspect wings. The effect of aerodynamic twist (wash) on these characteristics is shown by practical examples.

364. Loytsyanskiy, L. G., and Yu. V. Lapin. (Leningrad Polytechnical Institute). The application of Karman's method for calculation of turbulent boundary layer parameters in a gas flow past a plate.

<div style="text-align: right">LPoI, Tr
no. 217
7-16</div>

By using Karman's equation for turbulent flow and applying a simple asymptotic expansion, Karman's theory of an incompressible-fluid flow past a plate is extended to the case of a compressible-gas flow at large Mach numbers. The gas is assumed to be perfect and the flow is analyzed for two cases: with heat removal and without it.

365. Minostzev, V. B. Supersonic flow past axially symmetrical bodies flying at at angle of attack.

<div style="text-align: right">MoFTI, Tr
no. 7
110-123</div>

The supersonic flow of an ideal gas past axially symmetrical bodies flying at an angle of attack has been investigated in the case when M >> 1 and the isentropic exponent is constant. The theory is illustrated by the calculation of the gas flow past a cone and past a truncated cone with a groove.

366. **Bulakh, B. M.** Some problems in conical
flow theory.

    Boundary problems in the theory of
conical vortex flows are discussed,
and the pattern of flow past a tri-
angular wedge is established ac-
curately. Specific points formed in
coalescing nonvortex and vortex flows
behind attenuating shock waves are
defined.

PMMe
v. 25, no. 2
229-241

367. **Bulakh, B. M.** Some properties of conical
supersonic gas flows.

    The influence of a shock wave on a
conical flow is investigated. The
shock wave is produced in a uniform
nonperturbed supersonic flow by a
conical body located inside the Mach
cone.

PMMe
v. 25, no. 3
478-484

368. **Lunev, V. V.** A similitude law for thin
blunt bodies in a hypersonic gas flow.

    A theoretical investigation of the simi-
larity of hypersonic flow about thin
flat plates and axisymmetric bodies with
blunt leading edges or noses is extended
to obtain the generalized similitude law
for viscous and inviscid heat-conducting
gas flows. Observations regarding simi-
litude criteria for a perfect gas flow
are included.

PMMe
v. 25, no. 6
1050-1059

369. **Barantsev, R. G., and Wu, Tsjen-yu.** Forces
and moments acting on bodies of revolution
in a free molecular flow.

    Aerodynamic coefficients of convex
bodies of revolution are calculated
for an equilibrium free-molecular flow

VeLUMMeAS

no. 3
77-92

with diffusion reflection of molecules
from the surface of the body. Numerical
calculations for a cone with a half-
apex angle of 20° are included.

370. Baush, G. Supersonic flow of an ideal
gas past plane, axisymmetrical, thin
bodies.

VeLUMMeAS
no. 4
103-114

An approximate solution is obtained for
the region between the shock wave and a
body with a sharp leading edge. It is
assumed that the shock wave is of small
intensity. The method is an extension
of G. G. Chernyy's method to the region
of low hypersonic velocities.

371. Popova, I. A. (Leningrad State University).
An approximate analytical solution of
non-vortical equations for variable sur-
face wing in supersonic flow.

VeLUMMeAS
no. 7
87-104

An approximate analytical solution of
equations of a steady flow is obtained
by the method of successive approxima-
tions, and the pressure and density on
a wing surface in the absence of vorticity
are determined.

372. Popova, I. A. (Leningrad State University).
The effect of vorticity in supersonic
flow around variable surface airfoils.

VeLUMMeAs
no. 13
131-145

Corrections to hydrodynamic parameters
are given, with vorticity effects taken
into account. The solution is a genera-
lization of Donov's results for the
profiles of some finite span wings.

373. **Borisov, B. I.** (Moscow State University).   VeMoU MMe
       Minimum drag of an annular wing.   no. 1
       63

       A method for determining the minimum-
       drag profile for an annular wing in
       supersonic flow is presented.

374. **Shugayev, F. V.** (Moscow State University).   VeMoU MMe
       Supersonic flow around axisymmetric blunt   no. 2
       bodies with detached shock wave.   46-53

       The direct problem of the flow around
       blunted bodies of various shapes is
       discussed.

375. **Belotserkovskiy, O. M.** (Computing Center,   AN Vych Ts
       Academy of Sciences USSR). Formulas and   1-55
       tables of values for supersonic flow about
       blunt bodies.

       Formulas are given for determining flow
       fields about axisymmetric ellipsoids of
       revolution, including the sphere, in a
       supersonic flow of an ideal gas. A. A.
       Dorodnitsyn's method of integral relation-
       ships makes possible the direct solution
       of the problem of constructing the flow
       around a given body.

376. **Tirskiy, G. A.** A sweptback wing in hyper-   ZhPMeTF
       sonic flow.   no. 6
       54-68

       The problem of failure of the leading
       edge is discussed as an essentially
       three-dimensional one with a secondary
       flow in the boundary layer. The dis-
       placement of the ablated surface on the
       leading edge is taken into account. Two
       cases are analyzed in detail: when the
       material of the cylinder has a definite
       melting temperature and an arbitrary finite
       number of transient temperatures at which
       heat absorption occurs (metals and crys-
       talline modifications of some ceramics

follow this disintegration pattern); and
when the material does not have a definite
melting point and there is exponential
temperature dependence of the viscosity
of the molten material (various glasses
disintegrate in this way). A system of
equations for the disintegration process
and an approximate formula for the abla-
tion rate of vitreous materials (case 2)
are given.

377. Mishin, G. I., and V. A. Ovsyannikov.
    (Leningrad Physicotechnical Institute).
    The influence of gas-dynamic relaxation
    of CO_2 on the drag coefficient of a
    sphere at supersonic velocities.

ZhTF
v. 31
1467-1471

The results from measurements of the
drag coefficient for a sphere for long
and short relaxation times of deforma-
tion oscillations of a CO_2 molecule are
presented. The influence of relaxation
on the drag coefficient of a sphere is
evaluated.

378. Belotserkovskiy, O. M., and P. I. Chushkin.
    Supersonic flow past blunt bodies.

1962
ARCH MeSt
v. 14, no. 314
461-487

A numerical method is given for obtaining
a solution of the exactly formulated problem
of the supersonic steady flow of a non-
viscous perfect gas around a blunted sym-
metrical profile and a body of revolution
of arbitrary shape, both with zero angle
of attack. Sample calculations for
M = 1 to 10 and ∞ are presented.

379. Zhigulev, V. N. (Moscow). On the effect
    of the relaxation boundary layer.

DAN SSSR
v. 144, no. 6
1251-1254

The supersonic flow of a weak relaxation
gas around a wedge is investigated. It
is shown that the nonequilibrium effects

are essential not only in the layer adjacent to the shock wave, but also in a region called the "relaxation boundary layer" close to the surface of the wedge and extending infinitely downstream and having a thickness of several relaxation lengths. An exact solution is given for the oscillatory relaxation problem.

380. **Kosterin, S. I., Yu. A. Koshmarov, and Yu. P. Finat'yev.** Hydrodynamics of a turbulent air flow in the gap between rotating coaxial cylinders.

InFZh
v. 5, no. 5
15-20

The air flow in an annular channel between a rotating inner cylinder and a stationary outer cylinder was experimentally investigated. The investigation covered the range of Reynolds numbers in the gap from 10^3 to 10^4 and of Taylor numbers from 0 to $5 \cdot 10^4$. The test setup and the measuring instrumentation are described in detail.

381. **Krasil'nikov, Yu. I. (Moscow).** Aerodynamic characteristics of a triangular wing with ailerons, flaps, and slots in supersonic flow.

InZh
v. 2, no. 1
175-181

The problem of determining the lift, moment, and their coefficients for a thin triangular wing with a deflected aileron, open slots, and depressed flaps is reduced to evaluating a function of disturbed-velocity potential, and determining the distribution of the resultant pressure over the wing.

382. **Nikolayev, V. S.** Viscous hypersonic flow about a slender cone.

InZh
v. 2, no. 3
9-13

A viscous hypersonic flow of an ideal gas over a slender cone at zero angle of attack is considered. The trans-

verse curvature of the surface and the
interaction of the boundary layer with
the shock wave are taken into account.
Integral relations of impulses and
energy are used in the boundary-layer
calculations, assuming a constant sur-
face temperature.

383. Bogacheva, A. A., and M. D. Ladyzhenskiy.
  Hypersonic flow around slender, elliptic,
  blunted cones.

InZh
v. 2, no. 3
14-20

A hypersonic gas flow around slender, el-
liptic, blunted cones is examined under
the assumption of infinite compression
of the gas in the shock wave. The cone
can be considered as a model of tri-
angular wing with a very low aspect
ratio.

384. Fridlender, B. I. Cruciform and T-shaped
  finite-span wings in a compressible fluid.

InZh
v. 2, no. 4
245-261

The potential of disturbed velocity of
a compressible gas is determined in a
steady supersonic flight of thin cruci-
form and T-shaped wings similar to a
tail unit of an airplane. Each plane
has a different plan view. The wing-
tip effects are discussed in detail for
both wings.

385. D'yakonov, Yu. N., and V. G. Pirumov.
  Supersonic gas flows with dissocia-
  tion and ionization.

IzAN MeMa
no. 1
7-14

An approximate method for calculating
supersonic flow about a wedge and a
cone is presented. Two types of flow
are considered: A Prandtl-Meyer flow in
which complete thermodynamic equilibrium

of the gas is assumed and a frozen
Prandtl-Meyer flow. Some speculations
on the effects of thermodynamic and
chemical disequilibrium on this flow
are therefore possible. Equations are
also presented for the flow about a cone
at zero angle of attack, assuming perfect
thermodynamic equilibrium of the gas
behind the shock wave.

386. Kolodochkin, V. P. (Moscow). Pointed
     bodies of revolution in a supersonic
     flow at various angles of attack.

IzAN MeMa
no. 1
15-24

Properties of a supersonic axisym-
metrical air flow over bodies of
revolution with conical noses at a
small angle of attack are discussed.
Equations for characteristics of the
resultant flow are obtained by super-
position of disturbances on the basic
(undisturbed) flow at $M_\infty = 1.5$ to 6.

387. Karafoli, Ye. (Carafoli, E.). Pressure
     distribution on airfoils in supersonic
     and hypersonic flows.

IzAN MeMa
no. 1
59-65

Expressions are derived for positive
and negative pressure distributions
over an airfoil; the positive—as the
result of compression behind the shock
wave (assuming that the velocity there
is supersonic), and the negative—of
the Prandtl-Meyer expansion over the
whole range of reach numbers up to
$M_\infty \rightarrow \infty$. Formulas are also given for
the lift, drag, and moment coefficients.

388. Stulov, V. P. Flow over a convex angle
     of an ideally dissociating gas with
     nonequilibrium taken into account.

IzAN MeMa
no. 3
4-10

The problem is solved approximately
for an arbitrary angle in the vicinity

of its apex. Consideration is also given to variations in discontinuities of normal derivatives of gas-dynamic variables along the characteristic curve separating the uniform incoming flow from the rarefied flow.

389. Lunev, V. V. (Moscow). Similitude conditions for hypersonic turbulent boundary layers on slender bodies.

IzAN MeMa
no. 4
13-17

Similitude conditions for hypersonic flows around plane and axisymmetrical slender bodies with a turbulent boundary layer having a variable entropy along its outer interface are investigated.

390. Mel'nikov, D. A. Supersonic flow around triangular flat plate.

IzAN MeMa
no. 6
33-39

A study is made of supersonic flow over a compressible surface of a tri-angular flat plate at an angle of attack at which the supersonic component of the velocity vector of an undisturbed flow normal to the leading edge meets the plate at an angle smaller than the limiting angle of the corresponding wedge.

391. Kholyavko. V. I. Flow about plates at high supersonic velocities.

IzAN MeMa
no. 5
26-31

The similarity between high super-sonic flow past bodies and phenomena of an explosion wave is considered. On this basis, approximate solutions of supersonic flow past a blunt body may be obtained.

392. Lunev, V. V. Shock layer method in problems of hypersonic flow over slender blunted bodies.

An analysis is presented of the method proposed by H. Cheng, T. Hall, T. Collian, and A. Hertzberg for approximate calculation of a flow over slender blunt bodies. An equation establishing the relationship between shock-layer thickness and pressure is given. Reasons for the discrepancies are given, and it is stated that the method used by G. G. Chernyy is more accurate in this case.

393. Aslanov, S. K. Sonic motion of a diamond-shaped airfoil at zero angle of attack.

The sonic, steady-state, planar flow of a compressible gas past a diamond-shaped airfoil of a wing of infinite span at zero angle of attack is investigated. In the subsonic region, this investigation is based on Chaplygin's exact equation of flow and can serve as a standard for evaluating the accuracy of previous investigations made on the basis of the approximate equation of transonic flow.

394. Tumashev, G. G., and O. V. Troyepol'skaya. (Kazan' State University). Determining the shape of the jet of a wing with a jet flap.

The shape of a jet formed by steady potential flow of an incompressible fluid around a thin, slightly bent wing equipped with a jet flap is determined. A small angle of attack and a small angle of inclination of the jet are assumed.

395. Drakin, I. I. Determining the optimum
     geometric parameters of aircraft
     structure.

An analytical method is presented for
determining the optimum shape and
dimensions of aircraft structural
members. The initial gross weight is
taken for the optimality criterion
under the assumption that no change
in useful load and performance is as-
sociated with the variation in geo-
metry. The optimum wing loading for
a given speed and height of flight,
and the optimum fineness ratio of the
front portion of a fuselage are
determined as examples.

396. Bulygina, Ye. V. Optimally cambered
     and twisted wing in supersonic flow.

The balance of wings is achieved
within a wide range of lifting
forces without increasing the drag
through suitable twist and camber.

397. Monakhov, N. M. Applying the Riemann
     method to solution of problems in
     flows past slender bodies.

The potentials of disturbances of
longitudinal and transverse flows
are obtained at the generatrices
of slender bodies of revolution at
a small angle of attack.

398. Lunev, V. V. Hypersonic flow past
     slender, blunted power-law shaped
     bodies.

The hypersonic-similarity laws for flows past thin, blunted cones and wedges have been established by G. G. Chernyy. It is shown that analogous laws can be applied to thin and axisymmetric bodies whose shape is described by a power function.

399. **Bulakh, B. M.** Supersonic flow around an inclined circular cone.

An analysis of supersonic flow about a cone at an angle of attack which reconciles the findings of Stone, Ferri, and Willet is presented.

400. **Galkin, V. S.** Lift in a free molecule flow.

A calculation is presented demonstrating that the lift of some bodies of finite length in a free molecule stream can be negative at any angle of attack between zero and $90°$ and for any value of the criterion $\Omega = V/c$ (where V is body velocity and c the most probable thermal velocity of incident molecules) even when the forces act on the body bases. The problem is calculated for flow past a symmetrical finite-length wedge where the ratio of the temperature of reflected molecules to the static temperature of the incident flow is in the range 0.1 to 1.

401. **Bulakh, B. M.** On asymmetric hypersonic flow around a circular cone.

A steady inviscid homogeneous hypersonic gas flow at angle of attack

past a circular cone is discussed.
The velocity components on the cone
surface are obtained by a modification
of the A. L. Gonor solution presented
in IzOTN, 1959, no. 7.

402. Shebalov, A. N. Wave drag of plane
     body in unsteady motion under a
     free surface.

The problem of unsteady motion of a
plane body of arbitrary shape under
the free surface of a heavy, incom-
pressible fluid is investigated, and
a method for obtaining expressions
for complex velocities and acting
forces is presented. A Laplace
equation is used to determine velocity
potential. Special cases of the
peculiarities of unsteady motion,
such as plane vorticity and its
sources, are examined and analyzed.
An expression for the wave resistance
of a body of arbitrary shape is estab-
lished by using the formulas obtained
by L. N. Sretenskiy. A wave-resis-
tance formula for a cylinder of a
certain radius in unsteady motion and
submerged to a certain depth under
the free surface is derived. This
formula is found to be analogous to
that of Sretenskiy.

403. Carafoli, E., and A. Ghia-Nastase.
     (Institute of Applied Mechanics,
     Bucharest). Minimum drag problem
     for a wing of symmetrical thick-
     ness.

The problem of finding the surface
configuration of a minimum-drag wing
of asymmetrical-triangle planform
symmetrical thickness, and a given
volume is treated. The results ob-
tained can be applied to determining
the minimum drag of rectangular and
trapezoidal wings.

404. Carafoli, E., and D. Mateescu. (Institute of Applied Mechanics, Bucharest). Wing-fuselage interference in high-order conical flows.

The interference between wing and conical fuselage in a supersonic flow is analyzed in the case when the distribution of the angles of attack (or of incidence) is given as a sum of homogenqous polynomials of various orders, assuming that regions with different angle-distribution regimes are separated bv ridges.

405. Sandulescu, S. and A. Nastase-Ghia. (Insitute of Applied Mechanics, Bucharest). The mixed problem of a triangular wing in higher-order conical flow.

The distribution of the angles of attack and pressures over the wing surface is determined from their distributions along two wing sections given by homogeneous high-order polynomials. The sections are divided from each other by a straight line (called "mixing edge") passing through the apex of the wing. The flow past triangular wings, thin and symmetrically thick, is investigated. By placing the "mixing edge" on the left or right side of the triangle, the direct and inverse problems can be obtained as limiting cases of the mixed problem.

406. Matcescu, D. (Institute of Applied Mechanics, Bucharest). Wings with sharp edges in supersonic flow.

A special class of wings with all edges having zero thickness (called "wing with subtending surfaces") is

discussed. The supersonic flow past
a triangular wing (thin and of sym-
metrical thickness) with subtending
surfaces is analyzed and the problem
of a triangular wing with a diamond-
shaped profile is treated as an
example.

407. Belova, A. V., and V. P. Loshkina. A
thin airfoil in supersonic flow with
complex thermodynamics.

VeLUMMeAs
v. 7, no. 2
96-100

A thin airfoil in a supersonic flow
under complex thermodynamic conditions
is considered and equations of motion
are established in the first and second
approximations. Formulas for calculat-
ing the lift components of the air-
foil are also given.

408. Mikheyev, A. S. (Leningrad State
University). An analytical solution
to the problem of supersonic flow
about conic surfaces.

VeLUMMeAs
v. 7, no. 2
105-112

The supersonic steady flow of gas about
a cone is considered and an attempt is
made to derive an analytical approximate
solution which would be independent
of the thickness of the body and the
magnitude of the Mach number of the
flow and would apply to gases, other
than an ideal one, with a constant
heat capacity.

409. Smirnov, N. V. Supersonic conical flow
under complex thermodynamic conditions.

VeLUMMeAs
v. 7, no. 2
113-118

An analytical solution is given for
the problem of supersonic isentropic
flows of an arbitrary gas over a

single airfoil and over a cascade of
airfoils. The problem is solved in
the first and in the second approxi-
mations with the use of linearization.

410. Arkhipov, V. N. and K. S. Khoroshko.   ZhPMeTF
     (Moscow). A method of accounting   no. 6
     for relaxation in flow past a cone.   121-124

     The disturbance and relaxation of
     thermodynamic equilibrium in the
     supersonic flow of a mixture of
     perfect gases (with regard to
     chemical reactions only among
     components) past a fixed semi-
     infinite cone is discussed. Flow
     is parallel to the cone axis, and
     the disturbance is caused by gas
     compression when the gas passes
     through an attached shock wave.

411. Chuskin, P. I. (Computing Center,   ZhVychMMF
     Academy of Sciences USSR, Moscow).   v. 2, no. 2
     Hypersonic flow past blunted bodies   255-277
     of revolution.

     The results of computer calculations,
     carried out by the method of charac-
     teristics, of the axisymmetric hyper-
     sonic flow of a perfect gas past blunted
     circular cones and cylinders are analyzed.

412. Babayev, D. A. Numerical solution of   ZhVychMMF
     the supersonic flow past a delta wing. v. 2, no. 2
                                             278-289
     The supersonic flow of a perfect gas
     past a plane delta wing with a positive
     angle of attack is studied. The
     boundaries of the region of influence
     of the wing apex on the upper part of
     the wing are determined.

413. Nazarov, G. I. Pressure of a gas jet
     on an isosceles wedge.

ZhPMeTF
no. 1
25-33

Bergmann's method is used to solve
two problems of pressure determina-
tion on isosceles wedges: 1) the
symmetrical flow of gas over a wedge,
and 2) the flow of a compressible
fluid over a wedge at the inlet of a
channel. In the second problem, some
use is made of N. Ye. Zhukovskiy's
formulas for the flow of incompressible
liquids over wedges.

414. Murzinov, I. N. The effect of the
     Prandtl number on flow around a
     blunt body at low Reynolds numbers.

ZhPMeTF
no. 1
39-43

The equilibrium flow of a viscous,
fairly rarefied gas in the region
of the stagnation point of axially
symmetric blunt bodies moving at
high supersonic speed is considered,
and equations of continuity, motion,
and energy are derived. The variation
of the Prandtl number along the boun-
dary layer and heat flow at the stag-
nation point are discussed in relation
to wall temperature.·

415. Sychev, V. V. Small disturbance method
     in problems of hypersonic gas flow
     over slender blunted bodies.

ZhPMeTF
no. 6
50-59

An approximate solution of the problem
of a uniform hypersonic gas flow past
slender bodies with blunted noses is
presented by using a unified small-
disturbance method. Expressions are
obtained for determining the flow
parameters at a great distance from
the body and in a layer close to its
surface.

416. Babayev, D. A. Numerical solution of
    supersonic flow past a delta wing.

    The solution of a supersonic flow
    past the lower surface of a delta
    wing is studied in the domain of
    the influence of the wing vertex.
    Determination of flow parameters,
    entropy function, and the form of
    the shook wave is reduced to the
    solution of a system of correspond-
    ing equations of motion and contin-
    uity under certain boundary con-
    ditions.

417. Kuznetsov, S. T. Diagrams and tables of
    the flow about a wedge, cone, and
    concave surface of dissociated air.

    This book contains diagrams and tables
    of dissociated air flow for calcula-
    ting shook wave parameters of high-
    energy flows having velocities from
    2000-10000 m/sec, and for heights from
    0 to 80 km.

418. Nowak, Eugeniusz. Free molecule hyper-
    sonic flow past a sphere.

    Free-molecule approximation of a steady
    hypersonic gas flow past a sphere is
    considered. Distributions of mean
    velocity of rebounded molecules are
    discussed, disregarding intermolecular
    collisions.

419. Fridlender, B. I. A cruciform wing of
    finite span in a compressible flow.

    A thin cruciform wing in a supersonic
    flow, with its horizontal and vertical
    surfaces performing arbitrary harmonic

oscillations, is discussed. A linear
formulation is used to derive an
expression for the disturbed-velocity
potential, considering the interaction
of oscillations and the wing-tip effect.
The way of handling the "cruciform"
wings with arbitrary dihedral angles
(e.g. star-shaped) is indicated.

420.   Magomedov, K. M. Supersonic flow past   IzAN MeMa
       blunt bodies with known sonic points.   no. 1
                                                     111-117

       The flow field in the region between
       a detached shock wave and an axisym-
       metrical body with a known sonic point
       is studied in the case of a supersonic
       flow at zero angle of attack. The
       shape of the shock and the pressure
       distribution over the body are deter-
       mined. Approximate formulas are derived
       for shock detachment, pressure distribu-
       tion, and velocity gradient, depending
       on the ratio of shock densities ahead
       of and behind the normal shock, and on
       the bluntness parameters.

421.   Grodzovskiy, G. L. (Moscow). Super-   IzAN MeMa
       sonic flow with a subsonic axial   no. 4
       velocity component about a flat cas-   115-120
       cade and a perforated wall.

       Supersonic flow about a flat, periodic
       cascade with no separation having a
       subsonic axial component of the incident
       flow in a direction normal to the cas-
       cade-plane is considered. Expressions
       for basic flow parameters are established
       which take pressure losses into account.
       The flow fields both in front of the
       cascade and far upstream are studied.

422.   Ozerinin, V. N. The effect of wing   IzVUZ., AVT
       downwash on stabilizer lift.   no. 1
                                                    157-166

       An approximate method is presented

for determining the lift characteristic
of a stabilizer with a span greater than
that of the wing. An expression for
the vertical component of the induced
velocity at M > 1 is derived and
the downwash behind a wing and a wing-
cylindrical body combination is discus-
sed.

423. **Bulygina, Ye. V.** A self-balancing   IzVUZ, AvT
       airfoil of minimum drag.   no. 2
                                                        118-123

       The problem of determining the shape
       of an airfoil of minimum drag with
       given lift and moment coefficients in
       an ideal fluid at high supersonic
       speeds is presented.

424. **Buly ina, Ye. V., and L. T. Yakubo.**   IVUZ, AvT
       Hypersonic airplane with self-balanc-   no. 3
       ing surface.   3-10

       The problem of determining the lifting
       surface of a hypersonic airplane with
       a high lift-drag ratio and a known
       center of gravity is studied. The
       minimum-drag body problem with a
       given lift is treated in detail for
       given and arbitrary volumes of the
       body.

425. **Kholyavko, V. I.** Aerodynamic characteris-   IzVUZ, AvT
       tics of airfoils and wings with blunted   no. 3
       leading edges at high supersonic speeds.   43-50

       The plane supersonic flow of an in-
       viscid perfect gas over slightly
       blunted bodies is examined by ap-
       plying the principle of plane sections.
       The piston theory is used in deriving

the equations for shock wave propagation and pressure on the piston (body). The influence of edge bluntness and of the sweepback on the aerodynamic characteristics of a plate and triangle wing is discussed.

426. Val'kov, Yu. A. Entry of a winged aircraft into a vertical gust.   IzVUZ, AvT no. 4 3-14

Longitudinal motion of a winged aircraft (treated as a perfectly rigid, constant-weight body) which has flown into a strong vertical current is analyzed, assuming that the directions of gust and of flight are always perpendicular to each other, and the gust velocity is small in relation to that of the flight. Expressions for determining dangerous gust velocities for various gust patterns are derived.

427. Romishevskiy, Ye. A. (Moscow). Hypersonic gas flow past slender bodies, with radiation taken into consideration.   InZh v. 3, no. 1 12-17

Special features of high supersonic gas flow past slender bodies, whose form is described by a power or an exponential function, are discussed. The entry of such a body into dense layers of the terrestrial atmosphere is analyzed, and the radiation effect on the distributions of temperature, pressure, and velocities over concave and convex bodies is pointed out.

428. Bazzhin, A. P. Supersonic flow around a flat plate with detached shock wave.   InZh v. 3, no. 2 222-226

A study is presented of the flow past a flat plate at an angle of attack with

a detached shook in the entire super-
sonic and hypersonic regions. The method
of integral correlations is used for
calculating flow parameters and computer
programming of the flow-field configu-
ration. The location of the critical
point on the plate is examined under
certain conditions. Numerical calcula-
tions were made at M = 4.5, 6.85,
10, and 20; at angles of attack of 90°,
75°, 65°, and 45°; and compared with
experimental data.

429. Moiseyenko, A. F. Reversibility theorem
for steady motion of an annular wing
with fuselage.

InZh
v. 3, no. 2
355-362

The reversibility theorem is applied
to a combination of an annular wing
and a coaxial infinite cylinder in
steady subsonic or supersonic flow.
Aerodynamic characteristics and pressure
relationships of annular wings in
direct and reverse flow are discussed
and the lift-pressure relation is
established. Lift characteristics of
the wing-fuselage system are calcul-
ated for various wing-aspect ratios
and ratios of cylinder to wing radii
and are shown in graphs.

430. Neyland, V. Ya. (Moscow) and G. I.
Taganov (Moscow). Forward
separated flow region in nonsym-
metrical supersonic flow over a
spiked cone.

InZh
v. 3, no. 3
419-423

A generalization of the method used
by S. M. Bogdonoff and T. E. Vas
(Hypersonic Separated Flows. Seventh
Anglo-American Aeronaut. Conf., N.Y.,
1959) to solve the problem of hyper-
sonic separated flow over a spiked
cone at an angle of attack other than

zero is described. The results (given
in graphs) with respect to the maximum
value of the angle of attack compatible
with the flow model considered are
discussed.

431. Neyland, V. Ya. (Moscow). Hyper-
     sonic inviscid gas flow over a plate
     at an angle of attack.

InZh
v. 3, no. 3
424-426

A method is outlined for calculating
the parameters of an inviscid gas
flow. The correlations of the flow
theory of an inviscid gas makes it
possible to determine the one-para-
meter class of solutions at given
values of angle of attack and M of
the incident flow. Numerical results
are obtained for laminar flow in the
mixing region with no heat transfer
under the assumptions that the product
of the density and the dynamic co-
efficient of viscosity is constant
across the mixing region and that
the Prandtl number is equal to 1.

432. Golubinskiy, A. I. (Moscow). Lift and
     moment of a thin airfoil in an arbitrary
     unsteady flow.

InZh
v. 3, no. 3
442-445

Unsteady subsonic and supersonic flows
over a thin airfoil are considered
in linearized formulation. The reverse-
flow theorem is generalized to the
case of an arbitrary unsteady flow by
using the analogy with a steady flow
over an equivalent three-dimensional
wing.

433. Filippov, I. G. (Moscow). A theory
     of diffraction of weak shocks
     around wedges.

PMMa
v. 27, no. 1
75-84

A new method is used to study the
general problem of two-dimensional
weak-shock diffraction around wedges
and bodies of arbitrary shape. With
this method, the plane nonsteady flow-
diffraction problem is reduced to
the auxiliary problem of three-dimensional
steady supersonic flow around bodies
at an angle of attack.

434. Sapunkov, Ya. G. (Saratov). Hyper-
    sonic flow past a circular cone
    at an angle of attack.

PMM
v. 27, no. 1
190-192

The determination of the hypersonic
flow properties around a circular
cone at an angle of attack is deter-
mined by using Cheng's expansion of
the small parameters. Error analysis
indicates that the solution obtained
by this method is not valid in the
vicinity of the cone surface, which
may be due to erroneous calculation
of entropy.

435. Sapunkov, Ya. G. (Saratov). Hypersonic
    gas flow past a circular cone at an
    an angle of attack.

PMM
v. 27, no. 5
930-939

A method of successive approximations
(by using the Poincare-Lighthill-Kuo
method) is presented which uniformly
approximates the exact solution of
the problem of a hypersonic flow of
a homogeneous gas around a cone at
at an arbitrary angle of attack in
the whole region between the shock
wave and cone surface, including
the vorticity layer.

436. Bulakh, B. M. Asymmetrical hypersonic
    flow past a circular cone.

PMM
v. 26, no. 5
973-976

A steady, uniform, inviscid flow of
gas at an angle of attack is studied,
and solutions similar to those of
H. K. Cheng are obtained. It is shown
that A. L. Gonor's theory cannot be
applied in this case.

437. Ginzburg, I. P., and G. V. Kochery-
zhenkov. Turbulent boundary layer
in a compressible fluid on a thermally
noninsulated wing or axisymmetric
body.

VeLUMMeAs
no. 2
86-98

An approximate solution is presented
for the problem of motion of a compres-
sible fluid in a turbulent boundary
layer on a thermally noninsulated wing
or an axisymmetric body. The calcula-
tion procedure is outlined for a
numerical example of a spherical body
in an air flow of M = 20 with a
stagnation point temperature of 7000°K.

438. Mikheyev, A. S. Supersonic flow
around a body of revolution.

VeLUMMeAs
no. 2
120-127

A supersonic flow around a pointed
body of revolution with a curvilinear
generatrix is studied, and a system
of gasdynamic equations describing
a steady adiabatic gas flow with
arbitrary thermodynamic properties is
considered. The equation of a shock
wave is derived, and gasdynamic para-
meters of the shock wave and on the
body surface are determined.

439. Vereshchagina, L. I. Base pressure on
bodies of revolution in a supersonic
gas flow.

VeLUMMeAs
no. 3
139-143

A method for determining the base

pressure on bodies of revolution
rotating in a supersonic gas flow
(turbulent mixing) is presented.
The model used is described, the
flow in the mixing region is analyzed,
and the procedure of calculation is
given.

440. Perepukhov, V. A.   Rarefied gas flow
     about a plate.

     A flow of highly rarefied gas about
     a flat circular plate at a zero angle
     of attack was analyzed. It was as-
     sumed: 1) that the macroscopic velocity
     of the flow is higher than the thermal
     velocity of the free-stream molecules
     and greatly exceeds the velocity of
     the reflected molecules, 2) that the
     reflection of molecules from the sur-
     face takes place by diffusion accord-
     ing to the Maxwellian distribution
     function, and 3) that the molecules
     are solid elastic spheres.

ZhVychMMF
v. 3, no. 3
581-583

441. Syagayev, V. F.   A numerical method for
     solving the problem of supersonic gas
     flow around conical bodies.

     Supersonic flow of an ideal gas around
     a conical body having one or several
     planes of symmetry is discussed. The
     inverse type method of solving   the
     boundary problem based on iterated
     numerical solutions of the Cauchy
     problem with successive correction of
     the given initial data is used. The
     results are compared with those obtained
     by other methods and with experimental
     data.

ZhVychMMF
v. 3, no. 4
742-754

442. Borisov, V. M. (Moscow). On optimal
     shape of bodies in supersonic gas
     flow.

ZhVychMMF
v. 3, no. 4
788-793

Two variational problems of gas
dynamics are considered: constructing
optimal contours for flows of a perfect
gas with a shook wave and the minimum-
drag generatrices of portions behind
the nose of bodies of revolution are
determined; and the flow of a real gas.

443. Mikheyev, A. S. Supersonic flow
around blunted bodies of revolu-
tion.

An adiabatic equilibrium supersonic
steady gas flow (of given thermo-
dynamic properties) past a blunted
body of revolution with a corner
point on its contour is investigated,
using a simplifying modification of
A. A. Dorodnitsyn's method of integral
relations.

GROUP A   AEROMECHANICS OF HIGH-SPEED FLOWS

A-3   Testing and Research Facilities
       Wind Tunnels
       Shock Tubes
       Nozzles and Diffusors
       Other Testing Facilities
       Simulation and Modelling Facilities
       Re-Entry Testing Equipment

444. Zemskiy, O. M. (Moscow). Supersonic wind
tunnels.

1940
~~VoeVorA~~
Rep. No. 60

445. Nedelescu, Ion An open-type supersonic wind
tunnel in continuous operation

1959
~~ScuCeMeAp~~
v. 10, no. 1
287-301

The description and flow parameters of a
supersonic wind tunnel at the Traian Vuia
Institute of Applied Mechanics are given and
its test results are discussed. The possibility
of construction of a larger tunnel is examined.

446. Gusev, V. N. A study of flow in a discharge
device.

1961
~~InZh~~
v. 1, no. 3
161-165

A mathematical investigation of the shock-
wave propagation in an electric-discharge
device is presented by using a piston analog.
The working substance is a perfect gas, and
there are no physical or chemical transform-
ations during the motion. A formula for the
velocity of wave propagation is derived.
Waves with velocities over 10 km/sec can be
obtained in the device discussed here.

447. Antonov, A. M., and M. M. Sidlyar. Some
approximate solutions of problems of
hypersonic flow about slender bodies

PMe
v. 7, no. 6
649-656

A theoretical study by the method of
successive approximation of bodies at $M \leqslant 20$ is
based on general equations of conservation of
mass, momentum, and energy, and continuity of
the tangential component of velocity. Numeri-
cal data are given on pressures in the flow
about a wedge at M = 17, 18, 19, 20, and 21.

448. Jungowski, V. M.   Methods for calculating
     stagnation temperature in a hypersonic
     gun tunnel.

An analysis of phenomena in a gun tunnel is
presented, along with a description of the
method derived by Cox and Winter (AGARD Report
139). A sketch of the apparatus is given to-
gether with a time-versus-distance diagram,
and an operational description is presented.
It is stated that gas friction and heat trans-
fer have little effect on piston motion but
quite a distinct effect on stagnation temper-
ature through the attenuation of the primary
shock wave and a decrease in gas entropy. The
effect of piston weight on the strength of the
shock wave is outlined.

449. Lashkov, A. I., and Nikol'skiy, A. A.
     Shock-wave starting of a supersonic diffuser.

InZh
v. 2, no. 1
11-16

A method which uses nonstationary flow
phenomena for the starting process of a
supersonic diffuser has been developed.
The diffusers were tested at M = 2.905 and
M = 2.9 and results are shown in spark photo-
graphs.

450. Popov, N. N. The problem of imparting high
     flight velocities to bodies.

VeMoU MM
no. 4
69-74

A numerical solution of the classical
Lagrange problem (determining the motion of
a piston in a cylinder open on one end and
closed on the other end, the space between the
piston and the closed end being filled by an
ideal gas) is presented. This problem is then
applied in the case of one-dimensional motion
in a cylinder with the electric and magnetic
fields perpendicular to each other and to the
velocity vector; the solution is obtained by
successive approximations.

451. Krayko, A. N., I. N. Naumova, and Yu. D.
Shmyglevskiy. Designing optimum-shape
bodies in supersonic flow.

The design of the shape of the supersonic
position of nozzles with maximum thrust is
discussed.

GROUP B   AEROTHERMODYNAMICS OF HIGH-SPEED FLOWS

B-1   Aerothermophysics
       Mass and Heat Transfer
       Temperature Distribution
       Thermal Radiation Effects
       Ionization
       Dissociation

452. Kalikhman, L. Ye. (Moscow). Heat transfer in
the boundary layer.

Translation: NACA Tech. Mem. No. 1229
(1949)

<u>1946</u>
PMMe
v. 10, no. 4
449-474

453. Prokof'yev, V. A. . Influence of radiation on
the propagation of small disturbances in
viscous heat conducting fluids (hydrody-
namic theory).

An attempt is made to analyze the radia-
tion problem with an accurate evaluation of
the transfer of radiation. Heat radiation
and the absorption of radiation energy are
taken into account.

<u>1957</u>
IzAN OTN
no. 7
94-102

454. Sidorov, B. A. (All-Union Institute of Heat
Technology, Moscow). An approximate solu-
tion is derived for the case of nonstation-
ary convection heat transfer.

IzAN OTN
no. 9
116-117

455. Kim, Ye. I. (Kharkov). Concerning one prob-
lem of the heat exchange of a system of
bodies.

A study of the heat-exchange problem of a
system of bodies in thermal contact is re-
ported for the case of continuously vary-
ing temperature and heat flow in the
neighborhood of the contact boundary.

PMMe
v. 21, no. 5
624-633

456. Glikman, V. F. On the problem of nonsta-
tionary heat transfer through a plate.

Presents an expression for the specific
thermal flux through two surfaces of the
plate. Values are given for the relative
departure of the thermal flux from its
stationary value. (Refer to Sov. Phys.,
Dec. 1957, 2593-2595.)

ZhETeF
v. 27, no. 12
2794-2796

457. Grigor'yev, B. A.   Some problems of heating   **1958**
an infinite plate by unsteady flows.   IzAN OTN
no. 1
86-94

Unsteady, pulsed radiating flows, whose
density at the irradiated surface is
expressed by the product of a power and
an exponential function (both of time),
from the beginning of irradiation, are
discussed.

458. Tirskiy, G. A. (Moscow).   Nonstationary heat   IzAN OTN
transfer through a system of disks rotating   no. 7
in a viscous fluid.   106-107

A generalization of the problem of nonsta-
tionary heat transfer is presented for a
system of disks rotating in a viscous
liquid.

459. Grigoryan, S. S.   On heating and melting of   PMMe
a solid by friction.   v. 22, no. 5
577-587

The formulation and solution of two problems
of heating of solids by friction are pre-
sented. The first problem is that of fric-
tion between two solids; the second is the
flow of a viscous, incompressible fluid past
a solid body.

460. Sidorov, E. A. (All-Union Institute of Heat   Teploener-
Technology, Moscow). Calculation of effects   getika
of a nonstationary regime on convective   no. 4
heat exchange.   79-80

The development and application of approx-
imate methods of calculating the effect of
a nonstationary regime on convective heat
exchange are presented.

461. Zaydel', R. M., O. S. Ryzhov, and Ye. I. An-
     dryankin (Institute of Chemical Physics,
     Moscow). Propagation of nearly spherical
     heat waves.

     The propagation of heat waves of nearly
     spherical shape is calculated. The de-
     termination of the eigenvalue spectrum
     and the corresponding eigenfunctions is
     explained.

462. Fayzullov, F. S., N. N. Sobolev, and Ye. N.
     Kudryavtsev (Physics Institute, AN SSSR).
     Temperature of nitrogen and air behind a
     shock wave.

     The experimental results on the temperature
     of air and nitrogen behind a shock wave,
     obtained by using the method of conversion
     of spectral lines with photoelectric re-
     cording, are evaluated.

463. Kogan, M. N. (Moscow).   High conductivity
     flows.

     Certain characteristic types of flow
     occurring in the case of high heat con-
     ductivity are studied. The process for
     solving the case of an arbitrary body is
     briefly indicated, and it is pointed out
     that in the case of supersonic flow, the
     turbulence occurs upstream of the body.

464. Tirskiy, G. A. (Moscow). Heating of a heat-
     conducting wall behind a moving compression
     shock.

     An exact solution of the problem of heating
     of a flat wall behind a plane shock wave
     travelling through a gas at rest at con-
     stant speed parallel to the wall boundary
     is obtained.

465. Zarubin, V. S. A problem of unsteady heat
     conductivity.

     The unsteady heat transfer taking place in
     the casing of a liquid-cooled liquid-fuel re-
     action engine during transient regimes is
     discussed. It is assumed that the inner
     and outer walls of the engine casing are
     thermally connected by convective heat
     transfer by means of the liquid coolant
     whose temperature is time dependent, and
     that heat flux is proportional to the tem-
     perature of a given point at a given time.

IzAN EnAvtT
no. 2
38-44

466. Sidorov, E. A. (Moscow). A generalization
     of Gretz's solution to cover the case of
     radiative heat transfer.

     A generalization of Gretz's solution for
     convective heat transfer in laminar fluids
     to cover the case of radiative heat trans-
     fer is presented.

IzAN EnAvtT
no. 6
183-185

467. Sidorov, E. A. (Moscow). The interaction of
     convection and radiation in an absorbing
     medium.

     The further development of previously ob-
     tained results on the interaction between
     heat convection and radiation in absorbing
     media is presented. The study covers the
     case of a two-dimensional steady motion of
     an incompressible fluid in the neighbor-
     hood of a nonisothermal surface.

IzAN MeMa
no. 5
134-136

468. Cherpakov, P. V. (Voronezh State University).
     Periodic solutions of heat transfer equa-
     tions.

     Periodic solutions of the equations of heat
     transfer in finite and infinite regions
     characterizing the propagation of heat
     waves are obtained.

IzVUZ, M
no. 2
247-251

469. Merkulov, V. I. (Kiev). Heat transfer in a   PMMa
      plane stationary flow of viscous fluid.   v. 23, no. 3
                                                        581-582

      Equations of steady heat transfer in a
      stationary flow of viscous liquid are
      derived. The assumptions of constant
      heat transfer coefficients and of the
      known solution of the velocity field
      problem are introduced.

470. Kaplan, S. A., and I. A. Klimishin. Some   1960
      notes on shock wave radiation.   As Zh
                                                        v. 37, no. 2
                                                        281-283

      The heating of a gas before the front of
      a shock wave by the radiation emitted by
      it is discussed. Formulas for calcula-
      ting the width of the heated zone and
      its temperature field are given.

471. Nikitin, Ye. Ye. (Institute of Chemical Physics,   DAN SSSR
      Academy of Sciences USSR). A mechanism of   v. 132, no. 2
      intermolecular energy exchange during dis-   395-398
      sociation of a diatomic gas.

      A mechanism for intermolecular energy ex-
      change in the presence of diatomic gas
      dissociation is discussed.

472. Motulevich, V. P. (Power Engineering Insti-   EnI AN SSSR
      tute, Moscow). Heat exchange at the   16-22
      stagnation point of blunt bodies in su-
      personic gas flow.

      A relatively simple method for solving
      the problem of heat exchange at the stag-
      nation point of blunt bodies in super-
      sonic gas flow is proposed. The method is
      based on the process occurring in the cen-
      tral stream of the supersonic flow in an
      inviscid fluid.

473. Kusnetsov, N. M. (Institute of Chemical   InFZh
       Physics, Academy of Sciences USSR).   v. 3, no. 9
                                          17-24

       Problems of temperature distribution and
       concentration of the components of dis-
       sociating air in the nonequilibrium region
       behind a steep shock front are discussed.

474. Mikhaylov, V. V. (Moscow State University).   InSb
       An analytical presentation of thermodynamic   v. 28
       functions of dissociated air.   36-43

       Relatively simple and accurate expressions
       are given for thermodynamic functions of
       dissociated air, disregarding processes of
       additional excitement of the degree of
       freedom of the particles. It is assumed
       that progressive energy levels do not de-
       pend on inner levels.

475. Kvashnina, S. S., and V. P. Korobeynikov.   IzAN MeMa
       Solution of some problems of air motion,   no. 2
       with dissociation and ionization accounted   34-44
       for.

       Approximate gas-dynamics formulas are pre-
       sented for air in the temperature range
       from 1000 to 20,000° K.

476. Volodina, M. V., Yu. A. Dem'yanov, S. S.   IzAN MeMa
       Kellin and N. V. Chereshneva. Wall surface   no. 6
       temperatures behind a shock wave.   112-116

       A theoretical and experimental investi-
       gation of the wall surface temperatures
       behind a shock wave moving at constant
       speed is reported.

477. Povitskiy, A. S. Equilibrium temperature of   IzVUZ, AvT
       slender bodies in supersonic flow.   no. 1
                                          35-42

The corrections which must be introduced
in the coefficients of heat transfer of
a flat plate when those coefficients are
applied to slender wedges, thin airfoils,
slender cones, and slender bodies of revo-
lution moving at high supersonic speeds
are discussed.

478. Figurovskiy, V. I. The calculation of the   IzVUZ, AvT
     heating of two-layer plates.   no. 2
                                                         99-104

     The heating of a two-layer plate, one layer
     of which has low heat conductivity (thermal
     insulation) and the other is metal, is ana-
     lyzed under the assumptions that the tem-
     perature of the insulation layer is that
     of the surrounding air and that there is
     no heat transfer from the free surface of
     the metal layer.

479. Yarkho, A. A. (Khar'kov). Heat transfer in   IzVUZ, AvT
     the neighborhood of the blunt leading edge   no. 3
     of a cylindrical wing on slipping.   22-27

     The solution obtained previously for the
     problem of heat transfer in the neigh-
     borhood of the forward critical point in
     a plane flow of gas is generalized. The
     case of steady flow of gas around an in-
     finite cylindrical wing is studied. The
     assumption of a laminar flow in the boun-
     dary layer and of a constant Prandtl num-
     ber and specific heat is introduced.

480. Alimov, R. Z. (Kazan' Aviation Institute).   IzVUZ F
     The influence of diffusion on heat transfer   no. 3
     of gases in a boundary layer.   97-102

     An approximate method is presented for cal-
     culating the influence of diffusion on
     heat transfer of the gas in the boundary
     layer, based on criterional equations.

481. Petukhov, B. S., and V. V. Kirillov. Heat   Teploener-
     transfer in a turbulent compressible gas   getika
     flow in a tube at numbers up to 4.0.   v. 7, no. 5
                                                      64-72

     Local heat transfer in a compressible gas
     flow in a tube with Mach numbers from 0.5
     to 4.0, Reynolds numbers from $40 \cdot 10^3$ to
     $900 \cdot 10^3$, and relative tunnel lengths on
     heat transfer are determined, and gener-
     alized relations for the calculation of
     heat transfer are presented.

482. Stratonovich, R. L. Fluctuation thermo-   ZhETF
     dynamics of nonequilibrium processes.   v. 39, no. 6
                                                     1647-1659

     Equations of the theory of equilibrium
     fluctuations and of nonequilibrium
     thermodynamics were derived by estab-
     lishing a relationship between the
     fluctuations in two-dimensional dis-
     tribution and the one-dimensional dis-
     tribution of a nonequilibrium process.
     It is shown that the residual correla-
     tions and the ergodicity of the system
     are determined by the behavior of its
     thermodynamic fluctuations. The On-
     sager relations are generalized to the
     case of nonlinear nonequilibrium
     processes.

483. Nevzglyadov, V. G. Thermodynamics of   ZhETF
     turbulent systems.   v. 39, no. 6
                                                     1727-1733

     Some consequences of the second law of
     thermodynamics for single-component tur-
     bulent systems are discussed. It is shown
     that the law must be generalized in order
     to be applicable to such systems, and this
     is done by means of the concept of "turbu-
     lent-thermal entropy."

484. Loytsyanskiy, L. G. Heat transfer in tur-   PMMe
     bulent motion.   v. 24, no. 4
                                                     637-646

Literature on the theory of heat transfer
in turbulent motion is reviewed briefly.
The hypothesis of localization is gener-
alized for the case of interactions be-
tween the polar and molecular flow past
bodies, and von Karman's theory is ex-
tended to high Prandtl numbers.

485. Dem'yanov, Yu. A. (Moscow). The boundary   PMMe
     layer on a plate of a time-variable   v. 24, no. 4
     surface temperature.   647-650

     A method is developed for calculating the
     temperature field in the boundary layer of
     a semi-infinite plate in a uniform flow
     moving with a velocity $V\infty$. The onset of
     heating in the plate is governed by a time-
     dependent temperature function $T_W(t)$, where
     T_W is the wall temperature.

486. Kostandian, B. A. (Moscow). On the stability   PMMe
     of the solution of the nonlinear heat con-   v. 24, no. 6
     duction equation.   1112-1122

     The stability of solutions of the nonlinear
     heat conduction equation is analyzed. Suf-
     ficient conditions of asymptotic stability
     are obtained by making use of certain ap-
     proaches in Lyapunov's second method.

487. Nemchinov, I. V. (Moscow). Problems of heat   ZhPMeTF
     transfer by radiation.   no. 1
                                                       36-57
     The equations of radiative heating and
     cooling by radiation, and equations of
     motion are analyzed. Self-similar so-
     lutions are obtained for the case when the
     radiation path is a power function of
     the temperature, and the radiation flux
     depends on time.

488. Klimov, A. M. Flow of gas with high thermal   ZhPMeTF
     conductivity near the stagnation point of   no. 1
     a blunt body.   138-141

          Heat transfer in ionized and nonionized gases
          near the stagnation point at arbitrary
          Prandtl numbers is analysed.

489. Lapin, Yu. V. Friction and heat exchange   ZhTF
     in a compressible turbulent boundary layer   v. 30, no. 8
     on a plate with the injection of fluid.   984-993

          The above mentioned friction and heat ex-
          change analyses are based on boundary-
          layer equations for a two-component gas
          mixture under the assumptions that the
          rate of the inert-gas injection is low,
          the specific heat is constant, and the
          Prandtl and Schmidt numbers are each
          equal to unity. The effect of the
          physical properties of the injected fluid
          on the friction and of the injection it-
          self on the distortion of the velocity
          profile in the boundary layer are discus-
          sed.

490. Lapin, Yu. V. Friction and heat exchange   ZhTF
     in a compressible turbulent boundary   v. 30, no. 10
     layer with injection of a chemically   1227-1237
     reactive fluid.

          The friction and heat exchange in the
          presence of chemical reactions caused
          by injection of a fluid into a compressible
          turbulent boundary layer on a porous plate
          are investigated under the assumptions that
          the rate of the chemical reaction is
          infinitely faster than that of diffusion,
          and that the Prandtl and Lewis numbers are
          each equal to unity.

                                                           1961
491. Motulevich, V. P. and G. P. Malyshev (Moscow   InI AN SSSR
     Power Engineering Institute). The effect   104-113
     of dissociation on heat exchange and fric-
     tion of a plate in an air flow.

The calculation of friction and heat ex-
change of a plate in air flow is examined
under two extreme conditions: "frozen"
and "equivalent." The equations are based
on the real dependence of all calculated
parameters on both temperature and pres-
sure in the "equivalent" case, and only
on temperature in the "frozen" case.

492. Kutateladze, S. S., and A. I. Leont'yev.   InFZh
Drag and heat-transfer laws in a turbu-   v. 4, no. 6
lent boundary layer of a compressible gas   33-41
and a method for calculating friction and
heat transfer.

A method based on limit laws of friction
and heat transfer is proposed for calcu-
lating these parameters in a turbulent
boundary layer of a compressible gas. The
theoretical laws of resistance and heat
transfer obtained here permit to simpli-
fying the method for solving the integral
relationships of the boundary layer in a
compressible gas flow with longitudinal
velocity and temperature gradients in re-
gions not close to the separation point.

493. Devoyno, A. N. Basic heat-transfer reg-   InFZh
ularity patterns in a rarefied gas due to   v. 4, no. 6
natural convection.   70-77

The problem of heat transfer between a ver-
tical plate and a rarefied gas in the viscous
and transient states (corresponding to con-
tinuous and slip flow respectively) is dis-
cussed. The theoretical solution of the
problem is compared with the author's ex-
perimental data for a range of pressures
from atmospheric to 0.01 mu Hg.

494. Kudryashev, L. I., and A. A. Smirnov (Kuy-   InFZh
byshev Aviation Institute). Heat transfer   v. 4, no. 10
in fluid flow around a cylindrical body.   21-29

Unsteady isothermal heat transfer between a cylinder and the flow of an incompressible fluid is studied, and formulas for calculating the heat transfer coefficient are derived on the basis of a semiempirical theory of turbulence.

495. Motulevich, V. P. Heat and mass transfer at the stagnation point of a blunt body.

InFZh
no. 11
10-18

A theoretical analysis is presented of the heat and mass transfer at the stagnation point of blunt bodies in a multicomponent gas flow with the chemical reactions occurring between the gas and the material taken into account. The relation of ignition and attenuation processes to other parameters is analyzed. For purposes of simplification, the analysis is reduced to that of a homogeneous body with only one irreversible reaction taking place. The analysis indicates that 1) both ignition and attenuation temperature depend on the chemical reaction characteristics of the reacting substances, the flow rate, the gas density, and the dimensions and shape of the body; 2) mass transfer and surface temperature increase with rise in gas-flow temperature for reactions of all types; and 3) higher gas density results in increased mass transfer, as does increased modulus of the heat of the reaction in the case of endothermic reactions.

496. Brovman, M. Ya., and Ye. V. Surin. Heat conduction calculations.

InFZh
v. 4, no. 12
75-82

An approximate method is proposed for solving heat conduction problems with various boundary conditions. The solution is expressed as a polynomial series. In an illustration of this method, in which heat conduction is considered in the cooling of a plate, the error of the results did not exceed 3 to 4%.

497. Shishkov, Ye. V. Temperature measurements
in the boundary layer.

I Khim Ma.
Sb.
78-91

Results are presented of an experimental
study of the distribution of local values
of equilibrium temperatures and pressures
on the surface of a thermally nonconduc-
tive cylinder in sub- and supersonic flows.
Data obtained are compared with calculated
data, and some specific conclusions are
drawn concerning the work of a thermocouple
in a transverse flow.

498. Neyland, V. Ya., and G. I. Taganov. Heat
transfer to a body in the vicinity of the
frontal separation zone in a hypersonic
flow.

InZh
v. 1, no. 3
151-153

The maximum heat flow is evaluated in the
vicinity of the boundary of the frontal
separation zone, under laminar flow con-
ditions. The influence of dissociation
on heat flow at certain angles of the con-
ical shock wave is determined.

499. Golubev, V. A. Parameters of turbulent jets
at a very high temperature.

InZh
v. 1, no. 4
51-58

Plane parallel jet flow of a compressible
gas is analysed on the basis of Prandtl's
theory of free turbulence, under the as-
sumption that the length of the mixing zone
for heat transfer is twice that for trans-
fer of momentum. Calculations are made for
a jet initially heated to temperatures of
20,000 and 5000°K. The results obtained
and those based on Taylor's theory of tur-
bulence were found to be qualitatively
comparable.

500. Naziyev, Ya. M. The temperature distribution
in an infinite hollow cylinder.

IzAN InAvt
no. 4
60-63

The heat-conductivity problem is considered
in the case of an infinite hollow cylinder

thermally insulated on the outside and with
an inner surface heated by a heat flow which
varies exponentially. Applying the Laplace
transformation to heat-conductivity equa-
tions with corresponding boundary conditions,
a transform pair of the solution of the
equations is derived, establishing the dis-
tribution of the temperature in the cylinder.
Exact and approximate solutions are also pre-
sented for the case when the temperature
on the outside surface of an infinite hollow
cylinder is maintained constant and the in-
side surface is heated by a heat flow vary-
ing exponentially.

501. Rumynskiy, A. N. Heat transfer near the
stagnation point.

IzAN MeMa
no. 1
96-101

The effect of radiation on convective
heat transfer near the forward stag-
nation point of an axisymmetric blunt
body in a hypersonic stream of radi-
ating and absorbing gas is discussed.

502. Shakhnov, I. F. Disturbance of a supersonic
flow induced by discrete or continuously
distributed heat sources.

IzAN MeMa
no. 5
16-21

Expressions are given for the distribution
of disturbances in an originally undis-
turbed flow of ideal gas. It is demon-
strated that at a given distribution of
heat sources in the flow, condensation or
rarefaction waves may appear; on the other
hand, it is possible to reduce some shock
waves in an adiabatic flow over bodies by
introducing an adequate heat supply.

503. Stulov, V. P. (Moscow). Heat transfer in a
laminar boundary layer.

IzAN MeMa
no. 6
11-14

Calculations of the heat transfer in a
boundary layer on a plane plate are pre-
sented which take account of chemical non-
equilibrium. The results indicate that
nonequilibrium in a gas particle does not
affect the rate of heat flow significantly.

504. Shakhnov, I. V. The method of small dis-   IzAN MeMa
     turbances applied to nonadiabatic super-   no. 6
     sonic flow.   37-41

     Flow parameters are established and dis-
     cussed for a gas flowing at supersonic
     velocity over a flat plate at zero angle
     of incidence. A rectangular zone of heat
     transmission adjoins the plate. Basic
     parameters determining the flow inside and
     outside the heating zone are given.

505. Suksov, I. I. Determination of the ther-   IzVUZ, AvT
     mal characteristics of a two-dimensional   no. 1
     laminar boundary layer in a compressible   27-37
     gas without a longitudinal pressure gra-
     dient in the region of the stagnation point.

     Simple approximate solutions are presented
     which give good results in determining the
     coefficients of friction, recovery, and
     heat transfer for a plane plate and for
     the stagnation-point region. Analogous
     solutions can be obtained when the effect
     of high aerodynamic heating is taken into
     account. The method can be extended to
     bodies of revolution.

506. Bulygina, Ye. V., M. B. Polyakov, and   IzVUZ, AvT
     Ya. S. Shcherbak. Thin airfoil with   no. 2
     the minimum mean heat-emission coef-   17-25
     ficient for a given lift.

     A theoretical solution is derived for
     the problem of determining an airfoil
     shape which would provide the least mean
     heat emission coefficient for a given
     lift. It is assumed that the airfoil
     is thin, that both the top and the bottom
     surfaces are heat insulated, and that
     the boundary layer is either fully
     laminar or turbulent.

507. Kudryashev, L. I., and V. K. Lyakov. The   IzVUZ, AvT
     Influence of longitudinal nonisothermi-   no. 4
     city on heat-transfer coefficient.   104-110

The problem of finding the heat-transfer
coefficient in the case of a turbulent
flow in hydraulically smooth conduits was
reduced to determining a system of dif-
ferential equations of the boundary sub-
layer. The heat-transfer coefficient was
computed theoretically for large longitu-
dinal nonisothermicity, and the functional
form of the correction-factor equation is
found on the basis of a turbulent heat-
transfer model. It is shown experimen-
tally that if physical parameters are de-
termined at the mean temperature of the
flow, then the experimental data are best
generalized in the form of an equation of
the dimensionless temperature in functions
of Reynolds and Prandtl numbers and the
quotient of the length and diameter of the
tube. The generalizati of experimental
data according to the existing formula,
with the correction facto taken into ac-
count, requires the int. uction of the
actual mean temperature gradient and com-
plicates the procedure. A simple method
for practical evaluation of the influence
of longitudinal nonisothermicity is given.

508. Fedorov, I. G., V. K. Shchulin, G. A. Muk-   IzVUZ, AvT
    hachev, and N. S. Idiatulin. Heat transfer   no. 4
    and hydraulic resistance in laminar conduits   120-127
    consisting of two 0.5-mm steel sheets, main-
    tained at a distance of 2.5 mm by projec-
    tions 6.5 mm in diameter produced by stamp-
    ing with spherical dies. Thus, a channeled
    or checkered pattern was formed. Four dif-
    ferent samples were tested in 18 to 20 re-
    gimes determined by air consumption in the
    range of Reynolds numbers from 500 to 18,000.
    The results obtained are presented graphic-
    ally with the Nusselt number and hydraulic
    resistance as functions of the Reynolds
    number.

509. Gribkova, S. I., and L. S. Shtemenko. (In-   Konf. Tp
    stitute of Heat and Mass Transfer, Acad-   Mas
    emy of Sciences BSSR). An experimental
    investigation of slip and temperature jump
    in a flow of rarified air around a solid
    wall.

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The following papers were presented at the
Conference of Heat and Mass Exchange spon-
sored by the Belorussian Academy of Edu-
cation USSR, the Academy of Construction
and Architecture USSR, and the Institute
of Mechanics (Academy of Sciences USSR).
This conference was held in Minsk in June
1961.

510. Kudryashev, L. I., and V. A. Dzerul'skiy   Konf. Tp
      (Kuybyshev Aviation Institute). Demon-   Mac
      strating the existence of heat regular-   Minsk. 1961
      ity in a boundary layer with internal
      problem conditions.

      Translation: by ATD, Library of Congress,
      Report No. T-63-70

      Printed in rototype at the Institute of
      Scientific-Technical Information and
      Propaganda. Council of the National
      Economy BSSR.

511. Perel'man, T. S. (Power Institute, Academy   Konf. Tp
      of Sciences BSSR, Minsk). Heat exchange   Mas
      in the laminar boundary layer during flows   Minsk. 1961
      around a plate with internal sources.

      Translation: by ATD, Library of Congress
      Report No. T-63-74

512. Sovershennyy, V. D., and G. A. Tirskiy. (Cen-   Konf. Tp
      tral Institute of Aviation Motors, Moscow).   Mas
      Sublimation of a solid in the vicinity of a   Minsk. 1961
      critical point in plane and axisymmetric
      gas flows.

      Translation: by ATD, Library of Congress,
      Report No. T-63-68

513. Popov, N. A., and V. I. Rakhovskiy (All-Union   Konf. Tp
      Electrical Institute). The problem of cer-   Mas
      met depletion by highly volatile components   Minsk. 1961
      during heating in a vacuum.

      Translation: by ATD, Library of Congress,
      Report No. T-63-72

                                                          1961
514. Teoy, P. V. (Dushanba Polytechnical Institute).   Konf. Tp
      Analytical solutions of a system of heat   Mas
      and mass exchange equations for a semifi-   Minsk. 1961
      nite medium under various boundary con-
      ditions.

      Translation: by ATD, Library of Congress,
      Report No. T-63-65.

515. Vulis, L. A., T. P. Leont'yeva, I. B. Palat-   Konf. Tp
      nik, Z. B. Sakipov, and B. P. Ustimenko.   Mas
      (Power Institute, Academy of Sciences,   Minsk. 1961
      KazSSR). Transfer processes in a free
      (jet) turbulent boundary layer.

      Translation: by ATD, Library of Congress,
      Report No. T-63-73.

516. Zhukauskas, A. A., V. I. Makariavichus, and   Konf. Tp
      A. A. Shlanchyauskas (Institute of Power   Mas
      and Electrical Engineering, Kaunas). The   Minsk. 1961
      problem of the emission of heat in smooth
      pipe bundles in crossflow liquids.

      Translation: by ATD, Library of Congress,
      Report No. T-63-69

517. Lapin, Yu. V. Heat transfer in a turbulent   LPoI GiTr
      boundary layer.   no. 217
                                                         27-36
      Heat transfer in a turbulent boundary layer
      in a supersonic gas flow with a moderate

pressure gradient and nonuniform temperature distribution at the wall is determined by Karman's semiempirical theory. The temperature range investigated is that in which the Prandtl number and specific heat capacity may be considered as constants independent of temperature. Solution of the momentum integral equation and calculation of the heat transfer on the basis of a Reynolds analogy are presented. A numerical example of calculating the heat transfer and the skin friction on a wing airfoil in a supersonic flow (flight altitude 20 km at $M_\infty = 6$; $T_w = 700°K$) is given.

518. Tirskiy, G. A. (Moscow). Conditions on the surface of a strong discontinuity in multicomponent mixtures.

An analysis of the conditions on the surface of a strong discontinuity in multicomponent mixtures is presented. Relations are derived for viscous heat conducting multicomponent mixtures, taking into account the effect of thermal diffusion. An approximation of the boundary-layer theory is used to derive relations valid on the surface of discontinuity (density, pressure, particle velocity, temperature, and composition). Flow past a porous flat plate, allowing for the evaporation of the liquid film, as well as the case of a uniform gas flow past a sublimating wall are discussed as examples.

519. Pashchenko, N. T. Some aerothermodynamic problems associated with a free-molecule flow pattern.

In investigating the heat supply in rarefied gases the temperature of a slender body in a translatory motion accompanied by small transient motions (for example, oscillation) in cases of convective and radiative heat exchange is determined as a function of time, local angle of attack, velocity, surface characteristics, and thermodynamic parameters of the medium at high altitudes.

520. Drushinia, S. A. Calculation of internal   Teploener-
     heat exchange during porous cooling.   getika
                                                        v. 8, no. 9
     A method is presented for experimental   73-77
     study of the internal heat exchange in
     porous metals heated by high-frequency
     currents. Tests performed on two air
     cooled stainless steel specimens with
     30% and 50% porosity are described.

521. Bashkin, V. A., and Ye. Ye. Solodkin. On   ZhPMeMF
     determining the heat transfer coefficient.   no. 3
                                                        16-24
     Convective heat transfer between body and
     gas in high hypersonic flows (up to M=20)
     with boundary layer temperatures over
     20000K is discussed.

     The specific heat flux with a zero pressure
     gradient in flow direction in cases of a
     constant and longitudinally variable surface
     temperature is determined, taking into
     account the dependence of thermodynamic
     functions and transfer coefficients on the
     temperature. The case when both the pres-
     sure gradient and the temperature vary along
     the body surface is also briefly discussed.
     The application of results obtained to a
     turbulent boundary layer and to determining
     the heat transfer coefficients from experi-
     mental data is explained.

522. Marenov, A. B. (Institute of Mechanics,   ZhTF
     Academy of Sciences USSR). An investi-   v. 31, no. 9
     gation of the heat exchange in super-   1001-1011
     sonic gas streams flowing through a
     probe with a laminar boundary layer.

     The local heat transfer coefficients in
     a supersonic flow of air through a cylin-
     drical tube of constant cross section and
     a laminar boundary layer were determined
     experimentally. It was found that the gas
     flow cannot be stabilized over the given

tube length, with the result that the heat transfer coefficients are variable, decreasing from the beginning of the tube toward its end to the critical value of the parameter Re_x, referred to the length of the tube.

523.   Lapin, Yu. V. (Leningrad Polytechnical In-
        stitute). Mass-heat transfer in turbulent,
        compressible flow with the addition of
        foreign matter.

ZhTF
v. 31, no. 11
1395-1406

A tentative estimate of the effect of the presence of a laminar flow along a surface Pr≠Sc≠1. is obtained. The methods described were based on the assumption that the mean values of the numbers Pr and Sc are constant throughout the laminar sub-layer. Calculations are presented for cases in which air and helium are used as coolants. The general conclusion is that when the coolant is a light gas, the amount by which the Prandtl and Schmidt numbers differ from unity must be taken into account.

524.   Kobanskiy, P. N. Forced flow heat transfer
        from a heat exchange surface with a reso-
        nance system in the wall.

1962
AKZh
v. 7
313-319

The effect of secondary streams generated by a resonance system on heat exchange in forced convection is analyzed. Equations are obtained for computing the heat trans-fer coefficient under these conditions. The results of the theoretical calculations and experimental observations were compared and showed satisfactory agreement. On the basis of this comparison, the physical ef-fects observed on surfaces with resonance systems in the walls are given a more accurate description. Limits are found for the maximum possible intensification of the heat transfer process by the given method.

525.   Madejski, J. The thermal laminar boundary   Arch MeST
        layer at high velocities.   v. 14, no. 6
                                                           865-873

        Heat transfer in a high-velocity fluid
        flow over a flat plate with constant
        temperature is analyzed. The laminar
        boundary layer equations are integrated
        to yield two equations which can be used
        to determine the thickness of both the
        thermal and the hydrodynamic boundary
        layers. These equations can also be
        used in case of variable wall temper-
        atures (insulated surfaces).

526.   Bronskiy, L. N., and O. N. Kastelin (Power   InFZh
        Engineering Institute, Moscow). Heat   v. 5, no. 4
        transfer on rough and smooth bodies in   135-140
        supersonic flow.

        Test results are presented on investigation
        of heat transfer in axisymmetrical plane,
        spherical, and ellipsoidal models with
        smooth and rough surfaces in supersonic
        (up to M=2.77) high-temperature (up to
        420°C) jets.

527.   Kastelin, O. N., and L. N. Bronskiy (Power   EnI AN SSSR
        Engineering Institute, Moscow). Heating   233-238
        of the front part of blunt bodies in super-
        sonic flow.

        Two methods were used to investigate the
        heat transfer from a gas to blunt axisym-
        metrical bodies in the vicinity of the
        stagnation point: the exponential method
        and the method of surface points.

528. Polyakov, Yu. A. A thin-film transducer   EnI AN SSSR
      for studying heat transfer in dissociated   251-260
      gas flow.

      A resistance thermometer consisting of a

2mm wide Pt film 0.1 μ thick deposited on
the spherical end of a glass tube (11 mm in
diameter) was prepared by sintering, after
coating the tube with a paste containing
chloroplatinic acid. The film was connected
to Pt wires inside the tube and mounted at
the stagnation point of an axisymmetric
blunt body. Experiments at M ≈ 4 to 12
were conducted in a shock tube 50 mm in
diameter and 4.5 m long to study the un-
steady heat transfer between the model
and a shock wave propagating in air.

529. Yaryshev, N. A. (Institute of Precision   InFZh
     Mechanics and Optics, Leningrad). Cri-   v. 5, no. 4
     teria of irregularity of temperature dis-   135-140
     tribution and coefficients of the shapes
     of bodies in a regular second-order regime.

     The results of a study of nonuniformity
     of the temperature distribution and de-
     termination of the coefficients of body
     shape in the case of homogeneous iso-
     tropic bodies in a regular, second-order
     regime are presented. This regime re-
     presents heat exchange between a body, or
     a system of bodies, and the surrounding
     medium whose temperature varies with
     time at a constant rate.

530. Koshmarov, Yu. A. Turbulent flow of an in-   InFZh
     compressible fluid in the gap between ro-   v. 5, no. 5
     tating coaxial cylinders.   5-14

     A theoretical study was made of the hydro-
     dynamics and heat transfer of a perfectly
     turbulent flow in the annular channel (gap)
     formed by two coaxial cylinders rotating
     with respect to one another. The gap is
     assumed to be small compared with the radii
     of the cylinders. Both the axial and tan-
     gential velocity profiles are calculated
     and the turbulent viscosity coefficient

established from the results. The thickness of the laminar sublayers is determined from the value of the total tangential stress on the wall. Formulas obtained for the coefficients of axial friction are shown to be in good agreement with experimental data. The coefficient of heat transfer is determined from the calculated temperature profile in the turbulent part of the flow.

531. Shul'man, Z. P. (Power Engineering Institute, Academy of Sciences, BSSR). Laminar boundary layer with heat and mass transfer.

InFZh
v. 5, no. 5
102-104

An empirical formula is given for calculating heat transfer in a slightly curved body of arbitrary shape when in a flow of an incompressible binary gas mixture, mass transfer of various substances takes place through the walls into the laminar boundary layer.

532. Chaplina, A. I. (Power Engineering Institute, Academy of Sciences BSSR, Minsk). An experimental investigation of heat exchange of a longitudinally streamlined plate.

InFZh
v. 5, no. 7
34-38

Local heat transfer between a plate and a longitudinally forced turbulent air flow was investigated experimentally. An expression was derived which shows that the ratio of the mean heat transfer coefficient at the end of the plate is independent of the stream velocity and that the dependence of the mean heat transfer coefficient upon the stream velocity is analogous to that of the local heat transfer coefficient.

533. Polyak, G. L., and V. N. Adrianov (Moscow Power Engineering Institute). The algebra of radiant exchange flows.

InFZh
v. 5, no. 7
70-77

A system of equations was derived for calculating the radiant exchange in arbitrary systems of nonblack bodies. The analysis is based on formulas which express the general properties of the resolving fluxes in radiant exchange.

534. Kosterin, S. I., and Yu. P. Finat'yev (Institute of Mechanics, Academy of Sciences USSR, Moscow). Heat transfer in a turbulent air flow between rotating coaxial cylinders.

InFZh
v. 5, no. 8
3-9

Heat transfer from a stationary, electrically heated outer cylinder to a rotating coaxial inner cylinder was measured as a function of the rotation speed and the rate of air flow through the annulus between the cylinders. Equations are derived for calculation of 1) heat transfer between the cylinders, and 2) the transition from pure turbulent flow to a turbulent flow involving strong vortices.

535. Bukhvolstov, A. P., and V. Ya. Frenkel'. Temperature distribution over plates radiating heat in vacuum.

InFZh
v. 5, no. 8
78-80

The thermal behavior of circular, rectangular, and square plates with a given constant contour temperature during cooling by heat radiation in vacuum is analyzed mathematically. Expressions are derived which show the interrelationships among the contour temperature, the minimum temperature on the surface, the geometrical parameters of the plate, and the physical characteristics of the plate material.

536. Mironov, V. F. (Power Engineering Institute,   InFZh
    Academy of Sciences BSSR; Polytechnical   v. 5, no. 10
    Institute, BSSR). Heat and mass transfer   9-12
    from bodies to a flow of air.

    Heat and mass transfer of various bodies
    (sphere, cone, disk, and cylinder) in a
    steady turbulent flow and in a pulsating
    flow have been experimentally investi-
    gated in a wind tunnel. Results were ob-
    tained in terms of Nusselt criterion re-
    lations.

537. Mukhin, V. A., A. S. Sukomel, and V. I.   InFZh
    Veluko (Moscow Power Engineering Insti-   v. 5, no. 11
    tute). Heat transfer in supersonic gas   3-7
    flow through a tube with large tempera-
    ture gradients.

    Local heat transfer coefficients and heat
    fluxes were measured during cooling of air
    by water in a brass tube. It was shown
    that the adiabatic wall temperature ratio
    which varied from 1 to 3.1 did not affect
    the Nusselt number under the conditions
    studied. The study was made at the Power
    Engineering Institute imeni G. M. Krzhi-
    hanovskiy, Academy of Sciences USSR.

538. Danilov, Yu. I., and B. M. Galitseyskiy (Mos-   InFZh
    cow Aviation Institute). Gas motion in   v. 5, no. 11
    a straight duct with friction and heat   8-11
    transfer.

    An exact solution was obtained for a gas
    dynamics equation describing the motion
    of a gas in a straight duct with simul-
    taneous friction and heat transfer, under
    the assumptions that the friction co-
    efficient is constant and that the tem-
    peratures change linearly along the duct.
    The study was made at the Moscow Aviation
    Institute imeni S. Ordzhonikidze.

539. Kosterin, S. I., Yu. A. Koshmarov, and Yu. V. Osipov. Investigation of rarefied-gas flow and heat exchange in a flat supersonic nozzle.

InFZh
v. 5, no. 4
3-9

Heat exchange and frictional resistance in air are investigated in six nozzles for $\sqrt{Ra}/M = 5$ to 50. Results are discussed and shown in graphs.

540. Koshmarov, Yu. A. Heat transfer in a turbulent boundary layer.

InZh
v. 2, no. 1
41-54

An experimental study of heat transfer in a turbulent boundary layer of a supersonic flow of a compressible gas with negative longitudinal pressure gradients is presented together with a simple method for calculating the heat-transfer coefficient in the turbulent boundary layer of a compressible gas. The results are applicable to heat-transfer calculations in supersonic nozzles.

541. Bronshten, V. A. On ionization and recombination processes in hot air.

InZh
v. 2, no. 1
163-170

Ionization of air atoms behind very strong shock waves (such as are formed behind meteorites passing through the atmosphere) and recombination are discussed for hydrogen-like and compound atoms and ions. The ionization and recombination coefficients are determined.

542. Kosterin, S. I., Yu. A. Koshmarov, and N. M. Gorskaya. Experimental investigation of heat transfer on a flat plate in a supersonic flow of rarefied gas.

InZh
v. 2, no. 2
263-269

The temperature and average heat transfer coefficients of a plate are measured in a supersonic flow at a zero angle of attack at M = 2.6 to 3.2 and Re = 20 to 240.

543. Rapik, Ya. U., and V. Ye. Chekalin. Convective heat transfer in supersonic conical nozzles.

InZh
v. 2, no. 2
359-364

Heat transfer was studied experimentally in a specially designed apparatus. The tests were conducted at 4 to 5 atm, 695 to 795°K, and a nozzle-outlet velocity of M = 5.

544. Artamonov, K. I., and I. G. Krutikova. Thermoacoustic instability of an inhomogeneous gas flow.

IzAN MeMa
no. 3
19-23

Self-excited oscillations in a one-dimensional uniform gas flow with evenly distributed internal heat sources are discussed for the cases of constant and variable temperature gradients. In the first case, the flow is steady; in the second case, self-sustained oscillations occur due to interaction of the pressure and entropy waves.

545. Litvin-Sedoy, M. Z. Limitation of oscillations in aircraft autopilot systems.

IzVUZ, AeT
no. 2
39-47

An analytical method is presented for deriving a linear system control law for producing the desired limitation of controlling coordinates when disturbed motions are caused by specific instantaneous initial deviations of variable systems. The above is related to aircraft-autopilot systems, in which a specific restriction of oscillations of disturbed motion and maintenance of asymptotic stability of the motion are required. The method is based on evaluating the maximum value of the solution of a steady linear homogeneous differential equation with constant coefficients at given initial conditions.

546. **Yeh, T'ien-ch'i. Determining unsteady temperature fields in structures in transient flight regimes with regard to thermal radiation.**

The generation of unsteady temperature fields in aircraft structures by kinetic heating at high altitudes and large Mach numbers is discussed, taking account of heat radiation. An approximate finite-difference procedure, convenient for practical calculations, is used. Results of a sample calculation for a steel aircraft in accelerated flight (from M = 2 to M = 5 in 90 sec) at 1500 m altitude are presented.

547. **Yasinskiy, F. G. Analysis of heat flow through a three-layer plate.**

Heat flow through an infinite plate consisting of a metallic sheet with a heat-resistant (for example, ceramic) coating on its outer surface and an insulating coating (for example, fiberglass) on its inner surface was studied without considering heat radiation. The cumbersome formulas obtained can be simplified for given heat capacities of layers.

548. **Dolomanov, Ye. G. Inversion phenomena in supersonic flows of real gases.**

It is shown that impact temperature inversion must occur in compression shocks; incorrect results are possible if this fact is not taken into account in calculating the deceleration temperature behind the pressure shock in real gases.

549. **Kudryashchev, L. I., and I. A. Gusev, The effect of nonstationary pulsating gas flow on heat-transfer characteristics.**

An analytical and experimental study has
been conducted on the effect of unsteady
pulsating gas flow around a body on heat
transfer. The effect of flow velocity and
of the amplitude and frequency of pulsa-
tion was examined. The used equipment
and investigation method are described,
and results are discussed in detail.

550. Suksov, I. I. An approximate method for
calculation of steady high-temperature
gas flow.

I_zVUZ, AvT
no. 2
159-167

A study has been made of a high-temper-
ature gas flow in the presence of dis-
sociation and ionization. Equations of
a steady flow with heat transfer are
derived, an approximate grapho-analytical
method is developed, and the effect of
luminosity is discussed in detail. For
evaluation of the combined effect of
convective heat transfer, luminosity,
and friction, a numerical example of
a turbulent isentropic flow is given.

551. Alishaev, M G. (Moscow). Forced convection
of a viscous compressible gas near the
heat source.

PMMa
v. 26, no. 1
187-189

Forced convection in the neighborhood of
a heat source placed in a homogeneous flow
of a viscous, heat conducting gas is studied.
The approximate boundary layer theory is
used, and it is shown that the problem can
be reduced to the corresponding problem
for incompressible fluids by means of the
Dorodnitsyn transformation, if the tem-
perature dependence of viscosity is con-
sidered in the form given by Chapman-
Rubesin, and if the Prandtl number is
taken as a constant.

552. Zarubir, V. S. Calculation of temperatures   Voprosy
     in two-layer metal plates.   Mekhaniki, Sb.
                                                      127-137

     The unsteady heat transfer equation for
     a wall consisting of two metal plates
     and an intermediate layer of insulating
     material is solved by means of Laplace
     transformations to yield a space-time
     relationship for the wall temperatures.

553. Petrashitskiy, G. B., and V. I. Polezhayev.   Teploenergetika
     An engineering method for calculating   v. 9, no. 2
     nonstationary processes of heat con-   73-76
     ductivity in thin multilayer walls.

     Derivation of a solution to the one-
     dimensional heat transfer equation with
     third-order boundary conditions is ob-
     tained. The solution method is illus-
     trated, and results are presented for
     the case of heat transfer in thin,
     laminated plates.

554. Fedorov, I. G., N. S. Idiatuffin, V. K.   Teploener-
     Shchukin, and G. A. Mukhachev (Kazan'   getika
     Aviation Institute). Heat transfer and   v. 9, no. 6
     hydraulic resistance of slit channels   57-60
     with a checkered distribution of conical
     indentations.

     Experimental investigation of heat-exchange
     slit channels is presented. Equations are
     given for the evaluation of heat exchange
     over the range Re = 750 to 18,000 and for
     hydraulic resistance over the range Re = 750
     to 20,000.

555. Bulyeyev, N. N. A theoretical model me-   Teploperedacha
     chanism for turbulent transfer in fluid   64-97
     flow.

     The proposed three-dimensional heat- and

mass-transfer model is based on the use
of nine-component turbulent stress vectors
for mass and heat transfer. The velocity
profile in a rectangular duct at a given
distance from the inlet section, and the
velocity and temperature profiles in a
tube were determined on the basis of the
model.

556. Porechikov, V. B. Temperature of the leading
edge of a plate in aerodynamic heating.

VeMoU MMe
no. 1
47-52

The laminar boundary layer in a steady
compressible gas flow past a semi-infinite
thin plate is discussed and the time
dependence of the temperature of the lead-
ing edge is analyzed, taking account of
heat flow through the leading edge.

557. Rumynskiy, A. M. (Moscow). The effect of
diffusion of radiant components on con-
vective heat exchange.

ZhPMeTF
no. 2
50-58

Gas-dynamic hypersonic-flow parameters of
the boundary layer in the region of the
forward stagnation point of an axi-
symmetrical blunt body are analyzed with
regard to diffusion effects, and libera-
tion of heat-radiating gas from the body
surface. The energy equation is used to
derive formulas for determining the pa-
rameters of convective heat transfer in
the vicinity of the stagnation point.

558. Kaganov, M. A., and Yu. L. Rozenshtok. On
the temperature of bodies in a medium
with pulsating heat emission and temper-
ature.

ZhPMeTF
no. 3
90-92

The temperature fields in an infinite
cylinder and a sphere placed in a medium
with harmonically varying temperature and

heat emission are discussed, taking account
of fluctuations in their amplitudes and
mutual phase shift.

559. Onufriyev, A. T. An approximate study of
the problem of flow of a radiating gas
about a plate of finite length.

ZhPMeTF
no. 5
70-74

It is demonstrated, by using a flat plate
as an example, that the heat flow to a body
in a stream of high-temperature gas depends
on the ratio of the radiation period to the
dimensions of the body.

560. Vaulin, Ye. P., and N. N. Gvozdkov. On
diffusion cooling of a porous plate in a
gas-dynamic flow by injection of fluid
with physicochemical reactions into the
laminar boundary layer.

ZhTF
v. 32, no. 2
238-247

The process of heat exchange in a porous
plate with injected fluid is examined,
and the laminar-boundary equations are
analyzed, taking into account the physico-
chemical transformations and diffusion of
reaction products and evaporation into
the gas flow.

561. Grishin, A. M., and O. M. Todes (Saratov
Polytechnical Institute). Thermal ex-
plosion in the presence of heat transfer
by convection and conduction.

1963
DAN SSSR
v. 151, no. 2
365-368

A theoretical analysis was made to estab-
lish the accuracy and applicability of the
formula previously derived by the author
as a criterion for thermal explosion on
the assumption that heat removal takes
place by convection only.

562. Motulevich, V. P. Turbulent heat and mass
exchange on a plate with suction or
injection of various gases.

InFZh
v. 6, no. 1
3-13

A theoretical analysis of the effect of
suction or injection of various gases
through a porous plate in a gas flow on
the heat exchange and friction in the
turbulent boundary layer is presented.

563. Romanenko, P. N., and V. N. Kharchenko.
Effects of transverse mass flow on drag
and heat exchange in turbulent compres-
sible gas flow.

InFZh
v. 6, no. 2
52-57

Experimental data on the effects of in-
jection of various gases (air, helium,
carbon dioxide, and freon-12) through a
heated porous plate into a turbulent
boundary layer of hot air (450 to 550°K)
on heat exchange and drag are presented.
Potential flow velocity was 25 to 75 m/sec,
Reynolds numbers 10^5 to 5×10^5.

564. Motulevich, V. P. The effect of removal or
injection of substances through porous
walls on heat transfer to blunt bodies.

InFZh
v. 6, no. 4
9-15

An analysis was made of incompressible
fluid flow past the stagnation area of
a blunt axisymmetrical body through
whose walls a fluid is injected or, by
suction, withdrawn from the main stream.
A general heat transfer formula in terms
of the Gauss function and the ratio of
the Nusselt numbers for porous and im-
permeable walls was derived. It is
shown that the formula yields results
which are in good agreement with values
calculated by Hartnett and Eckert, who
used a laborious numerical method. The
solution for the injection of a fluid
having different physical properties than
the main flow showed that fluid injection
decreases heat transfer; the effect of
injection increases with an increase in

the specific heat of the injected fluid
and with a decrease in its thermal con-
ductivity and density.

565. Usanov, V. V. Possible solutions of   InFZh
      thermodynamic equations for viscous   v. 6, no. 4
      gas flow with heat transfer.   22-26

      A system of equations in terms of gas-
      dynamic influence coefficients de-
      scribing one-dimensional gas flow with
      allowance for friction and heat transfer
      through the wall is considered. Pos-
      sible methods of solving the equations
      are discussed. It is shown that in case
      of intensive heating, the effect of heat
      transfer on the friction factor must be
      taken into consideration.

566. Kudryashev , L. I., and V. K. Lyakhov. The   InFZh
      dependence of heat transfer coefficient   v. 6, no. 4
      on longitudinal and transverse noniso-   56-60
      thermicity in turbulent fluid flow.

      An analysis based on a two-boundary-layer
      model was made to derive generalized
      relationships for turbulent heat transfer,
      with allowance for transverse and longi-
      tudinal variations in physical properties.

567. Chervyakov, S. S. (Institute of Heat and Mass   InFZh
      Transfer, Academy of Sciences BSSR). An   v. 6, no. 8
      experimental study of the influence of vi-   10-14
      brations on heat and mass transfer of a
      cylinder and a cone in turbulent air flow.

      Experimental data were obtained on the
      influence of vibrations on the heat and
      mass transfer of a cylinder and a cone
      under various flow conditions. The pro-
      cedure and method used in the experiments
      are the same as those used by Chervyakov

with a sphere (InFZh, no. 6, 1963). The Re
number varied from 2.8 X 10⁴ to 7.6 X 10⁴,
the degree of turbulence of the air flow
varied from 2.4 to 3.2%, and the tempera-
ture 40°C. The frequency of vibration of
a test model was varied from 9 to 16.5 cps
at an amplitude of 12 mm.

568. Dolinskaya, R. A. Bibliography of heat and   InFZh
       mass exchange.   v. 6, no. 9
                                                           127-137

       This bibliography lists 11 books, includ-
       ing two translations and 250 Soviet jour-
       nal articles, most of which were published
       in 1962-1963. The subjects include math-
       ematical methods (29 articles), experi-
       mental methods (35 articles), superhigh
       speed processes (7 articles), thermo-
       physical and thermodynamic properties
       of materials (15 articles), physics of
       high-temperature processes and magnetic
       hydrodynamics (64 articles), processes in
       nuclear reactors (14 articles), and pro-
       cesses and apparatus (31 articles).

569. Kozlov, L. V. An experimental investigation   IzAN MeMa
       of surface friction on a plate in super-   no. 2
       sonic flow with heat exchange.   11-19

       The values of local surface-friction
       coefficients on a plate at zero angle
       of attack in subsonic and supersonic
       flows with extensive heat exchange
       between the plate and flow are experi-
       mentally determined. Brief descriptions
       of the surface-friction transducer and
       of the testing technique are given. An
       empirical formula is obtained for calcula-
       ting the friction coefficient in a turbu-
       lent flow over a wide range of Mach and
       Reynolds numbers and temperatures.

570. Tagirov, R. K. (Moscow). Calculation of   IzAN MeMa
       heat fluxes in the flow of two different   no. 6
       supersonic streams about a step.   55-61

A method is developed for calculating the base enthalpy and base temperature in the flow over a flat or round back-step by two different supersonic streams having different Mach numbers, total pressures, and stagnation enthalpies.

571. Tirskiy, G. A. Heat transfer to cylinder in flow of dissociating air.

IzAN Me
no. 6
125-130

Formulas are derived for calculating two cases of specific heat fluxes to the leading edge of a swept-back wing (cylinder of infinite length) in a flow of dissociating air: 1) equilibrium dissociation in the boundary layer, and 2) "frozen" flow over ideal catalytic and noncatalytic surfaces. The determination of the flow in the boundary layer in the vicinity of the leading edge of the cylinder, with the recombination of air atoms in the relatively cool boundary layer taken into account, is reduced to the solution of the boundary problem presented by the author in a previous work.

572. Nikitenko, N. I. The numerical solution of a temperature field problem.

IzVUZ, AvT
no. 1
26-32

The problem of determining the nonstationary temperature field in a moving medium is studied. The problem is reduced to the solution of a heat propagation equation; it is proposed to do this by the method of numerical integration. The method is illustrated by a solution of the problem of the temperature field of a laminar flow in a circular tube. It is shown that the numerical solution results are in good agreement with Nusselt's analytic solution of this problem.

573. Sozin, Yu. A. Heat transfer during pulsed flow of an incompressible fluid.

IzVUZ, AvT
no. 2
102-110

An analysis was made to derive relation-
ships which can be used in the design of
heat exchangers with pulsed flow of in-
compressible fluid. The effect of the
nonlinear relationship between the heat
transfer coefficient and sinusoidal flow
pulsations was expressed by the formula:

$$\delta\alpha = \frac{\Delta\alpha}{\alpha_1} \, 100\% = -4(U_o')\ \%$$

where $\delta\alpha$ is the relative change in the heat
transfer coefficient; $\Delta\alpha$, the absolute
change in the heat transfer coefficient;
α_1, the heat transfer coefficient under
steady flow conditions; and U_o', the rela-
tive amplitude of flow velocity pulsations.
The formula shows that, compared with steady
flow, flow pulsations caused a decrease in
the average heat transfer coefficient.

574. Sozin, Yu. A. An experimental study of
      convective heat transfer in pulsed flow
      of an incompressible fluid.

A study of pulsed heat transfer has been
made in an annulus 276 mm long. Results
for steady and pulsed flow are given. It
is concluded that the majority of the ex-
perimental points for pulsed flow are lo-
cated below the line calculated for steady
flow, so that flow pulsations generally
reduce the heat transfer. At low and
intermediate pulsation amplitudes, pulsed
heat transfer is not more than 4—5% lower
than under steady flow conditions; this
is within the limit of experimental error.
Therefore, pulsed heat transfer can be
calculated by conventional methods for
steady flow.

575. Shlanchiauskas, A., I. Zhiugzhda, and A.
      Zhukauskas. Heat exchange in a bound-
      ary layer.

Relationships for calculating heat ex-
change when the properties of a fluid

are changing were derived by measuring
the velocity and temperature fields in
the boundary layer over a heated and
cooled plate in oil and water jets.

576. Kutateladze, S. S., and A. I. Leont'yev.
Protecting bodies by a cooling turbulent
boundary layer.

The problem of protecting bodies in
a high-temperature gas flow by forming a
cold boundary layer on them is discussed.
The cooling boundary layer is established
either by extensive cooling of the front
portion of the body, or by making this
portion porous (or with slits) with
injection of cold gas.

577. Panevin, I. G., and P. P. Kulik. A
method for experimental determination
of the coefficient of thermal conduc-
tivity of a high-temperature gas.

An experimental method is presented which
is based on the fact that regardless of
the conditions in a flow around a blunt
body, the stream in a small area around
the critical point is always laminar.
Since heat transfer transverse to the
laminar boundary layer is due only to
molecular heat conduction, measurement
of the temperature profile in the bound-
ary layer near the critical point and
determination of the heat flux at this
point yields the value of the coefficients
of molecular thermal conductivity in a
larger range of temperatures than pos-
sible heretofore. The experimental
set-up has been described elsewhere
(V. B. Tikhonov, Ye. A. Yakovlev,
Sb. tr. MAI, A. V. Kvasnikov, ed,
Oborongiz 1960). The experimental
results agreed within 9% at T = 12,000K
and 5% at T = 14,000K with approximate
theoretical values calculated by the
method of W. Lochte-Holtgreven (Repts.
Progr. Phys. v. 21, 312, 1958). It
is pointed out that the method is most
effective at high pressures. Orig. art.
has: 7 figures and 3 formulas.

578. Kutateladze, S. S., and A. I. Leont'yev. Teplofizika
The effect of gas dissociation on Vys Tm
friction and heat exchange in a turbu- v. 1, no. 3
lent boundary layer. 458-460

The frozen-flow pattern of a dissociated
gas is used in examining the effect of
changes in density distribution (caused
by dissociation) in the boundary layer.
An expression for the limit law of
friction in the dissociated gas boundary
layer is derived and theoretical results
are compared with experimental data.

579. Gribkova, S. I., and L. S. Shtemenko (De- VeLUMMeAs
partment of Molecular Physics, Moscow no. 3
State University). Estimation of the 11-17
effect of second-order approximation
terms in temperature-jump experiments.

Comparative evaluations are presented of
the heat flow parameters obtained in the
first- and second-order approximations by
using empirical data obtained at the
Department of Molecular Physics of the
Moscow University in investigations
of viscous-molecular flows of rarefied
gases. The heat flow is represented in
the Burnett approximation. A quantitative
estimate is also given of the effects
caused by taking account the second-order
terms on the temperature jump in the
interface between the gas flow and the
solid.

580. Rosenshtok Yu. L. (Leningrad). The problem ZhPMeTF
of thermal conductivity with time-dependent no. 1
heat transfer coefficient. 136-137

A solution of thermal conductivity problem
by an approximate integral method is given
for the case of linear and exponential
variation of the heat transfer coefficient
and the ambient temperature.

581. Kutateladze, S. S. (Novosibirsk); A. I.   ZhPMeTF
Leont'yev (Novosibirsk); N. A. Rubtsov   no. 4
(Novosibirsk). Evaluation of the role   88-93
of radiation in calculating the heat
transfer in a turbulent boundary layer.

Heat transfer by radiation and convection
in a turbulent boundary layer was analyzed.
Thermal radiation from a high-temperature
gas affects the temperature field in the
boundary layer and consequently the con-
ditions of heat transfer by conduction
and convection.

1964

582. Murzinov, I. N. (Moscow. Heat transfer at   ZhPMeTF
the stagnation point of a blunt body at   no. 5
low Reynolds numbers.   139-141

On the basis of an analysis of hypersonic
flow around a sphere, a parameter $N = R_0 k^2$
is defined which determines the stagnation-
point heat transfer at low Reynolds numbers,
where R_0 is the Reynolds number related to
stagnation conditions and k is the ratio
of densities at the shock. A system of
equations of motion and energy in the
stagnation-point region is solved numer-
ically by the Kutta-Runge method, and the
results show that the heat flow depends
almost exclusively on the parameter N.

583. Volosevich, P. P., S. P. Kurdyumov, L.N.   ZhVych MMF
Busurina, and V. P. Krus (Moscow). Piston   v. 3, no. 1
problem in an ideal heat-conducting gas.   159-169

A one-dimensional problem of piston motion
in an ideal gas with given conditions on
the piston is discussed. The self-similar-
ity solutions are compared with numerical
solutions of a system of partial differen-
tial equations, under the same initial and
boundary conditions.

584. Punchkovskiy, V. V. Features of heat and mass transfer in the presence of a heat source which is dependent on temperature and mass content.

InFZh
v. 7, no. 1
66-70

A system of differential heat- and mass-transfer equations for an infinite plate with an internal heat source is solved. 1) The problem is examined as applicable to a moist dielectric plate in an alternating electrical field and is restricted to the internal problem, assuming the temperature of the medium and the moisture content to be constant. The process is governed by the heat and mass transfer characteristics and similarity criteria, as well as by the varying output of the internal heat source, which requires the introduction of dynamic criteria. The minimum electric field strength producing thermal breakdown is given. 2) Finally, the mean value of the moisture content is found for the steady-state regime, which is in equilibrium only when the argument for a thin plate is vanishingly small.

585. Murzinov, I. N. (Moscow). Temperature-profile similitude in bodies moving freely in the atmosphere with supersonic velocities at extreme altitudes.

IzAN MeMa

no. 1
115-120

The similitude of the temperature profiles in bodies entering the atmosphere at extremely high velocities is considered. It is shown that the temperature profiles for most of the orbit are determined by only one parameter so long as the velocity is practically constant. Similitude parameters for the temperature profiles in the presence of ablation and physicochemical transformations in the body material are discussed.

586. Kalashnikov, V. N. On the stagnation temperature of a two-phase turbulent jet in a high velocity gas stream.

ZhTF
v. 34, no. 1
174-182

If liquid is injected into a fast gas stream,
the material in the resulting turbulent wake
may lose thermal energy more rapidly by
heat conductivity than it gains kinetic
energy from the gas flow, with the result
that the stagnation temperature in the
wake may be lower than either the initial
temperature of the liquid or the stagnation
temperature of the gas. This phenomenon
is investigated theoretically both for a
plane parallel jet and for an axially sym-
metric jet.

GROUP B   AEROTHERMODYNAMICS OF HIGH-SPEED FLOWS

B-2   Aerothermal Structural Response
       Thermal Shields
       Ablation and Sublimation
       Injection Cooling
       Instrumentation

587. Danilovskaya, V. I. (Moscow).   An approximate
       solution of the problem of a steady tem-
       perature field in a thin shell of arbitrary
       shape.

       An approximate solution to the problem of
       the steady temperature field in a thin
       shell of arbitrary shape and constant
       thickness is presented.

1957
IzAN OTN
no. 9
137-138

538. Tirskiy, G. A.   Ablation of a heat-conducting
       wall behind a moving shock wave.

       An exact solution of the ablation problem
       of a flat wall behind a normal shock
       moving in a quiet gas with a constant velo-
       city parallel to the wall is presented.
       The motions of the molten-metal film and of
       both its interfaces are analyzed, taking
       account of heat conduction into the wall
       and disregarding evaporation of the film.

1959
DAN SSSR
v. 129, no. 5
989-992

589. Gorban', N. F., and L. N. Bronskiy.   An
       experimental study of the melting of
       bodies in a hot supersonic gas flow.

       The ablation-testing conditions of
       conical and cylindrical (lead and alu-
       minum) specimens, with and without shiel-
       ding, under flow temperatures up to
       1000°C and speeds up to 2.7 M are explained,
       the experimental data are presented, and
       the ablation mechanism is discussed.

InFZh
v. 2, no. 7
61-66

590. Danilova, I. N. The temperature field in an
       infinite hollow cylinder when the ambient
       temperature varies according to a broken-
       line law.

       The temperature distribution in an infinite
       annular cylinder varying with the ambient
       temperature on its outer surface according
       to a broken-line law, and with constant tem-
       perature on its inner surface is investigated
       by means of an operational method.

IzAN En AvtT
no. 1
131-133

591. Kastelin, O. N., Ye. A. Mit'kina, and
A. S. Predvoditelev. Melting of bodies
in supersonic flows.

IzAN En AvtT
no. 2
140-141

Some experimental results on the melting
of solids in supersonic flow (Mach number
1.7, temperature 88 to 89°C) obtained
with models made of Wood alloy. The rate
of ablation, the heat emission coefficient,
and the location of the most intensive
disintegration are determined.

592. Sokolova, I. N. (Moscow). The calculation of
the heating of shells at high velocities.

IzAN En AvtT
no. 3
90-94

An approximate solution is found for the
heating problem of shells stablized in a
flow of gas with variable velocity, pressure,
and density.

593. Vatazhin, A. B. Ablation of a plate in a
supersonic or high-temperature gas flow.

IzAN MeMa
no. 6
7-13

The problem of ablation and sublimation
of a semi-infinite plate is investigated
under the assumption that the ratio of
products of density and the coefficient
of dynamic viscosity in both the liquid
and gaseous phases (of the plate material)
has a large value. The solution obtained
is generalized for the case when a part
of the heat flux is conducted into the
body.

594. Babichev, A. I. Selecting the optimum porous-
cooling regime.

IzAN MeMa
no. 6
147-149

The problem of finding that rate of fluid
injection in porous cooling of an airfoil
which will ensure a minimum heat flow through
its skin is discussed. A porous plate with a
constant surface temperature in a steady
uniform gas flow is used as a model.

595. Szaniawski, A. Certain dynamic problems of
    perfect partly dissociated gases.

Certain problems of the dynamics of ideal
gases containing particles subject to dis-
sociation are studied. The analysis of de-
composition pnenomena is approximated by re-
placing a gas mixture in which one of the gases
dissociates in accordance with the chemical
formula AB ⇄ A + B, by a simplified model which,
in turn, permits substitution of an equation
which is analogous to the equation of phase
change for the complex Guldberg-Wage chemical-
equilibrium equation. The equations of state,
thermal functions, and isentropic equations
developed for this model are presented.

596. Tirskiy, G. A. Ablation of a semi-infinite
    body in plane and axisymmetric incompres-
    sible gas flows.

A procedure is presented for obtaining
exact equations describing a steady
ablation regime (with a constant abla-
tion rate) near the stagnation point and
methods for solving them are outlined.
The possibility of generalizing these
solutions for a compressible gas flow
with variable viscosity and heat-conduc-
tivity coefficients (in the gas and in
the molten-metal film) is indicated.

597. Prokof'yev, V. A. (Department of Aeromechanics
    and gas dynamics, Moscow State University).
    The theory of forced harmonic small-amplitude
    pressure-wave propagation based on gas-dynamic
    Euler equations with radiative heat transfer
    taken into account. (I)

In this part (see item No. 598), the absorp-
tion, dispersion, and rate of propagation of
harmonic compression waves in a perfect com-
pressible fluid are investigated under such
conditions and at such frequencies that the
Bouguer "wave" number and the product of the
Bouguer and Boltzman "wave" numbers can be
either small or large quantities.

598. Prokof'yev, V. A. (Department of Aeromechanics Ve MoU MMe
     The theory of forced harmonic small-amplitude   no. 3
     pressure-wave propagation based on gas-dynamic   31-48
     Euler equations with radiative heat transfer
     taken into account. (II)

     In this part (see item No. 597), the absorption,
     dispersion, and propagation rate of pressure waves
     are discussed in a general case, with arbitrary
     values of the Bouguer and Boltzmann "wave" numbers.

599. Popov, N. N. (Department of Wave and Gas   Ve MoU MMe
     dynamics, Moscow State University).   no. 4
     Discontinuity propagation in the presence of   45-49
     a heat source.

     The problem of discontinuity propagation is
     studied. A general expression for the velocity
     and a formula for the early stage of motion are
     established.

600. Kiselev, K. A., and A. I. Lazarev. The temper-   ZhTF
     ature gradient of an infinite plate with   v. 30, no. 6
     variable heat loss coefficients in a medium   616-621
     of varying temperatures.

     An analysis is presented of the problem of the
     heating (or cooling) for 2 hr of a plate of in-
     finite thickness with boundary conditions of he
     third kind that are symmetric relative to the
     plane bisecting the plate.

601. Vulis, L. A. (Kazakh State University), and   ZhTF
     Kashkarov, V. P. Local redistribution of the   v. 30, no. 12
     total energy in the boundary layer of a com-   1477-1484
     pressible gas at the surface of a burning body.

     The effect of a local redistribution of the
     total energy (the sum of the kinetic energy and
     the physical and chemical enthalpy) in the
     boundary layer of a compressible gas flowing

parallel to a plane surface, when a heterogeneous rate of reaction, is studied. The possible generalization of the results is considered, along with their application to turbulent flow.

602. Yeroshenko, V. M., M. G. Morozov, V. P. Matulevich, Yu. N. Petrov, and V. S. Pushkin. A gas-dynamic device—NT-14 interferometer.

1961
EnI AN SSSR
M. 1961
51-59

The Laboratory of Combustion Physics of the Academy of Sciences USSR has built a universal NT -14 gas-dynamic testing device for shapes in subsonic and supersonic gas flows with sublimation, ablation, erosion; porous and local supply of various coolants; and with chemical reactions in the flow as well as on the surface of the body in the flow.

603. Petrov, Yu. N. Cooling of the leading face of a cylinder in supersonic flow with coolant gas feeding.

EnI AN SSSR
M. 1961
89-93

An experimental study was made of a supersonic flow (M = 1.7, static pressure = 0.2 atm) along a cylinder with a front face having a 2-mm opening in its center through which various gases (nitrogen, hydrogen, and argon) were fed into the boundary layer.

604. Artyukh, L. Yu., L. A. Vulis, and V. P. Kashkarov. Flow of a gas burning on the surface of a plate.

InFZh
v. 4, no. 3
39-45

A homogeneous, compressible gas flow past a burning plate is investigated. The previous research results in this field are generalized and supplemented. A laminar boundary layer along the plate is assumed; a normal advance of the burning front on the plate surface is disregarded because of the low burn-out

rate of the solid phase. The ignition
and extinction associated with variation
of Mach numbers are discussed. The problem
is regarded as a limit pattern of the
high-speed motion of a body in the atmos-
phere.

605. Shakhov, Ye. M. One-dimensional unsteady   InFZh
      heating and melting of solid bodies   v. 1, no. 3
      moving longitudinally to their flat   46-59
      surface in a gas.

      A two-dimensional mathematical model is
      used to solve heating and melting problems
      and evaluate the influence of practically
      significant factors in this case.

606. Shakhov, Ye. M. Evaporation of a solid   InFZh
      absorbing radiant energy.   v. 1, no. 4
                                                     27-38
      The one-dimensional problem of the
      evaporation of a solid heated by the
      absorption radiant energy is discus-
      sed, assuming that the flow of radiant
      energy is absorbed on the surface of
      the body and is equivalent to the heat
      flow at the boundary (both depend on
      time and on the surface temperature of
      the body). Two cases of evaporation:
      into a vacuum and into a perfect gaseous
      medium are considered.

607. Tirskiy, G. A. Ablation of a body and vapori- ZhPMeTF
      zation of the melt at the stagnation point   no. 5
      and line in dissociated air flow.   39-52

      Ablation of a blunt body in dissociated-
      air flow at the stagnation point (axi-
      symmetric case) and at the stagnation
      line (plane case) with evaporation of the
      molten-metal film and heat absorption by
      the body taken into account is discussed,
      assuming arbitrary dependence of thermo-
      physical body parameters and molten-
      material viscosity on the temperature.

608. Tirskiy, G. A. Ablation of the leading   ZhPMeTF
     edge of a swept-back wing in a hypersonic   no. 6
     flow.   p. 54

     Thermal disintegration of the leading edge
     of a swept-back wing in hypersonic flow is
     studied. Equations describing the disin-
     tegration process and an approximate for-
     mula for ablation rate are presented.

609. Sanochkin, Yu. V. (Mathematics Institute,   ZhTF
     Academy of Sciences USSR). Thermal ion-   v. 31, no. 2
     ization and electrical conductivity of   188-193
     gas mixtures.

     General formulas for the initial and suc-
     cessive thermal ionization of gaseous
     mixtures were derived and analyzed. The
     effects of introducing impurities into
     the gas are evaluated. As an example, the
     degree of ionization and the electrical
     conductivity of the gas behind a shock
     wave propagating in argon containing small
     amounts of cesium and aluminum are deter-
     mined. Calculated and experimental values
     were found to agree.

610. Tirskiy, G. A. Sublimation of a blunt   ZhVychMMF
     body at the stagnation point in a plane   v. 1, no. 5
     and axisymmetric gas-mixture flow.   884-902

     An exact solution is given for the
     problem of equilibrium and nonequilibrium
     sublimation of a blunt body in the vicinity
     of the stagnation point with an arbitrary
     dependence of physical properties of the
     body on temperature. The temperature
     profile in the body is determined by
     quadratures. The solution of any specific
     problem in the general case is reduced
     to the solution of a system of three
     finite equations for determining the
     concentration, temperature on the front
     of evaporation, and the rate of ablation.

611.   Jungowski, W. (Institute of Aerodynamics,
       Technical University of Warsaw), Methods
       for calculating stagnation temperature in
       a hypersonic gun tunnel.

       An analysis of phenomena in a gun tunnel
       (with a description of the method derived
       by Cox and Winter [AGARD Report 139]) is
       presented. A simplified method for cal-
       culating the stagnation temperature is
       briefly described.

612.   Zotikov, I. A., and L. N. Bronskiy. Experi-
       mental study of heat exchange in ablation
       of metal and in molten-metal injection
       through a porous wall in a supersonic flow.

       A study was made of heat exchange on the
       surface of the flat front faceplate of a
       hollow glass-reinforced textolite cylinder,
       16 mm in diameter, being covered with a
       film of molten tin in a longitudinal super-
       sonic flow. The sources of the metal film
       were: 1) a tin rod protruding through the
       center hole in the cylinder faceplate into
       the hole and melted by it, and 2) molten
       tin fed under pressure through a porous chro-
       mium plug inserted in the same hole.

613.   Chakalev, K. N. Heat flow in ablation
       melting of a plate.

       An approximate analytical investigation
       of the heat-exchange in an infinite plate
       of constant thickness placed in a medium
       with a temperature higher than the melting
       point of the plate material is presented.
       The molten material is continuously
       removed from the solid remainder of the
       plate so that a moving melting plane is
       formed. The dependence of the instantan-
       eous temperature at an arbitrary point
       in the solid on the position of the
       melting plane is examined.

614. Neyland, V. Ya. On the effect of radiative   InZh
      heat exchange on ablation at the stagnation   v. 2, no. 4
      point of a blunt nosed body.   227-231

      The effect of thermal radiation in the
      boundary layer on ablation at the stag-
      nation point of blunt nosed body is
      analyzed. The influence of radiation on
      other flow regions is accounted for by
      setting appropriate boundary conditions
      for the gas temperatures on the outer
      interface of the boundary layer and
      for the oncoming radiation flux.

615. Shakhov, Ye. M. Determining the constant   InZh
      melting rate of a semi-infinite solid.   v. 2, no. 4
                                                               237-244

      A quasi-steady regime of melting of a
      semi-infinite body in a high-temperature
      gas flow is discussed, assuming immediate
      removal of molten material. Approximate
      asymptotic expressions for the rates of
      ablation and of heat conduction into the
      solid are derived for arbitrary initial
      conditions.

616. Vetlutskiy, V. N., and A. T. Onufriyev.   ZhPMeTF
      Cooling of radiating gas flowing in flat   no. 6
      duct.   29-34

      Heat transfer during the cooling of a grey
      radiating gas flowing in a flat duct is
      analyzed by a previously developed dif-
      fusional approximation method. It is as-
      sumed that: 1) the gas is ideal; 2) the
      streamlines are parallel with the duct
      axis; and 3) the flow velocity is limited
      by the relationship $M^2 \ll 1$. Heat transfer
      by molecular and turbulent conduction is
      neglected. The system of equations was
      solved by A. A. Dorodnitsyn's method of
      integral relations. Heat-flux profiles
      along the duct were also obtained for
      the case when a cool gas is injected along
      the wall in a direction parallel to the
      hot gas flow. As an example, the wall
      temperatur. and heat flux profiles along a
      duct 100 cm wide were calculated only for
      air flows at 10,000°K, at 10 and 100 atm,
      and radiation cooled.

617. Pleshanov, A. S. Ablation of centrosym-
metric solids by heat-flow.

An approximate method is presented for
determining the law and parameters of
the boundary motion caused by ablation
of molten material in a heat flow past
centrally symmetric bodies. A qualita-
tive solution is reduced to determining
only one dimensionless criterion inde-
pendent of the melting temperature which
characterizes the whole process. It is
also indicated how to use the method
offered for solving Stefan-type problems
when heat flows on the boundaries of
bodies are given.

618. Rasgovorov, L. Ya., and V. I. Prosvirin.
Disintegration of hot metals and alloys
in a hypersonic air flow.

High-temperature (up to 1500°C) oxidation
of metals and alloys in high-speed (up to
M = 3) air flows, accompanied by corrosion,
erosion, and burning of the material was
experimentally investigated. Equipment,
specimens, and techniques are described and
empirical data are given.

619. Golubev, V. A. (Moscow Aviation Institute).
A theoretical investigation of a turbulent
plane-parallel jet at high temperature with
dissociation and ionization.

Calculations of air flow parameters based
on the solution of differential boundary-
layer equations with dissociation and ion-
ization taken into account are presented.

GROUP C   FLIGHT MECHANICS

C-1   Aerodynamic Performance
      Stability and Control

620.   Taratynova, G. P. Motion of an artificial   1957
       satellite in the presence of atmospheric   USPN
       drag in the earth's noncentral gravity   no. 1a
       field.

       A method is developed for calculating the
       orbit of an artificial earth satellite by
       means of a high-speed digital computer,
       taking account of atmospheric drag and
       deviation of the earth's gravity field
       from the central.

621.   .Barabanov, A. T., and B. A. Rayzberg.   1958
       Satellite deviation from an elliptical   Izvuz, AvT
       orbit.   no. 4
                                                       3-8

       The deviation of a satellite from an
       elliptic orbit which it might follow if
       there were no air resistance is discus-
       sed.   Only the atmospheric drag is
       considered as a disturbing force and
       because of its smallness, the method
       of small disturbances is used in the
       solution.

622.   Tipei, N., and C. Guta. Motions of an   StuCeMeAp
       Aircraft along a given trajectory.   no. 4,
       (Institute of Applied Mechanics,   855-866
       Bucharest).

       The dynamic behavior of an aircraft
       covering motions along a given trajectory
       in the vertical plane is discussed. Load
       coefficients are determined and a synthesis
       is derived which can be analyzed by means of
       the obtained results.

623.   Tipei, N. Nonsteady Motion of an Aircraft   RevMeAp
       in the Horizontal Plane.   v. 3, no. 3,
                                                       199-213

       The nonsteady motion of an aircraft along
       a given trajectory in the horizontal plane
       is studied.

624. Batrakov, Yu. V., and V. F. Proskurin. Perturbations of artificial satellite orbits caused by atmospheric drag.

1959
Isk SpZe
no. 3
39-46

Expressions for determining secular and periodic disturbances in the elements of an elliptic orbit of an artificial satellite caused by the atmospheric drag only, are derived, and an example of calculating the first-order disturbances is given.

625. Lavrent'yev, M. A. The puncture problem at space velocities.

Isk Sp Ze
no. 3
61-65

The one-dimensional problem of determining the impulse imparted to a finite-length cylinder by a circular plate of the same diameter moving at a very high speed (50 to 100 km/sec) under assumption that the evaporation of material takes place in the impact. An analogous three-dimensional problem (small sphere and a finite-radius semisphere) is also discussed. Finite formulas in both cases are obtained.

626. Fridlender, G. O. A system for determining the motion parameters of a body in space.

IzAN EnAvt T
no. 6
108-117

A system for determining the coordinates, velocities, and acceleration of aircraft moving in space is discussed. For elimination of errors caused by gravitational fields and inaccuracy of instruments, a device is proposed which is not sensitive to the effect of weightlessness.

627. Kleyman, Ya. Z. Steady motion of a multi-component compressible medium.

IzAN MeMa,
no. 1
50-55

The analog of the conditions of the "sound crisis", that is, subsonic, sonic, and supersonic steady motion of an n-component mixture, is considered. Local variations of parameters of a two-component medium, knowledge of which is indispensable for qualitative motion studies, are investigated, together with the problem of variations in the mass of the mixture.

628. **Isayev, V. K.** Pontryagin's maximum principle in thrust programming of rockets.

1961
AvtT1
v. 22, no. 8
986-1001

Optimum programming of the magnitude and direction of rocket thrust in two- and three-dimensional cases is discussed on the basis of Pontryagin's maximum principle. Equations of motion are derived for the two-dimensional case in terms of projections onto coordinate axes under the assumption that the rocket is a point of variable mass moving in a homogeneous gravitational field and neglecting the effect of aerodynamic forces.

629. **Motulevich, V. P.**, V. M. Yeroshenko, and Yu. N. Petrov. The effect of electrostatic fields on convective heat exchange.

EnI AN SSSR
M. 94-103

A theoretical and experimental study was made in order to compare different quantitative data obtained by various scientists on electrostatic fields and convective heat exchange. Special attention was given to an explanation of the nature of the phenomenon which determines heat-exchange intensity due to electrical convection, experimental investigation of the effect of electrical field intensity on heat exchange, and optical study of the process by means of an interferometer.

630. **Gu⁸evich, A. V. Perturbations in the**
     ionosphere caused by a travelling body.

The effect produced by a body moving
through a rarefied, partially ionized
gas are analyzed. Variations in the
neutral particle density near the moving
body are calculated. Perturbations of
electron and ion densities are analyzed,
and the resulting electric field value is
determined with and without taking into
account the Earth's magnetic field.

631. **Bodner, V. A., and V. P. Seleznev. Control**
     of the motion of a body in inertial space.

In a study of an automatic control system
for programmed motion of a body in an
inertial space, the moving body is assumed
to be subject to forces of thrust, gravi-
tation, and resistance. Equations are de-
rived for the motion of the body in an
inertial system of coordinates and for the
motion of components in a closed control
circuit (e.g., navigational systems, control-
signal systems).

632. **Fulev, V. A. Necessary and sufficient con-**
     ditions for extremals in variational prob-

Starting with the four necessary and suffi-
cient conditions which must be satisfied by
an extremal obtained in solving any varia-
tional problem with given boundary conditions
(satisfaction of the Euler equations of
motion, the requirements on the extreme values
of the Weierstrass function, the Clebsch con-
dition, and the Jacobi condition), the author
proves the realizability of the last condition
(the possibility of constructing a field of ex-
tremals around the given extremal), taking into
account the special features usually true of
variational problems of flight dynamics. Ex-
pressions are derived for the Weierstrass
function for the extremals and the Clebsch
condition for optimal maneuvers in the verti-
cal plane.

633. Biryukov, Ye. A. Theoretical determination   IzVUZ AvT
     of the vibratory motion of a winged rocket.   no. 2
                                                        3-16

     Theoretical determinations of the vibra-
     tory motion of a winged rocket are pre-
     sented for the following cases: motion with
     the motor in operation for a statically
     stable rocket and for a statically unstable
     rocket, and for motion with the motor not in
     operation for a statically stable rocket and
     for a statically unstable rocket.

634. Vereshchagin, I. F. Motion of a rocket   IzVUZ AvT
     along a three-point path with constant   no. 2
     tangential acceleration.   35-46

     Rocket motion at constant tangential
     acceleration along a beam rider curve is
     analyzed. The rocket is assumed to be
     directed by line-of-sight control toward
     a moving target so that its center of
     gravity is located on a straight line be-
     tween the control point and the target.
     The analysis is limited to the case of
     straight horizontal target motion at con-
     stant speed, but the method can be extended
     readily to more complex target motions.

635. Yasinskiy, F. G. The gliding range of a   IzVUZ AvT
      winged vehicle at space velocities.   no. 3
                                                      31-37

     The use of the kinetic energy of a
     vehicle moving at space velocity for
     a gliding flight is discussed. The
     gliding is considered as quasi-steady-
     state immersion in the atmosphere at
     altitudes of 70-75 km in unpowered flight
     at orbital velocity with overloads of
     4 to 5 g's.

                                                      1962
                                                      MoAvI
636. Mikhaylov, F. A., and V. M. Strumilov.   Avtom. Reg.
     Dynamic accuracy in automatic longi-   no. 139
     tudinal stability control of winged   87-107
     aircraft in disturbed air.

The accuracy attainable in automatic con-
trol (by an autopilot) of the dynamic
longitudinal stability of a winged air-
craft exposed to random wind disturbances
is discussed. A qualitative control cri-
terion related to structural parameters
of the aircraft-autopilot system is estab-
lished for determining the degree of per-
fection of the system.

637. Klimov, V. I. Effect of gyroscopic moments
    of an aircraft engine on the dynamic char-
    acteristics of an airplane.

IzVUZ AvT
no. 2
15-22

It is shown that gyroscopic moments of the
engine can affect considerably, and even
deteriorate the control characteristics of
a modern airplane (with a reaction engine),
so that in some cases special automatic
devices for aerodynamic balancing of gyro-
scopic moments will be warranted.

638. Chakalev, K. N. Heating of a plate in the
    process of ablation.

InFZh
v. 5, no. 4
25-30

An approximate solution is obtained for
the problem of heat transfer during the
melting of an infinite plate, with
ablation of the liquid phase. Relation-
ships are obtained for determining the
rate of advance of the melting front and
the flow of heat into the solid part of the
plate from a given temperature variation
with time at some point inside the plate.

639. Makarov, O. F. Optimality of multistage
    rockets.

IzVUZ AvT
no. 4
18-26

An investigation is made of optimality
conditions for multistage-rocket motion
in force-free and gravitational fields.
The problem of establishing optimality
conditions is reduced to determining ratios
of component masses at which the

attainment of a given velocity by an
n-stage rocket is ensured and which
minimize a given performance function-
al. Exponential, linear, and linear-
fractional laws of mass expenditure are
considered.

640.   Ivanov, Yu. N. Optimum power variation in   PMMe
        the motion of a variable-mass body in a   v. 26, no. 4
        a gravitational field.   780-782
        Under the assumption that the initial
        total relative weight of the power
        source and fuel is known, the following
        variational problems are solved: to
        determine the laws of: 1) optimum continuous
        decrease in the relative weight of a power
        source, and 2) acceleration-vector
        variations caused by reactive thrust,
        which ensure the minimum time of motion
        between two given points in phase space.
        A system of equations with a set of boun-
        dary conditions describing the problem
        is written.

641.   Tokarev, V. V. The effect of a random power   PMMe
        decrease on the motion of a variable-mass   v. 26, no. 4
        body in a gravitational field.   783-789

        The influence of a random stepwise decrease
        of source of power caused by damage to its
        sections on the motion parameters of a body
        of variable mass in a gravitational field
        is studied. The case when the power source
        has a large number of autonomous sections
        is analyzed.

                                                          1963
642.   Ostoslavskiy, I. V., and I. V. Strazheva.   Dinamika
        Dynamics of flight. Aircraft traject-   poleta
        ories.

        This book contains methods for determining
        the flight trajectories of aircraft
        (airplanes, guided missiles, ballistic
        rockets, rocket planes). The trajectory
        optimization methods based on application

of the calculus of variations are discussed. It is a textbook for students of the higher aeronautical schools.

643. Il'in, V. A. Transfer of a space vehicle decelerated in a planetary atmosphere into a satellite orbit.

InZh
v. 3, no. 2
203-206

In discussion of this problem it is assumed that the gravitational field of the planet is a central Newtonian field and that the atmospheric portions of the braking ellipses are small in comparison to the total orbit. The additional thrust impulse necessary to transfer the vehicle from an elliptical orbit into a given circular orbit is determined.

644. Grodzovskiy, G. L., Yu. N. Ivanov, and V. V. Tokarev. Mechanics of low-thrust space flight (1).

InZh
v. 3, no. 3
590-615

The following topics are discussed in the first article concerning the mechanics of low-thrust space flight: 1) formulation of the problem of flight mechanics of vehicles equipped with solar sails, their weight ratios, transfer trajectories between planetary orbits, and escape from gravitational fields; 2) general formulation of the optimization problem in the flight mechanics of low-thrust space vehicles, their optimum weight ratios for the simplest modes of motion and a perfectly controlled propulsion system (its optimum weight proportions and power control). Seventy-three Soviet and non-Soviet references are given.

645. Grodzovskiy, G. L., Yu. V. Ivanov, and V. V. Tokarev. Mechanics of low-thrust space flight (2).
The following topics are discussed in this article on low-thrust space flight mechanics: optimum trajectories and

InZh
v. 3, no. 4
748-768

acceleration vectors produced by thrust in force-free and central fields, the parameters of a low-thrust perfectly controlled propulsion system in optimum trajectories. The noncontrolled propulsion systems and optimum trajectories with constant and variable accelerations produced by thrust are discussed. Forty-three Soviet and non-Soviet references are given.

645a   Beletskiy, V. V. Libration of a satellite in an elliptic orbit.

Isk Sp Ze
46-56

Small forced oscillations of a satellite in the plane of its orbit (caused by the ellipticity of the orbit) around its center of mass are investigated, especially with respect to resonance effects.

646.   Gaushus, E. V. An investigation of a certain mode of self-induced oscillations of a spaceship.

Isk Sp Ze
no. 16
57-67

Plane self-induced oscillations in motion of a spaceship controlled by an impulse-type automatic system are discussed. It is assumed that the directional-deviation sensors of the spaceship have a dead zone on whose boundaries constant-intensity short-duration control impulses are produced by servos and that the perturbance moments acting on the vehicle in flight are of constant magnitude and direction.

647.   Lur'ye, A. I., and M. K. Cheremkhin. The motion of a mass point under a small transverse thrust in a gravitational field.

Isk Sp Ze
no. 16
246-251

The motion of an aerospace vehicle (treated as a mass point) in a central gravitational field with a small transverse thrust is discussed. It is shown that by introduction of a "correction member" with a factor ϵ^2 (ϵ-is the thrust-to gravity ratio) in the equations of motion, a more exact computation of the trajectory can be obtained.

648. **Lebedev, V. N., and B. N. Rumyantsev.**
Variational problem of the transfer
between two points in a central
[gravitational] field.

Isk Sp Ze
no. 16
252-256

The plane problem of the minimum-time
transfer of a spaceship between two points
in a central gravitational field is
studied under the assumptions that accel-
eration (due to the thrust) is constant
and that distances between the points and
the gravitation center are given. Trans-
fers between two circular orbits and from
a point to a given orbit are considered.

649. **Tarasov, Ya. V.** On optimum aircraft-
motion regimes.

IzVUZ, AvT
no. 3
34-42

The selection of a characteristic
of the throttling of the engine of an
aircraft in motion in which one of
the characteristics of motion (e.g.
velocity, altitude range, weight)
reaches its extremal value is dis-
cussed.

650. **Kozhevnikov, Yu. V.** On selecting the
optimal control of aircraft.

IzVUZ, AvT
no. 4
15-24

The problem of selecting an optimum
control system for an aircraft is
generalized with consideration of
characteristics of controls. The
motion of an aircraft about its
centroid is taken into account, and
the Pontryagin maximum principle is
used in formulating optimization criteria.

651. **Kosmodem'yanskiy, A. A.** Variational
problems of orbital-airplane dyna-
mics.

Ve MoU, MMe
no. 4
70-76

The optimum regimes of circular orbital motion of an airplane, equipped with a liquid-fuel rocket engine, at high velocities (M > 10) and altitudes of 60 to 100 km are discussed with emphasis on the effect of aerodynamic forces on the motion parameters.

652. Mel'ts, I. O. The optimal aerodynamic maneuver for changing the orbital plane at near-circular velocities.

The variational problem of optimizing the velocity loss during aerodynamic maneuvering at small angles of the trajectory with the local horizon is considered. Equations for three-dimensional motion of a lifting vehicle as a point mass are written. The optimum control of the angle of attack, lift-drag ratio, and banking angle are discussed and the existence of an optimum flight regime with almost constant angles of attack and of banking for the maximum lift-drag ratio is shown.

653. Ioslovich, I. V. On the problem of optimal rocket trajectories.

The problem of determining the final mass for the given time and vice versa, for flights in horizontal and vertical planes is discussed.

654. Smol'nikov, B. A. Optimum regimes of retarding the rotary motion of a symmetric body.

Two methods of braking the angular motion of a symmetric body by a system of jet nozzles are discussed: braking in the shortest time, and braking minimum fuel consumption. The problem is reduced to programming the optimum thrust of jet nozzles by using Pontryagin's maximum principle.

655. Pol'skiy, N. I., and O. M. Shchegolev.
Isothermal flow of conducting gas in
channels.

The author derived in dimensionless form,
by variational means, relations for the
extremal values of the power generated by
the stream, the pressure ratio, and the
electric field intensity. The effects of
the induced magnetic field (the magnetic
Reynolds number), of the pressure depend-
ence of the conductivity, and of friction
are also taken into account. It is pointed
out that for isothermal flow with constant
velocity, the dimensionless field intensity
is a measure of the thermal efficiency and
that the dimensionless pressure ratio is a
measure of the channel broadening.

GROUP C   FLIGHT MECHANICS

C-2   Re-Entry Dynamics
      Re-Entry Angles
      Re-Entry Velocities
      Re-Entry Manouvers
      Re-Entry Gliding
      Re-Entry Vertical Landing

656. Yegorov, V. A. On the solution of a degenerate varia-
      tional problem and the optimal climb of a space
      rocket.

      1958
      PMM
      v. 22, no. 1
      16-26

      This article gives a solution of Mayer's problem for
      Pfaff's equation with one free function. The solution
      is used for selecting the form of the rocket trajectory
      which yields maximum rate of climb to a given altitude.

657. Gorelov, Yu. A. (Moscow). Two classes of plane extremal
      motion of a rocket in a vacuum.

      1960
      PMM
      v. 24, no. 2
      303-308

      The conditions governing the extremal (in relation to
      time and mass consumption) motion of a rocket along a
      curvilinear trajectory are studied. The problem of
      plane motions is solved separately in the horizontal
      and vertical planes, assuming that no effect is pro-
      duced by aerodynamic force.

658. Krotov, V. F. Optimal conditions for horizontal flight
      of an aircraft.

      1961
      MoVyU, Tr
      no. 104
      54-65

      The author's theory of discontinuous solutions of varia-
      tional problems is applied to the study of optimal thrust
      programming of the horizontal flight of an aircraft to
      achieve the maximum flying range. The solution of the
      problem is reduced to determining from the class of ex-
      tremals v = v(m) (v being the velocity and m the instan-
      taneous mass of the aircraft), passing through the initial
      and final points (m_0, v_0), (m_k, v_k) of the flight, an ex-
      tremal v = v(m) for which the integral defining the flight
      range of the aircraft has an absolute maximum. When
      thrust P is a nonlinear function of fuel consumption, it
      is shown that the maximum flight range can be achieved
      for special (type a) extremals which are different from
      ordinary continuous extremals and cannot be found by using
      classical variational methods.

659. New ejection seats and emergency capsules.

      ALiK
      no. 3
      2-4

      New models of ejection (at 24,000 km/hr) seats pro-

tected by a hermetically closed capsule have been
developed with the explosive charge replaced by a
rocket engine. The capsule is provided with a para-
chute and contains emergency provisions, oxygen equip-
ment, and a raft.

660.   Tirskiy, G.A. Ablation of the leading edge of a swept-   ZhPMeTF
        back wing in hypersonic flow.

        Thermal disintegration of the leading edge of a swept-
        back wing in hypersonic flow is studied. Equations
        describing the disintegration process and an approxi-
        mate formula f\r the ablation rate are presented.

661.   L. G. Vvedenskiy and A. I. Peshkova, No. 147097. Authors   1962
        certificate in aviation.   BIzobr.
                                                                    no. 9

        Controllable parachute with slit-type canopy. For im-
        proved utilization of the reactive effect during control
        of the canopy, the slits are made along a straight line
        from the lower edge of the apex with a vent in the lower
        edge of the canopy. The lower edge near the vent is
        tightened by a double cord with a sliding attachment which
        makes control possible by pulling up one section of the
        lower edge with a control cord.

662.   El'yasberg, P. Ye. Determination of an orbit from two   IskSpZe
        positions.   no. 13
                                                                  3-22
        A full analysis of the determination of the nonperturb-
        ed orbit of a cosmic body from two given positions is
        presented. Considerable attention is devoted to the ex-
        istence and the uniqueness (or multivalence) of the
        solution. Determination of the form of an orbit is
        analyzed for $\Delta\phi < 2\pi$ and $\Delta\phi > 2\pi$. Particular
        cases of orbit determination when D_1, D_2, and 0 are
        located on a straight line are studied. All possible
        versions of determining orbits from two given points
        for given $\Delta\phi$ and Δt values are presented in tables.

663. Kislik, M. D. An analysis of the integrals of the equa-
tions of motion of an artificial earth satellite.

An analysis is made of the exact integrals of the equa-
tions of motion derived earlier by the author and put
into a form convenient for high-speed computers for an
artificial earth satellite in a normal gravitational
field in the general case of motion; only orbits of
real satellites are taken into consideration. This
method reduces computer time by 15 to 20 times as com-
pared with numerical integration with the same accuracy.

664. Beletsky, V. V. Orbit of equatorial earth satellite.

The properties of the equatorial trajectory of an arti-
ficial earth satellite and the effect of the behavior
of osculating elements (the longitude of the perihelion
and the eccentricity) or the orbit on the motion of the
satellite are studied.

665. Illarionov, V. F., and L. M. Shakadov. The rotation of
the circular orbit of a satellite.

The motion of a body along a circular orbit under the
action of a transverse force is studied. The system
of equations of the motion of a mass point in the
central gravitational field was taken and the initial
conditions are established on the assumption that the
circular orbit of a nonperturbed motion is located in
the equatorial plane. General expressions for deter-
mining the declination angle of the plane of the
satellite orbit from the equatorial plane (of nonper-
turbed motion) are derived in terms of transverse force
and of satellite velocity attained after exhaustion of
the propellant.

666. Brykov, A. V. Estimating the effect of correlation
between measurements of the accuracy of processing
results.

The present study is regarded as the first step in
determining the influence of the measurement corre-
lation (the interdependence between measurement er-
rors) on the processing accuracy. A method for

processing such data, a procedure for estimating the
processing accuracy, and a method of selecting the
scope and character of the optimal measurement infor-
mation are described in detail, and quantitative esti-
mates of the effect of measurement correlation on the
accuracy of final results are discussed.

667. Charnyy, V. I. On optimal trajectories with many
      impulses.

IskSpZe
no. 16
257-264

The plane problem of the motion of material point in a
single-center Newtonian gravitational field has been in-
vestigated under the assumption that instantaneous velo-
city impulses may be imparted to the point at certain
discrete moments of time, and that concentric rings
emanate from the center of gravity through which the op-
timal trajectory can pass only after certain conditions
have been fulfilled.

668. Bezgin, L. S., and M. I. Ivashchenko.
      Approximate designing of protective
      shielding against meteors.

Iz AN MeMa
no. 1
127-129

A method of designing a protective mantle
over a space vehicle to protect it against
meteoritic impacts is presented. The
method is based on the idea that both the
meteorite and the mantle evaporate at
impact. Approximate estimation of the
mantle thickness and of the gap between
the mantle and the wall of the vehicle
is discussed.

669. Mirolyubov, G. Shock absorbing methods in manned
      spaceships.

Izvestiya
20 Jun 1963
3-5

In an article dealing with reentry and impact over-
loads, G. Mirolyubov, a physician-physiologist, states
that reentry overloads are more difficult to withstand

than injection overloads. Extensive experiments with
men immersed in a tank of water indicated that under
these conditions, muscle tonus and strength are reduced
and cardiovascular activity is sharply disrupted. Since
it is these very organs that resist overloads, it is
necessary to be particularly accurate in determining
tolerable overload forces in reentry.

670. Kozhevnikov, Yu. V. Optimization of the flight regimes
    and parameters of multistage rockets.

IzVUZ AvT
no. 3
11-20

The solution of the variational problem for the motion
of a multistage rocket, under the assumptions that the
stage number is given, the trajectory consists of active
and passive sections, and the stage separation takes
place at zero relative velocity, yielded a generalized
equation for the optimum mass distribution in the individ-
ual stages. Calculation of the optimum mass distribution
for maximum flight range yielded expressions which show
that the angle between the thrust vector and the horizon-
tal coordinate remains constant along the entire trajec-
tory, even when air resistance is taken into account.

671. Akim E.L., and T.M. Eneyev. Determination of parameters of
    of the motion of a spaceship from trajectory measure-
    ments.

KosIsl
v. 1, no. 1
5-50

A statistical approach is used to solve the problem of
determining the unknown parameters characterizing the
motion of a spaceship on the basis of measurements
carried out at certain instants. By applying the method
of maximum likelihood, the problem is reduced to the
solution of a system of nonlinear equations to which
Newton's method and the method of steepest descent are
applied. A series of important problems connected with
estimating the accuracy of predicting the motion of a
spaceship from the processed data of trajectory measure-
ments is studied, and certain algorithms for estimating
are derived.

672. Yarov-Yarovoy, M. S. On the solution of the Euler-
    Lambert equation for transfer orbits which are close
    to Hohmann ellipses.

KosIsl
v. 1, no. 1
51-54

A transfer trajectory along the unperturbed orbit be-
tween two terminal points (the starting and finishing
points) is studied. A solution of the Euler-Lambert
equation is sought for transfer orbits which are close
to Hohmann ellipses. An iterative method for determin-
ing the root n_1 with the necessary accuracy is described.
From the value of n_1, the semimajor axis and other param-
eters of the transfer orbit are calculated. As an
example, determination of the semimajor axis of the unper-
turbed orbit for transfer between the location of Earth
on 13 September 1962 and the location of Venus on
22 December 1962 is presented.

672a. Sagomonyan, A. Ya., On the problem of interaction
between bodies at very high velocities.

The mechanism of impact of a body of small mass on a
body of large mass at speeds of the order of 5 to
10 km/sec is discussed with the aid of an impact
model which makes it possible to determine the
basic parameters of the impact process.

GROUP D   STRENGTH OF SPACE VEHICLE COMPONENTS

Static Stress and Strain Analyses
Minimum Weight Design
Load Carrying Capacity
Thermal Stresses and Strains
Buckling

Dynamic Stresses and Strains
Dynamic Stability
Vibration and Flutter
Aeroelasticity
Aerothermodynamics
Liquid-Filled Bodies

673. Carafoli, E. (Institute of Applied Mechanics, Bucharest), and S. Sandulescu (Institute of Applied Mechanics, Bucharest). Harmonic vibration of ailerons of general form under supersonic conditions.

1958
Arch Mech
no. 6
771-782

The motion of triangular wings oscillating harmonically in supersonic flow is investigated. The harmonic oscillations of an aileron are considered as a special case in which the problem is reduced to the calculation of motions of two appropriately selected triangular surfaces.

674. Shorr, B. F. The effect of nonuniform heating under creep conditions on changes in stress distribution.

DAN SSSR
v. 123, no. 5
809-812

The time-dependent variation in stress distribution caused by nonuniform heating under creep conditions is discussed for the uniaxial state of stress, taking strain hardening into account.

675. Vorob'yev, N. F. Unsteady vibration of a thin wing in supersonic flows.

IzAN OTN
no. 3
153-156

A finite-span wing is studied in an infinite volume of fluid. The wing creates a small disturbance. The problem is linearized and analyzed according to the general conceptions of thin-wing theory.

676. Lebedev, A. A. Application of the "frozen-coefficient" method to investigation of the stability of nonsteady motion.

IzVUZ AvT
no. 1
11-18

The method of "frozen coefficients" is applied in the simplification of linear, uniform, differential equations of the disturbed motion of a dynamic system. The application of the method is shown for the calculation of free oscillations of rockets of the V-2 type.

677. **Vakhitov, M. B.** Design for strength of a swept-back wing of monolithic construction.

IzVUZ, AvT
no. 1
61-68

The general strength of swept-back wings with thick skin stiffened by stringers and flanges of ribs is investigated. The skin is able to carry normal and tangential stresses which are variable over its thickness.

678. **Karavanov, V. F.** (Moscow Aviation Institute). Equations of shallow sandwich shells with a light core under finite displacements.

IzVUZ, AvT
no. 1
69-77

Equations which describe stress-strain relationships of these shells under the assumptions that the face layers obey the Kirchhoff-Love hypothesis and the core layer is elastic and isotropic are presented. The flexural rigidity of the faces is neglected; transverse shearing and compression strains of the core are taken into account.

679. **Kopzon, G. I.** Vibration of a thin rectangular wing of high aspect ratio in supersonic flow.

1959
PMM
v. 22, no. 6
810-814

Fourth-order differential equations describing the torsional-flexural strains of a thin high-aspect-ratio rectangular wing in a supersonic flow are used in wing's flutter analysis. Expressions for determining the frequency equations for a wing in vacuum and in supersonic flow are derived as well as expressions for dynamic-stability conditions.

680. **Savulescu, S. N.** (Institute of Applied Mechanics, Rumanian AS, Bucharest). Considerations on a solution of the case of an unsteady compressible boundary layer.

StuCeMeAp
v. 9, no. 4
867-879

Conditions are established for the external parameters of an unsteady compressible boundary layer (velocity and temperature of the external flow, and temperature at the wall) in order to extend the applicability of the Crocco solution.

681. **Lyamshev, L. M.** The problem of the reciprocity principle in acoustics.

The results of Helmholtz and Rayleigh in respect to the reciprocity principle are extended to a mathematical formulation of the reciprocity principle describing the connection between three-dimensional sources in an acoustic medium; certain external forces acting on shells, membranes, et cetera; and radiation fields created by these sources and bodies.

682. **Gerasimov, I. S.** On a dynamic similarity problem for a conical shell.

An elastic conical shell subjected to the action of a moving load (constantly axially symmetric pressure normal to the surface of the cone) which propagates at a constant velocity from the apex of the cone in the longitudinal direction is analyzed. Formulas are given for the bending moments and deformations.

683. **Bolotin, V. V., Yu. V. Gavrilov, B. P. Makarov, and Yu. Yu. Shveyko.** Nonlinear buckling stability of flat plates at high supersonic velocities.

Rectangular plates at a zero angle of attack are investigated. Aerodynamic forces are determined by asymptotic formulas which may be used for velocities of $M \gg 1$.

684. Vakhitov, M. B. On determining the natural modes and frequencies of a monolithic wing.

IzVUZ, AvT
no. 1
16-27

The modes and frequencies of free vibration of a cantilever plate of most general type (anisotropic, laminated, swept-back, with thickness varying over the chord and span) are discussed. Flexural and torsional vibrations along the chord and span are analyzed by using the Ritz and successive-approximation methods. Theoretical and empirical values of frequencies are compared.

685. Kan, S. N. (Kharkov Higher Military Aviation Engineering School). Stress distribution in cylindrical shells with large cutouts.

IzVUZ, AvT
no. 1
32-37

The state of stress around large cutouts in a circular cylindrical orthotropic shell stiffened by stringers and frames, and subjected to transversal bending and torsion is discussed. Normal (axial) and tangential forces in the skin, and the bending moments of frames (on their planes) are analyzed.

686. Galkin, S. I. (Novosibirsk), V. V. Kabanov (Novosibirsk), and S. S. Lyashenko (Novosibirsk). An experimental investigation of stresses in a stiffened circular cylindrical shell with a large rectangular cutout.

IzVUZ, AvT
no. 2
49-61

Results of an experimental investigation of a shell under concentrated load are presented. Data on normal and tangential stresses in the open and closed parts of the shell are given and compared with those determined analytically by using the V. S. Vlasov method.

687. Sibiryakov, V. A. (Moscow Aviation Institute).   IzVUZ, AvT
Design of an orthotropic conical shell un-   no. 2
der arbitrary external loading by the V. Z.   72-82
Vlasov method.

States of stress and of strain of an ortho-
tropic conical shell under asymmetrical
loading are determined by using V. Z.
Vlasov's theory for semi-membrane medium-
length shells. Equations are derived for
designing them and their application is
demonstrated by a sample numerical calcula-
tion.

688. Sirazetdinov, T. K. (Kazan' Aviation Insti-   IzVUZ, AvT
tute). Vibrations of a wing of small as-   no. 3
pect ratio in a subsonic flow.   16-23

The derivation of an integral differential
equation for a wing oscillating in a sub-
sonic flow is given, and an approximate
method for the case of small aspect-ratio
wings is presented.

689. Vakhitov, M. B. (Kazan' Aviation Institute)   IzVUZ, AvT
Design for strength of an elastic monolithic   no. 3
wing.   24-32

Stress-strain relationships are discussed in
an elastic monolithic wing with thick skin
stiffened by ribs and stringers using a
cantilever anisotropic plate as a model. The
formulas derived can be also used for deter-
mining the wing loading, the aerodynamic
coefficients with consideration of the effect
of deformation, et cetera.

690. Kornishin, M. S. (Kazan), and Kh. M. Mushtari   PMM
(Kazan). An algorithm for the solution of   v. 23, no. 1
nonlinear problems of the shallow-shell   159-163
theory.

A description of the algorithm for solving a system of nonlinear algebraic equations is presented and applied to investigation of the considerable flexure of a rectangular, shallow, simply supported panel under uniform transverse loading. The numerical calculations were carried out on a Strela computer.

691.   Rakhmatulin, Kh. A. The propagation of elasto-   PMMe
       plastic waves in a half-space.   v. 23, no.
                                                           419-424

An approximate method is developed for
solving the problem of elastoplastic
waves propagating in a half-space
with normal pressure along the boundary
equal to zero. Three examples are ana-
lyzed, and the state of stress in the
neighborhood of the load boundary is
calculated.

692.   Chao, Hwei-Yuan. Thermal stresses in   Scientia Sinica
       shells of revolution with variable   v. 8, no. 4
       elastic properties.   383-400

Thermal-stress analysis in shells of
revolution made of a material possessing
a linearly time-dependent Young's modulus
and a constant Poisson ratio is
presented. The temperature gradient is
axially symmetric over the shell and
constant along its thickness.

693.   Carafoli, E. (Institute of Applied Mechanics,   StuCeMeAp
       Bucharest), and S. Sandulescu (Institute of   v. 10, no. 1
       Applied Mechanics, Bucharest). Aerodynamic   13-40
       characteristics of ailerons subject to
       harmonic oscillatory motion at supersonic
       speeds (supersonic flutter).

Aerodynamic characteristics of ailerons

subject to harmonic oscillatory motion at
supersonic speeds was studied. Oscillatory
motion of a polygonal aileron was found to
be equivalent to that of two triangular
surfaces; all forms of ailerons are calcu-
lable by a specifically developed equation.

694. **Slobodkin, A. M.** (Moscow). Stability
of an elastic beam with rigid empennage
in a supersonic flow.

The stability of an elastic beam with
a constant cross section and mass
per unit length with rigid empennage
moving along its axis at high super-
sonic speed is investigated.

695. **Mouchan, A. A.** (Moscow). The behavior of com-
plex values in the problem of plate flutter.

The results of complementary calculations
in the domain of high supersonic speeds are
given. These results may be used for in-
vestigating the experimental data concerned
with flutter of the supersonic aircraft
structural covering.

696. **Bolotin, V. V.** (Moscow). Nonlinear
flutter of plates and shells.

Nonlinear hypersonic flutter (hard and
soft) of plane and curved panels, with
pliable and perfectly rigid stiffening
is investigated in flows with very high
Mach numbers. Expansion of the middle
surface and buckling of the panel caused
by aerodynamic heating are taken into
account.

697. **Gerasimov, I. S.** (Moscow). Elastoplastic axisymmetrical strains in a closed circular cylindrical shell.

InSb
v. 28
241-246

The elastoplastic behavior of a circular cylindrical shell with plane bottoms, subjected to a combination of: internal pressure, radial compression of the bottoms, and external pressure on the bottoms is investigated. The joint deformation, the elastic deformation of the shell, and the elasto-plastic deformation of the bottoms are investigated.

698. **Mouchan, A. A.** Effect of aerodynamic damping on supersonic skin flutter.

IzAN MeMa

no. 1
175-177

Aerodynamic-damping effects on the flutter speed of a circular cylindrical shell moving axially in a gas at supersonic speed and performing additional axisymmetrical small movements are discussed. It is shown that the error caused by disregarding aerodynamic damping can reach considerable values.

699. **Morozov, M. G.** Acoustical radiation of cavities in a supersonic flow of air.

IzAN MeMa
no. 2
42-46

Schlieren photographs of the supersonic flow patterns over a plane surface with cavities of various shape, depth, and attitude obtained in a wind tunnel at $M = 1.7$ and $Re = 1.2 \cdot 10^5$ are presented and discussed.

700. **V. A. Sibiryakov.** (Moscow Aviation Institute). Determining thermal stresses in a conical shell.

IzVUZ, AvT
no. 1
72-82

Elastic thermal stresses in a constructionally orthotropic circular conical

shell placed in a gas flow are determined
by using semimembrane shell theory.
Constant temperature over the wall
thickness, and a modulus of elasticity
and a coefficient of thermal expansion
which are independent of temperature
are assumed.

701. Karavanov, V. F. (Moscow Aviation Insti-   IzVUZ, AvT
       tute). Stability of shallow cylindrical   no. 2
       light-weight-core sandwich panels with   50-60
       clamped longitudinal edges under axial
       compression.

       Analyzing the stability of finite-
       length and infinite shells, the effect
       of transverse deformation of the core
       is neglected, and the flexural rigidity
       of the face layers is taken into account.

702. Malakhovskiy, R. A. (Gomel'). The   IzVUZ, AvT
       design of orthotropic circular conical   no. 2
       shells.   61-68

       Stress distribution is analyzed in an
       elastic thin-walled conical shell
       stiffened by stringers and frames.
       The S. N. Kan method of designing
       cylindrical shells is generalized.
       The torsional rigidity of stiffen-
       ing elements and eccentricity of the
       stiffening system toward the skin are
       neglected. The equivalent thicknesses
       and moments of inertia are constant in
       a cross section, but arbitrarily
       variable in the axial direction.

703. Shchetnikov, Ye. S. On the speed   IzVUZ, AvT
       of sound in gaseous media with   no. 2
       relaxation processes.   110-117

The speed of sound in a reacting gas with vibratory degrees of freedom is investigated. The case of a gas mixture consisting of partially dissociated diatomic gases with excited vibratory degrees of freedom is considered.

704. Rapoport, L. D. (Ufa). Determining the free vibrations of non-prestressed circular cylindrical shells.

IzVUZ, AvT
no. 3
43-50

Natural frequencies of transverse vibrations of circular cylindrical shells of arbitrary length are ex-examined in cases of simply supported, clamped, and free edges as well as for combinations of these boundary conditions.

705. Manokhin, D. G. (Kazan' Aviation Institute). Approximate determination of thermal stresses in thin-walled structures.

IzVUZ, AvT
no. 3
124-134

A cylindrical thin-walled beam with airfoil cross section, longitudinally and laterally stiffened, is under discussion. The temperature varies along the contour of the cross section, but is constant over the thickness of the skin and stiffeners.

706. Malkina, R. L. (Urals Polytechnical Institute). Forced vibrations of cylindrical shells.

IzVUZ, AvT
no. 4
51-60

Forced vibrations of circular and non-circular closed cylindrical shells are discussed. Pure flexural vibrations caused by shaking forces normal to the middle surface are examined, neglecting the shell of tangential inertial forces.

707. **Bolotin, V. V.** (Institute of Mechanics, Academy of Sciences, USSR). The edge effect in elastic shells under vibration.

PMMe
v. 24, no. 5
831-842

The theory of the dynamic edge effect (for example, clamping) is presented. Classification of various types of the effect for shells with positive, zero, and negative Gaussian curvatures is given. Methods for evaluating the edge effect characteristics in the vicinity of distortions are discussed.

708. **Bublik, B. N.**, and **V. I. Merkulov.** (Kiev). On dynamic stability of liquid-filled thin elastic shells.

PMMe
v. 24, no. 5
941-946

The problem is reduced to the solution of the energy equation by a variational method, and a system of four differential equations is obtained as a result. Dynamic-stability analysis of a simply supported circular cylindrical shell filled with liquid is presented as an example.

709. **Carafoli, E.**, and **S. Sandulesou.** Harmonic oscillation of tail units in supersonic flow.

StuCeMeAp
v. 11, no. 3
557-568

The problem of low-frequency and small-amplitude oscillation of a tail assembly in supersonic flow is reduced to investigation of certain higher-order conical motions. The particular case of oscillation with subsonic leading edges is discussed. The interaction between vertical and horizontal control surfaces is considered.

710. **Savin, G. M.**, **Van-Fo-Fy**, and **V. M. Buyvol.**

1961
DopAN UkrSSR
no. 11
1435-1439

A successive approximation method of

analyzing the stress distribution around two unequal circular holes in a shallow spherical shell under constant internal pressure is presented. The superposition of stresses in an intact shell and of stresses caused by each hole is used to obtain the final state of stress. A numerical example and a diagram illustrate the discussion.

711. Lyubimov, V. M. (Moscow). Some exact solutions of the problem of self-sustained vibrations of a swept-back wing in a supersonic gas stream.

InSb
v. 31
171-178

A bending-torsion model (a cantilever beam of variable rigidity in bending and torsion) is used for vibration analysis of a swept-back constant-chord wing by applying the piston theory to account for the effect of aerodynamic forces, assuming the concidence of the flexural axis with the line of centroids (of cross sections). The particular cases of pure torsional, pure flexural, and combined vibrations are discussed.

712. Kislyagin, N. N. Downwash produced by a wing in an unsteady flow.

IzAN MeMa
no. 4
20-25

The concept of coefficients of rotary derivatives is introduced in a method proposed for determining the downwash produced by a rigid or an elastic wing of arbitrary shape in unsteady flow of an ideal fluid. Approximate formulas based on the linear theory of flow are derived for calculating aerodynamic forces and moments acting on the wing-empennage system, taking into account the downwash effect.

713. Ambartsumyan, S. A., Zh. Ye. Bagdasaryan. Stability of orthotropic plates in a supersonic gas flow.

IzAN MeMa
no. 4
91-96

Nonlinear flutter of a plate in a super-
sonic flow is discussed. The influence
of transverse slips on the character of
flutter is accounted for. The problem is
solved in its linear version by variation-
al methods.

714. **Biryukov, Ye. A.** **Theoretical analysis**
of oscillatory motion of a winged
rocket.

IzVUZ, AvT
no. 2
3-16

The oscillation of a winged solid-
fuel rocket in the vertical plane
caused by some disturbance (for
example, moving the elevator, switch-
ing the engine on and off, sudden
changes in the eccentricity of the
thrust) in its steady flight is dis-
cussed, assuming that the angles of
incidence of the wings and the control
surfaces are fixed, thrust eccentri-
city is constant, and the mass and
centroid of the rocket do not change
during the flight.

715. **Vakhitov, M. B. (Kazan' Aviation Institute).**
Designing a monolithic wing with a set of
nonparallel stringers for strength.

IzVUZ, AvT
no. 2
47-58

The strength of a swept-back wing with
thick skin, parallel ribs, and nonparallel
stringers, as well as wings with a central
section are under discussion. The previous
works of the author (1958) on the strength
of wings with orthogonal stiffening
elements are generalized.

716. **Figurovskiy, V. I. (Moscow Aviation Insti-**
tute). A design method for a conical shell
clamped on a part of its cross-sectional
contour.

IzVUZ, AvT
no. 2
67-77

The stresses in a conical shell, similar
to a wing with a large taper and low aspect
ratio stiffened with stringers and frames
(on ends) are analysed. In the root section,
the skin is clamped on a part (about the
middle) of the contour, the parts adjoining
the leading and trailing edges are supported
by a rigid rib. The shell is symmetrical
to the horizontal middle plane and has a
low thickness-to-depth ratio.

717. Yershov, V. V. Cylindrical flexure of un-   IzVUZ,AvT
     symmetrical light-core sandwich plates.   no. 3
                                                      38-55
     A stress analysis of rectangular sandwich
     plates in a state of slight cylindrical
     flexure is presented. The outer layers
     are of different materials and unequal
     thickness; their flexural rigidity is
     neglected. The core material is not
     resistant to longitudinal forces and
     bending moments, and its modulus of elas-
     ticity is far smaller than those of the
     outer layers.

718. Karnozhitskiy, V. P. The effect of thermal   IzVUZ, AvT
     stresses on the stability of a sandwich   no. 3
     wing panel.   69-77

     The thermal buckling of aerodynamically
     heated wing skin, of sandwich construc-
     tion, between spars and two neighboring
     ribs is investigated. The skin, free of
     external loading, is compressed in the
     direction of the span by uniformly
     distributed forces.

719. Matyushev, Yu. S. Design for strength   IzVUZ, AvT
     of a conical shell shaped like a low-   no. 3
     aspect-ratio wing.   89-99 .

An analysis of the stresses in a
constant-thickness, tapered, thin
shell with the shape of a low-aspect-
ratio wing is presented. Equations are
derived by using Vlasov's variational
method assuming uniform stress distri-
bution over the thickness of the shell.

720. Gur'yev, N. I. Calculation of cylindrical
and prismatic shells by the method of dis-
crete unknowns.

IzVUZ AvT
no. 3
153-154

An engineering method is presented for
calculating thin-walled shells of arbi-
trary cross-section (open and closed, long
and short), with constant or variable wall
thickness. This method consists in assigning
a finite number of degrees of freedom to
a transverse shell element and an infinite
number of degrees of freedom to a longi-
tudinal element. The unknown state of
stress is approximated in the form of two
states: 1) the principal, determined by
the elementary theory of thin-walled strips;
and 2) the secondary, investigated by an
energy method, with the use of Castigliano's
variation principle.

721. Il'gamov, M. A. (Kazan'). Forced vibrations
in shallow sandwich panels.

IzVUZ, AvT
no. 4
58-65

An analysis of forced vibrations in a shal-
low rectangular simply-supported sandwich
panel with a symmetrical structure is pre-
sented, taking into account the energy
dissipation in the cone only, which is
assumed to be absolutely plastic in its
plane but incompressible over its thick-
ness.

722. Vakhitov, M. B. On the investigation of
stress distribution in monolithic wings.

IzVUZ, AvT
no. 4
128-131

Effect of nonuniformity in location and

strength of stringers (or spars) along
the chord of the wing on the stress
distribution in skin is discussed in cases
of straight, swept-back, and triangular
wings. The effect of location of flexural
(elastic) axis on stress distribution
in skin along the span is examined for
each of above cases.

723. Gabril'yants, A. G., and V. I. Fedos'yev.
Axisymmetrical equilibrium configurations
of uniformly compressed spherical shells.

PMMe
v. 25, no. 6
1091-1101

The buckling behavior of an elastic shallow
spherical shell under uniform external pres-
sure is discussed. The solution obtained
is independent of the R/h ratio. A dimen-
sionless pressure parameter and the rela-
tive local deflection are used to illus-
trate graphically the pressure-deformation
relationship. A critical review of Soviet
and non-Soviet data on this problem is gi-
ven.

724. Petre, A. C., Stanescu, C., and L.
Librescu. (Physics Institute,
Rumanian Academy of Sciences).
Aeroelastic divergence of multicell
wings taking their fixing restraints
into account.

RevMeAp
v. 6, no. 6
689-698

Aeroelastic divergence of lifting
surfaces of constant cross-section
is analyzed with consideration of the
span-wise variation of the twisting
moment as well as the effect of re-
straints at the root cross section.

725. Kan, S. N. The strength of closed and open
cylindrical shells.

RaPro, Sb
no. 6
M. 1961
213-246

An approximate method is presented for the
design of cylindrical and prismatic shells

of closed and open cross sections, stiffened
by diaphragms rigid in their own planes.
The transverse loading, longitudinally and
laterally variable, may be either contin-
uous or by concentrated loads (as a par-
ticular case). The support conditions are
arbitrary.

726. Aksel'rad, E. L. Large axisymmetrical de-   RaPro, Sb,
      flections of a heated shallow shell of   no. 6
      revolution under loading.   M. 1961
                                                       275-278

      The general problem of determining large
      deflections under transverse axisymmet-
      rical loading of a shell with the elas-
      ticity modulus and Poisson's ratio vary-
      ing along the thickness of the shell,
      causing a variable thermal expansion in
      that direction during heating, is con-
      sidered. The deformations of a simply
      supported shell of arbitrary profile,
      with and without a hole at the top,
      determined by a quadrinomial are in-
      vestigated. The approximate Bubnov-
      Galerkin method is used to study the
      large axisymmetrical deflections of a
      shell under these conditions.

727. Ogibalov, P. M. (Department of Elasticity   VeLUMMeAs
      Theory, Moscow State University). The   no. 5
      problem of flutter of shells and panels.   60-65

      A brief survey of investigations on flutter
      is presented. The problem is stated on the
      basis of A. A. Il'yushin's law of plane
      sections for supersonic aerodynamics.

                                                       1962
728. Tskhovrebadze, D. S. Designing circular   AN GruzSSR
      cylindrical shells.   Soob,
                                                       v. 28, no. 6
      An analysis of the stress-strain   641-648
      relationships of very thin shells

(where the thickness-to-radius ratio
is negligible in comparison to unity)
begins with a system of equilibrium
equations of an elastic body in non-
dimensional coordinates. By application
of I. N. Vekua's method of reducing the
three-dimensional problem to a plane
problem, the relationships among the so-
called moments of component stresses,
strains, and displacements are obtained
instead of these quantities themselves.

729. Palley, I. Z. The effect of the history of
     loading on state of stress in two-layer
     shells.

AN LatSSR.
IAvMe, Sb.
no. 9
115-126

     An investigation is made of the influence
     of sequence in the application of component
     loads (e.g., heating and pressure) to a
     two-layer shell beyond the proportional
     limit on the stress-distribution pattern.

730. Lebedev, Yu. A. The simplest cases of
     structural damping in joints of thin-
     walled members.

AN LatSSR
IAvMe, Sb.
no. 9
5-14

     The dissipation of vibrational energy
     interfacial Coulomb slip damping in
     skin joints with beam flanges or stif-
     feners is discussed. The rigidity
     effects of elastic joining elements (e.g.,
     rivets or fitted-body screws) is taken
     into consideration.

731. Broude, B. M. Practical methods of shell
     design for stability.

AStr Ar SSSR
IStr Tr
no. 13
38-69

     The development of practical methods for
     use in analyzing the buckling stresses
     and critical loads in shells under
     various loading conditions is discussed.
     It is assumed that the shells were in a

membrane-stress state prior to buckling.
Conventional analysis procedures and
mathematical tools used in practice are
outlined, and the suitability of either
the Galerkin-Papkovich or the Ritz
method for buckling analysis in both the
linear and nonlinear formulation of the
problem is explained.

732. Petukhov, V. G. A method for accelerated de-   B Izobr
termination of the life of an aircraft   no. 22
structure.

Strain gauges are used to measure stresses
in a plastic specimen attached to a struc-
tural member of the aircraft in flight and
to an identical member of the aircraft
tested in a laboratory under repeated static
loading to destruction of the specimen.
The two sets of data are then compared; a
conversion factor is calculated, and the
number of flight hours corresponding to
one loading cycle is obtained.

733. Borshchevskiy, A. P. A flight-safety system   B Izobr
which signals the occurrence of fatigue   no. 22
cracks in the rotor-blade longerons to the
pilot of a helicopter.

The longerons, hermetically sealed and
filled with air compressed to a pressure
> 1 atm, contain pickups connected to an
indicator in the cabin which respond when
cracks appear and pressure drops.

734. Obremskiy, S. V. The effect of stiffening   DopAN UkrSSR
rings in a closed cylindrical shell taken   no. 7
directly into account.   883-887

It is shown how the effect of elastic
stiffening rings in a closed circular
cylindrical shell may be taken directly
into account in the application of V. S.

Vlasov's variational method, with shear
strains also considered. The assumption,
different from that of Vlasov, is that
some of the rings have finite rigidity
both in their own plane and when deformed
beyond it.

735. Guz', O. M. Stress concentration at a hole   DopAN UkrSSR
     with a nipple in an orthotropic cylindrical   no. 12
     shell.   1594-1597

     Stress distribution on the edges of a cir-
     cular hole stiffened by a rigid nipple is
     analyzed by the Ritz method. The shell is
     under uniform internal pressure. The the-
     ory of shells with a large index of vari-
     ation is applied, and the effect of the
     orthotropy of the material and of the nipple
     on the stress distribution around the hole
     is analyzed.

736. Shorr, B. F. (Engineering Physics Instit-   InFI. Sb.
     ute, Moscow). Designing for creep under   M. 1962
     nonuniform heating.   183-240

     The determination of creep stresses and
     strains, as well as their cross-sectional
     and axial distribution in bodies subjected
     to nonuniform heating, is discussed. The
     application of creep theories to the
     investigation of the behavior of non-
     uniformly heated bodies in a state of
     steady and transient creep is considered.

737. Makhovikov, V. I. Thermoelasticity problem   InFZh
     of a plate.   no. 3
                                                       95-102

     The thermal stresses in an elastic, iso-
     tropic plate without external loading
     in a stationary temperature field are
     analyzed. Thermal stress concentrations
     around circular and square holes in an
     unbounded plate with an infinite number of
     holes are also discussed.

738.   Yel'pat'yevskiy, A. N., and V. V. Vasil'yev.   InZh
        Designing prismatic shell structures in   v. 2, no. 1
        terms of stresses.   117-129

        Castigliano's principle is applied in
        developing a variational method of stress
        analysis of the membrane-stressed canti-
        lever shull structure of a box-type multi-
        cell cross section.

739.   Omitted. See page 242 ⁺ 740.

740.   Uzdalev, A. I.   Plane thermoelastic problem   InZh
        of an anisotropic body.   v. 2, no. 2
                                                       280-286
        The elastic equilibrium of a homogeneous-
        thickness plate, anisotropic for both
        elastic and thermal effects, is analyzed.
        The plate is in a state of plane stress
        caused by external forces and a stationary
        temperature field. The material of the
        plate has a linear stress-strain relation-
        ship; there are no body forces. The plate
        region is multiply connected (holes in the
        plate), and the temperatures on the closed
        contours are given.

741.   Bolotin, V. V. On the behavior of heated   InZh
        plates and shallow shells in a gas flow.   v. 2, no. 3
                                                       119-125
        The thermal buckling and flutter of a
        rectangular aircraft skin panel under
        kinetic heating in a supersonic gas
        flow and internal pressure is investi-
        gated, taking account of the flow
        pressure on the distorted skin. The
        behavior of a steel skin under real
        flight conditions is briefly discussed.

742. Durgariyan, S. M. Thermal stress
       analysis of thin orthotropic shells
       of revolution.

       The axisymmetrical problem of thermo-
       elastic stress-strain relations in
       thin orthotropic shells of revolution
       with a positive Gaussian curvature and
       low thickness-to-radius ratio is treated
       in a linear formulation, with time-
       variable coefficients of elasticity
       and thermal expansion.

743. Yelpat'yevskiy, A. N. Investigating
       the state of stress in two-layer
       cylindrical shell.

       A plain cylindrical shell streng-
       thened by an outer layer of fiber-
       reinforced plastic is discussed. The
       whole shell is under internal pres-
       sure and an axisymmetrical tempera-
       ture field. The stress distributions
       in both layers are determined and
       relationships ensuring minimum weight
       of the shell are established.

744. Abramyan, B. L., and A. A. Babloyan. Stress
       and strain in a hollow cylinder.

       An exact general solution is presented of
       the axisymmetrical problem in the elas-
       ticity theory for a hollow circular cylin-
       der of finite length under arbitrary ex-
       ternal load, with given normal displacements
       and tangential stresses on its faces. The
       derivation of general-form equations for
       stresses and strains in terms of the Fou-
       rier and Fourier-Dini series is presented.

745.   Arutyunyan, N. Kh.   Torsion of thin tubular
        shells.

        The torsion of long, thin, cylindrical
        shells of arbitrary-contour closed cross
        section is investigated. The small-param-
        eter method used here allows appraisal of
        the validity of approximate formulas (e. g.
        Bredt's); it gives solutions in cases where
        Bredt's formulas cannot be used, and ac-
        counts for stress concentration in fillets
        of polygonal cylindrical shells.

746.   Sarkisyan, V. S.   The deflection of long e-
        lastic plates at constant supersonic ve-
        locity.

        The small parameter is used in the approx-
        imate solution of the deflection problem of
        a thin, narrow plate of an arbitrary sym-
        metric form, fixed at the edges and moving
        in a gas with constant supersonic velocity,
        at a fixed angle of attack. The problem
        of determining the deflection function is
        reduced to the solution of a fourth-order
        partial differential equation with certain
        boundary conditions.

747.   Bagdasaryan, Zh. Ye.   The stability of a cyl-
        indrical shell in a supersonic gas flow.

        The elastic stability of a thin circular
        shallow shell is analyzed. The material
        of the shell is orthotropic and obeys the
        generalized Hooke's law. There is an un-
        disturbed supersonic compressible-gas flow
        along the shell. The hypothesis of the
        preservation of the normals is accepted.
        Cases of symmetrical and nonsymmetrical
        buckling are discussed, and formulas for
        the minimum critical velocities are given.

748.   Kordashenko, A. B. The stability of stiff-   IzAN MeMa
ened shells (USSR).   no. 1
                                                    115-120

In a study of the stability of double-
curvature shells with arbitrarily
located stiffeners, the state of stress
of the shell itself is examined by the
use of the principle of virtual dis-
placements; a variational equation is
obtained which furnishes the differential
equations of elastic stability of a shell
with an arbitrary initial (precritical)
state of stress.

749.   Mushtari, Kh. M. Making the approximate   IzAN MeMa
theory of sandwich plates more exact.   no. 1
                                                   125-130

The state of equilibrium of a sandwich
plate with elastically orthotropic face
layers and a light core is discussed,
with core compressibility taken into ac-
count. An approximate formula of the
critical forces of both face layers is
derived. An exact formula for these
forces is also presented and its deriva-
tion is outlined. The values of critical
forces obtained by approximate and exact
formulas are compared with values given
by other authors.

750.   Sokolov, P. A. A spherical axisymmetrically   IzAN MeMa
loaded shell.   no. 2
                                                       150-157

Two cases of a spherical shell under a
symmetrical load are analyzed: 1) a shell
with a small circular hole at the top;
and 2) a closed shallow shell (without a
hole). It is assumed in case (1) that
there is no interaction of the edge of
the hole with the edge of the shell or
with any other cross section. A sugges-
tion is made on how to apply this method
for large central angle of the hole (large
holes). In case (2) there are no special
conditions on the top.

751. **Bolotin, V. V. Unsteady flutter of plates**
      and shallow shells in a gas flow.

      The unsteady flutter of plates and
      shallow shells in supersonic gas flows
      is discussed. Solutions are sought
      for transient regimes with simultaneously
      variable parameters of velocity, density,
      and temperature. Approximate equations
      for the flutter amplitude and phase are
      derived.

      IzAN MeMa

      no. 3
      106-113

752. **Bolotin, V. V. The effect of membrane**
      stresses in thin shells on their natural
      vibrations.

      An asymptotic method is used in investi-
      gating the spectra of natural vibrations
      of thin elastic shells, with the initial
      membrane stresses in the middle surface
      taken into account. The known initial
      equations for deflections comparable with
      the shell thickness are used.

      IzAN MeMa

      no. 4
      52-60

753. **Mushtari, Kh. M. The theory of shallow sand-**
      wich shells with layers of variable thick-
      ness.

      Generalized expressions for stress-strain
      relationships in nonsymmetrical sandwich
      shells with nonuniform temperature fields
      are extended to shells with variable-
      thickness face layers and minimal volume
      (weight).

      IzAN MeMa

      no. 4
      71-76

754. **Balabukh, L. I., and L. A. Shapovalov.**
      Contact problems of stiffening membrane-
      stressed shells of revolution by rings.

      The flexure and stability of circular
      rings used for stiffening membrane-
      stressed shells of revolution are examined

      IzAN MeMa

      no. 4
      77-90

from the standpoint of contact problems.
A general discussion is presented of an
elastic system consisting of two arbi-
trary membrane-stressed shells of revolution
joined together by an inextensible circu-
lar ring which is continuously loaded
by the action of the shells.

755. Vasitsyna, T. N. The stability of an axially
      compressed cylindrical sandwich-type panel.

IzAN MeMa
no. 4
137-139

Stability equations previously derived
for nonsymmetrical shallow sandwich-type
shells with orthotropic face layers and
orthotropic rigid cores are used to inves-
tigate the stability of a shallow cylin-
drical panel with a light-weight isotropic
core layer and isotropic face layers of
different thicknesses.

756. Landa, P. S., and S. P. Strelkov.
      Flutter of a wing under nonlinear
      aerodynamic forces.

IzAN MeMa
no. 5
111-117

Results of investigating the effect (on
an electronic analog computer) of
flexural-torsional flutter of a
cantilever wing with a nonlinear
dependence of aerodynamic forces at
hypersonic speeds on the angle of
attack are presented. The depen-
dence of the flutter speed on wing
parameters and initial disturbances
is obtained, and the effects of
the value of the ratio of flexural
to torsional frequencies and of
the presence of the fuselage are
discussed.

757. Razzhivin, K. A. Stress distribution in an open
      circular cylindrical shell clamped on
      straight edges.

IzAN MeMa
no. 5
147-150

An approximate method is presented for

determining the state of stress in a shallow, circular shell under arbitrary loading, with clamped straight edges with exactly satisfied arbitrary boundary conditions on the circular edges. A sample strain analysis is given for a long, shallow, circular cylindrical shell clamped on all [four] edges under the following loadings normal to its surface: uniform continuous, hydrostatic, and that caused by wind.

758. Durgar'yan, S. M. On thermal stress analysis of an orthotropic plate with consideration of transverse shear.

IzAN.MeMa
no. 6
154-160

The effect of transverse shear on thermal stresses in a rectangular orthotropic plate is analyzed under the assumptions that elasticity constants and the thermal expansion coefficient of the material are temperature-dependent, and that the strains over the plate thickness are determined by free thermal expansion. The shear-stress-distribution functions are given.

759. Aleksandrov, A. Ya. An analogy between stress functions in elasticity theory.

IzAN SibO
no. 2
15-24

An analogy between stress functions of the axisymmetrical and plane problems of elasticity theory is established. Some new solutions of the axisymmetrical problem of an infinite, hollow, heavy cone are found for solid or hollow semi-infinite wedges. The problem is worked out in polar (plane and spherical) coordinates. It is shown that the proposed method also makes possible an analogous solution in other coordinates.

760. **Malkina, R. L. Plates and shells under vibrational loading.**

IzVUZ
no. 1
57-65

Under discussion is the behavior of circular and rectangular thin plates and of cylindrical and shallow spherical shells under the action of forces changing according to a harmonic law. The proposed method of analysis is based on the fact that all normal forced vibrations of the system are of the same frequency and phase.

761. **Yershov, V. V. The stability of asymmetrical sandwich plates.**

IzVUZ, AvT
no. 1
120-124

A rectangular sandwich plate, supported along two opposite edges and compressed by forces applied at these edges, is discussed. The determination of the critical forces is based on equations and relationships established by Kh. M. Mushtari, without taking account of the flexural rigidity of the outer layers and the compressibility of the core.

762. **Kabanov, V. V. The stability of a circular cylindrical shell in a nonuniform temperature field.**

IzVUZ, AvT
no. 2
65-71

The local stability of a long circular cylindrical shell subjected to longitudinal forces variable along the circumference (due to heating) is studied. A sample analysis of the thermal stability of a shell partially filled with liquid at 0°C and surrounded by a medium of arbitrary temperature is given.

763. **Sverdlov, A. I. (Moscow Aviation Institute). The design of a stiffened cylindrical shell under concentrated loads.**

IzVUZ, AvT
no. 2
72-85

The state of stress in a circular cylindrical shell stiffened by stringers and by frames under concentrated loads applied

to longitudinal beams on the outer surface,
is examined. Stresses in the beam and shell
are analysed by applying Castigliano's
principle to the beam-shell system.

764. **Sivchikov, B. Ye.** Static-flexure and free-
vibration equilibrium equations of irregu-
larly-shaped cantilever plates.

The application of the variational Lagrange
equation in the analysis of flexure and
vibration of a uniform-thickness cantilever
plate by substituting the deflection in
polynomial form (thus obtaining a system
of ordinary linear equations) is general-
ized to the case of a variable-thickness
irregularly shaped quadrangular plate with
straight edges located arbitrarily relative
to each other.

765. **Akhmed'yanov, I. S.** A method for integrating
flexure equations of a spherical shell

A new method for the exact integration of
equations which describe the flexure of
spherical shells under symmetrical loading
and arbitrary boundary conditions is dis-
cussed. The simplified solution of basic
equations gives the expressions for forces
and moments per unit length, as well as for
strains and displacements, in series form.

766. **Yefimov, I. A.** Plastic stability of a cor-
rugated-core cylindrical sandwich shell
under combined loading.

The stability in the small of a simply sup-
ported circular cylindrical sandwich shell
under external pressure combined with axial
compression is investigated. The core layer
is made of corrugated sheet material. Its
strains are assumed to be in the elastic
range at the instant of the loss of stability,
while the conventional face layers are

strained beyond this range. The corrugated core is treated as an orthotropic solid having equivalent elastic characteristics, and the flexural rigidity of the isotropic face layers is taken into account.

Sivchikov, B. Ye. Variational method for analyzing static flexure and free vibrations of a cantilever plate.

IzVUZ, AvT
no. 3
102-110

The static flexure and free vibrations of a rectangular, elastic, continuously loaded, rigid plate of variable thickness (in both longitudinal and lateral directions) with its clamped edge nonparallel to the free-end (lateral) edge are analyzed, and the effect of root beveling on the flexural and vibrational behavior of this swept-wing-form plate is examined.

Burmistrov, Ye. F. An analysis of structurally orthotropic shells of revolution.

IzVUZ, AvT
no. 4
57-67

By starting with equilibrium equations for shells of revolution and using the relationships between elastic forces and the strains of the middle surface of structurally orthotropic shells of revolution, as well as between strains and displacements, a general solution of shell-behavior problems is obtained. A multilayer shell with an odd number of orthotropic layers symmetrical about the middle surface and a two-layer shell with isotropic layers of different elastic properties are treated as special cases of the general solution.

9. Il'gamov, M. I. Equilibrium and vibration equations of asymmetrical sandwich shells.

IzVUZ, AvT
no. 4
68-78

Thin asymmetrical sandwich plates with orthotropic outer layers and an orthotropic core are discussed, taking into account the linear deformability of the core over its thickness. Free vibration and stability of a sandwich are analyzed

by using the equations derived. A numerical example of calculating the critical loading of an infinite thin sandwich plate in symmetrical and skew-symmetrical buckling is given.

770. **Sachenkov, A. V. Determining the lower buckling loads of thin shells.**

An approximate method is proposed for determining the lower critical load in local buckling of thin shells. The anisotropy of the material and effect of initial imperfections of the middle surface are taken into account.

771. **Gerasimov, I. S. (Institute of Mechanics, Academy of Sciences, UkrSSR). The effect of a moving load on a conical shell.**

It is assumed that an elastic infinite circular conical shell with a wall thickness proportional to the distance from the vertex is under a constant axially symmetric pressure which is moving with constant velocity from the cone vertex in the direction of its axis. An infinitesimal element of the conical shell is analyzed in a movable coordinate system. Displacements, stresses, and bending moments are determined.

772. **Twardosz, F. (Gdansk Polytechnical Institute). The dynamic stability of a conical shell under longitudinal and transverse continuous pulsating loads.**

Equations of the dynamic stability simply supported thin conical shells are derived from equations of their static stability. Equations for critical frequencies are also derived, and resonance ranges are determined.

773. Kan, S. N. Flexure of circular cylindrical shells.

PMe
v. 8, no. 1
3-11

The flexure of solid and sandwich-type circular cylindrical shells stiffened by diaphragms rigid in their own planes is discussed under arbitrary support conditions, and external loading varying in axial and lateral directions.

774. Kovalov, K. V. The effect of a stiffening ring in a cantilever circular cylindrical shell.

PMe
v. 8, no. 1
12-19

Cylindrical shells with a length 1 to 5 times greater than their diameter, fixed on one end and provided with a stiffening ring (frame) at the free end, are discussed. Lines of influence, obtained experimentally with the use of celluloid models, are used to determine the normal and shearing forces, and bending moments acting on the frame. The method can be applied to stress analysis of any anisotropic shell, and to cases where the analytical solution is either impossible or involves considerable difficulties.

775. Kan, S. N. The stability and natural vibrations of cylindrical sandwich shells.

PMe
v. 8, no. 2
120-132

The dynamic behavior of a circular cylindrical sandwich shell under uniform radial pressure and axial pressure uniformly distributed along its circumference is discussed.

776. Petrov, V. V. (Saratov Polytechnical Institute). State-of-stress analysis of plates and shallow shells under finite deformations by the stepwise-loading method.

PMe
v. 8, no. 4
352-357

An approximate method of solving nonlinear

differential equations which describe the state of stress of plates and shells is proposed. The whole load acting on the structure is divided into parts which are applied stepwise until the structure is fully loaded. The steps are so selected that the deformations are small compared with the thickness of the structure, and a linear load-deflection relationship can be assumed.

777.   Yershov, N. F. The equilibrium of flexible elastic-plastic shells and plates.

PMe
v. 8, no. 5
489-499

Expressions showing the effect of the local plastic deformations (buckling) of plates and shells under loading beyond their critical state are derived in terms of strain and stress functions. It is assumed that these bucklings (treated as initial imperfections) are small if compared with the thickness of the plate (shell). The post-buckling behavior of rigid plates (where Euler stresses are near the yield point of the material) is also indicated.

778.   Tsurpal, I. A. Experimental determination of constants of the nonlinear elasticity theory.

PMe
v. 8, no. 5
555-563

The constants of H. Kauderer's law of non-linear elasticity — the bulk modulus, the shear modulus, and functions defining the physical nonlinearity of the material — were determined experimentally, plotted on stress-strain planes, and approximated by fitting polynomial curves. The procedure for determining the constants from diagrams is outlined.

779.   Karpov, M. I. Strength problems of stiffened shells.

PMe
v. 8, no. 6
619-626

The strength of a circular cylindrical

- 240 -

shell stiffened by equally spaced stringers
of identical geometric and elastic charac-
teristics is discussed. The faces of the
shell butt against diaphragms rigid in their
planes but easily deformable in the trans-
verse direction. The shell is under arbit-
rary external loading, and its strength
is treated as a contact problem.

780. Ryzhov, O. S. The energy of sound waves.

PMM
v. 26, no. 2
317-319

Analytical expressions for sound-wave
energy are derived.

781. Ryzhov, O. S., and G. M. Shefter. Energy
of sound waves propagating in moving
media.

PMM
v. 26, no. 5
854-866

An equation is derived describing sound-
wave propagation in arbitrary nonuniform
moving media, and an investigation is
made under the assumption that the width
of the perturbed gas is small as compared
with the radius of shock-wave curvature,
and with the distance over which the
initial parameters of the medium change
substantially.

782. Nigul, U. K. Asymptotic theory of statics
and dynamics of circular cylindrical
shells.

PMM
v. 26, no. 5
923-930

A linear theory of the statics and dynamics
of elastic, circular cylindrical shells is
developed on the basis of an asymptotic
approximation of the three-dimensional
elasticity theory. From this asymptotic
theory it is possible to determine, with
a small asymptotic error, the slowly
changing state of stress in the shell.

783. **Librescu, L.** The dynamic problem of shallow viscoelastic thin shells.

The vibrational behavior of thin shallow shells of constant thickness made of viscoelastic, isotropic, homogeneous, physically linear material of the Maxwell type is discussed under the assumption that the Kirchhoff-Love hypothesis is valid.

784. **Dol'berg, M. D.,** and V. I. Malykhin. A general design method for shells of revolution under symmetrical loading.

An approximate method of structural mechanics for investigating the states of stress and strain of symmetrically loaded thin-walled shells of revolution with an arbitrarily shaped meridional section is proposed. The method is similar to Ritz's; however, it ensures the convergence of successive approximations to the exact solution, and thus facilitates determination of the value of the error.

785. **Kan, S. N.** The stability and static and dynamic strength of circular cylindrical sandwich shells.

Problems in designing circular cylindrical sandwich shells -- for flexure, stability, and vibration -- are discussed under the assumption that there is a distortion in the cross-sectional contour of the shell. The conventional hypothesis of infinite rigidity of the core layer in the radial direction and zero rigidity in other directions is accepted. The flexure of a thin sandwich shell stiffened by circular frames rigid in their planes is investigated under arbitrary loading and support conditions. The stability and vibrational behavior of simply supported and clamped shells are examined.

786. Kan, S. N.   The strength, stability, and
     load-carrying capacity of construction-
     ally orthotropic cylindrical shells.

     The problems of flexure, and elastic
     and plastic stability under radial
     pressure and uniform axial compression,
     and load-carrying capacity of construc-
     tionally orthotropic cylindrical shells
     are investigated. Cylindrical shells
     stiffened by stringers and circular frames
     and shells made from corrugated sheets
     are discussed, with the effect of the
     stiffening (or of corrugation) taken into
     account by introducing equivalent thicknesses
     and flexural rigidities in both axial and
     circumferential directions.

787.   Moiseyev, N.N Variation problems in the
       theory of oscillation of liquid and
       liquid-filled bodies.

       The use of variational methods in
       solving the problems of oscillation of
       bodies filled with liquid is discussed
       and substantiated. The stability of
       the body-liquid system is investigated.
       The convenience of the methods for use
       on electronic computers is emphasized.

788.   Bublik, B. N., and V. I. Merkulov. Dynamic
       stability of liquid-filled rib-stiffened
       thin elastic shells.

       The dynamic stability of thin, stiffened,
       elastic shells filled completely or
       partially with an ideal incompressible
       liquid is analyzed by using variational
       methods. The stiffeners are flexurally
       rigid in a plane normal to the middle
       surface and are rigid in tension (comp-
       ression); their joint deformation with
       the shell is secured. The shell-liquid
       system described is acted on by arbitrary
       time-dependent loads applied to the
       shell surface.

789. **Kuznetsov, A. P., and L. M. Kurshin. The stability of circular cylindrical shells under creep conditions.**

The creep stability of hollow cylinders is investigated on the basis of analysis of accelerations of disturbed motions. In this respect, a shell is stable (unstable) when a disturbance in the form of an initial buckling causes a decrease (increase) in the rate of its development. It is assumed that stresses in the shell before buckling are distributed uniformly along its thickness and are not time dependent.

790. **Kuzmak, G. Ye., V. K. Isayev, and B. Kh. Davidson. Optimal regimes for motion of a variable mass point in a homogeneous central field.**

The optimal regimes for controlling the reactive thrust and its angle of inclination in a plane motion of a variable-mass point in a homogeneous central gravitational field are established by using Pontryagin's maximum principle.

791. **Kil'chyns'ka, G. A. The thermoparametric resonance of a circular cylindrical shell in an unsteady temperature field.**

The influence of a nonstationary, periodically changing temperature field on the stability of a simply supported circular cylindrical shell without external loading and initial stresses in the middle surface is analyzed under the assumptions that the temperature over the shell thickness and the dependence of the elasticity modulus and of the thermal expansion coefficient on the temperature are all linear.

792. **B. M. Bublyk. Vibration and stability of a stiffened cylindrical shell in a compressible flow.**

The vibrational and buckling behavior of
a simply supported, closed, elastic,
cylindrical shell with a discrete arrange-
ment of stiffening frames is investigated.
The shell is in a potential flow of in-
viscid fluid along its longitudinal axis.

793. Valilenko, M. V., and Yu. O. Klikh (Institute
 of Cermets and Special Alloys, Academy of
 Sciences UkrSSR). Mechanical vibration in
 a variable-temperature field.

The applicability of asymptotic methods,
developed by Yu. N. Mitropol'skiy for
investigation of transient processes with
a small variation of parameters per cycle
in nonlinear vibratory systems, is illus-
trated by a sample analysis of forced vi-
brations of a system with a single degree
of freedom (a cantilever bar with a large
mass at the free end) in a time-variable
temperature field.

794. Goncharenko, V. M. (Kiev Polytechnical
 School). Determining the average
 time of snapping of a cylindrical panel
 under a random pressure.

The time-related buckling behavior of a
shallow oblong cylindrical panel under
uniform normal pressure combined with
stationary random perturbances which speed
up its buckling, is discussed. The load-
carrying capacity of the panel can be
estimated from the duration of the time
interval up to buckling.

795. Manevych, A. I. Optimum design of a
 stiffened cylindrical shell under
 uniform external pressure.

A medium-length or a long cylindrical

shell of given wall thickness divided
axially into sections by frames of
different rigidity and subjected to
uniform external pressure is discussed,
assuming the same buckling stability in
all sections. The rigidity parameters for
shells with one, two, and three frames
are determined. The attaining the equi-
stability by changing either the spacing
or the rigidity of frames is mentioned.

796.   Karpov, N. I. (Institute of Mechanics, UkrSSR).   DopAN UkrSSR
          On free vibration of a stiffened cylindrical   no. 8
          shell.   1018-1021

          A method of solving the almost unsolvable
          problem of free vibrations of a shell with
          a discrete spacing of stiffeners is pre-
          sented. The method based on exact compli-
          ance with vibration equations of a stif-
          fened shell yields an expression for fre-
          quencies in the form of a transcendental
          equation which is convenient for the qual-
          itative investigation of the frequency spec-
          trum and for numerical computations as well.
          The problem is treated as a contact problem
          in the theory of shells.

797.   Antipov, O. O. (Nikolayev Shipbuilding   DopAN UkrSSR
          Institute). Flexure of sandwich plates   no. 11
          under nonuniform heating.   1441-1447

          The flexure of asymmetrical sandwich plates
          with a rigid isotropic core and faces of dif-
          ferent thickness made of different materials
          is analyzed. Flexure parameters of such a
          plate compressed in its plane under lateral
          loading combined with nonuniform heating
          (by a linear source) are determined.

798.   Aleksandrov, G. V., and V. K. Svyatodukh.   InZh
          Controllable motions of winged aircraft   v. 3, no. 1
          in the plane of symmetry.   3-11

          Controllable motions of aircraft of various

design configurations (conventional, canard,
and pivoting wing) with respect to the rel-
ative position of the control force and the
center of gravity are studied. An attempt
is made to determine the specific nature of
the aerodynamic characteristics inherent
in the various layouts by taking the control
force Y_δ into account.

799. Karnozhitskiy, V. P.   Stability of a simply   InZh
     supported sandwich plate under pure   v. 3, no. 1
     flexure.   183-186

     The buckling behavior of simply supported
     symmetrical sandwich plates subjected to
     bending in two orthogonal directions is
     examined under the assumption that the
     hypothesis of straight normals is valid
     for the outer layers and that the core-
     layer material obeys the general relation-
     ships of the elasticity theory.

800. Livanov, K. K. (Institute of Mechanics,   InZh
     Academy of Sciences USSR).   Axisymmetrical   v. 3, no. 2
     vibration of cylindrical shells in a su-   322-330
     personic gas flow.

     A method of investigating axially symmet-
     rical vibrations of a cylindrical shell
     in a supersonic gas flow along its longi-
     tudinal axis is given. The method produces
     an exact solution when inertial forces due
     to all displacement components are taken
     into account. The vibrational behavidr of
     the shell in quiet gas (or in vacuum) is
     also discussed.

801. Kukudzhanov, V. N. (Moscow).   Propagation of   InZh
     spherical waves in a viscoelastic medium.   v. 3, no. 3
                                                           472-481
     The propagation of spherical waves is in-
     vestigated in an infinite linear visco-
     elastic solid having a spherical cavity on

whose boundary a time-dependent, uniform
impulse pressure (or velocity) is applied.

802. Tryanin, I. I. (Gor'kiy). The effect of   InZh
      transverse loading on the stability and   v. 3, no. 3
      skin-participation factors of a contin-   504-512
      uous multipanel plate under compression.

      The buckling stability of an infinite
      elastic plate with an orthogonal system
      of equidistant stiffeners simply sup-
      porting the skin is investigated. The
      plate is under uniform continuous trans-
      verse load and is compressed along the
      stiffeners in one direction, either ten-
      sion or compression is applied to the
      plate along the stiffeners in the other
      direction.

803. Sokolovskiy, V. V. (Institute of Mechanics,   InZh
      Academy of Sciences USSR). Plastic flexure   v. 3, no. 3
      of a circular plate.   563-568

      The flexure of a circular plate, simply
      supported on the edge, beyond the elastic
      range is discussed. The plastic-bending
      behavior of the plate under normal pressure
      is examined over the whole area of the plate
      and over the area of a smaller concentric
      circle.

804. Kozarov, M. (Sofia). The stability of   InZh
      orthotropic shells under temperature effects.   v. 3
                                                         no. 3
      A system of differential equations for   579-584
      solving problems associated with the thermo-
      elastic stability of orthotropic circular
      cylindrical shells is derived, starting with
      Love's basic equilibrium equations for isotropic
      shells and assuming a membrane-stress state
      of the shell prior to buckling. .Thermal

buckling of a shell in a temperature field is investigated. This buckling is caused by a considerable difference in temperatures of the skin and of inner shell elements.

805. Daravskiy, V. M, (Moscow). Stability equations of cylindrical shells.

InZh
v. 3, no. 4
658-664

General differential equations describing the buckling behavior of medium-length cylindrical shells under torsion combined with axial compression are derived.

806. Kalinin, V. N. Equations of motion of an artificial earth satellite.

IskSpZe
no. 16
238-245

A complete system of exact differential equations is derived which describe the controlled motion of a satellite with a single constraint: that the gravitational field must be central. The equations derived will facilitate the study of such maneuvers as automatic approach on the orbit, or maneuvering in close vicinity of the orbit. A coordinate system moving along a central elliptic orbit and a fixed one (in the center of Earth) are used. Systems of approximate (linear) equations are also deduced.

807. Shamiyev, F. G. The design of minimum-weight shells.

IzAN AzerSSR
FMTN
no. 5
37-41

The yield conditions for the maximum reduced stress is used to obtain the lower limit in the minimum-weight problem of a cylindrical shell under uniform internal pressure.

808.   Bardasaryan, Zh. Ye. On the stability of   IzAN MeMa
        orthotropic shallow shells in   supersonic   no. 1
        gas flows.   92-98

        The flutter behavior of a thin, orthotropic,
        rectangular, simply-supported, shallow, constant-
        thickness shells of constant double curvature
        is discussed in linear formulation. There is
        a supersonic gas flow on one side of the shell.
        The effect of transverse displacements on the
        flutter parameters is analyzed. A qualitative
        analysis in the case of a weak aerodynamic non-
        linearity is given.

809.   Kabanov, V. V. Stability of a circular   IzAN MeMa
        cylindrical shell under nonuniform   no. 1
        compression.   181-183

        The linear problem of the local
        stability of a circular, closed,
        cylindrical shell under circum-
        ferential axial compression forces
        distributed along the face edges
        according to the cosine law is
        discussed. The shell is abutted
        on its faces against rigid dia-
        phragms.

810.   Grigolyuk, E. I., and D. D. Chulkov. Theory   IzAN MeMa
        of sandwich shells with a rigid core.   no. 2
                                                             75-80

        The vibrations of an arbitrarily shaped
        sandwich shell with face layers and core
        of different constant thicknesses and ma.
        of different orthotropic materials is dis-
        cussed. The Kirchhoff-Love hypothesis is
        valid for the faces; the core is rigid;
        compressibility in transverse direction is
        approximated by linear functions.

811.   Landa, P. S., and Yu. V. Ponomarev. A simu-   IzAN MeMa
        lation method for boundary value problems.   no. 2
                                                             75-80

        A method is presented for the solution of

natural vibration problems in linear in-
homogeneous systems with distributed pa-
rameters by using electronic models with
d-c amplifiers. The method can be applied
to the eigenvalue problems with boundary
conditions of a general type and also to
the solution of the problem of self-induced
vibrations (for example, wing flutter prob-
lems).

812. Lamper, R. Ye., and L. G. Shandarov (Novosi-   IzAN MeMe
       birsk). Theoretical and experimental inves-   no. 3
       tigation of self-induced vibrations of cyl-   58-64
       indrical shells in a gas flow.

       The dynamic stability of finite-length
       cylindrical shells and curved panels in
       a supersonic gas flow parallel to their
       generatrices is discussed, taking into
       account the aerodynamic excess pressure
       generated by flow disturbances caused by
       the normal displacements of the shell
       surface. Special attention is paid to
       peculiarities in designing short cylin-
       drical shells and panels.

813. Bolotin, V. V. (Moscow). On the theory of   IzAN MeMe
       laminated plates.   no. 3
                                                          65-72
       The equations of flexure, with boundary
       conditions, of elastic plates built up of
       a "rigid" and n-1 "soft" alternate laminas,
       both of constant thickness, are derived.
       The behavior of this "multilayer sandwich"
       under normal continuous load is discussed.

814. Pal'mov, V. A. (Leningrad). Dependence of   IzAN MeMe
       stress concentration on the surface quality   no. 5
       of machined parts.   60-66

       The stress distribution over the surface
       of machined parts is discussed and the
       stress-concentration factor is determined.

The surface roughness is regarded as a model
of a stochastic field with certain sta-
tistical stress characteristics which are
determined by the methods of the random-
function theory. Asymptotic methods are
used in cases of minute surface-roughness
heights.

815. Aksel'rad, E. L. (Leningrad). Designing a   IzAN MeMa
       corrugated diaphragm as a nonshallow shell.   no. 5
                                                 67-76

Equations for large axisymmetrical dis-
placements in elastic shells of revolution
previously derived by the author are trans-
formed to a form suitable for determining
large deflections of rotationally symmet-
rical corrugated diaphragms of an arbi-
trary cross-section profile with various
types of rim clamping. The effect of
geometrical corrugation parameters (ampli-
tude, wavelength, thickness, diameter of
the flat central part) on the pressure-
deflection characteristics is discussed.

816. Mushtari, Kh, M. The range of applicability   IzAN MeMa
       of approximate theory of asymmetrical sand-   no. 5
       wich plates.   176-178

An approximate theory of asymmetrical sand-
wich plates based on the hypothesis that
the transverse shear in the core layer is
constant over its thickness is shown to be
applicable to a large number of flexural
problems concerning sandwich plates. The
validity of the theory is demonstrated in
the case of the cylindrical flexure of a
simply supported plate under a lateral load
acting on the upper face layer.

817. Darevskiy, V. M. (Moscow). Determining the   IzAN MeMa
       critical pressure for a cylindrical shell   no. 3
       stiffened by arbitrarily spaced rings of   73-82
       different rigidity.

The author's method for stability analysis
of a cylindrical shell stiffened by equally-
rigid equidistant rings and subjected to
external normal pressure is generalized to
the case of a cylindrical shell with sim-
ply supported faces and stiffened by ar-
bitrarily spaced rings of different rigid-
ities.

818.   Pal'mov, V. A. (Leningrad). Stress concen-   IzAN MeMa
       tration close to the rough surface of an   no. 3
       elastic solid.   104-108

       The concentration of stresses caused by the
       surface roughness of machined parts is dis-
       cussed. A sample expression for the stress-
       concentration factor is derived.

819.   Kononenko, V. O. (Moscow). On oscillations   IzAN MeMa
       of a body about its centroid.   no. 4
                                                       23-30

       The oscillation of a body joined by elastic
       springs to a stationary frame and subjected
       to the action of external moments is inves-
       tigated. The center of body's mass is im-
       movable and the moments directly excite
       oscillations about only one coordinate axis.
       Cases of indirect excitation of oscillations
       about other coordinate axis are discussed
       in nonlinear formulation. Stability con-
       ditions of a disc, a sphere, and a cylin-
       der are discussed and pertinent equations
       are derived.

820.   Kan, S. N., and D. Ye. Lipovskiy. Combined   IzVUZ, AvT
       compression and flexure of stiffened cir-   no. 1
       cular cylindrical shells.   33-47

       The states of stress and strain of circular
       cylindrical shells stiffened by stringers
       and rings are analyzed. The shells are sub-
       jected to transversal loading combined with
       axial compression uniformly distributed

along the faces. The effect of manufacturing imperfections of the shell's middle surface is taken into account. The problem is discussed in a linear formulation under conventional assumptions of the theory of elastic thin shells.

821. Malkina, R. I., and V. G. Godzevich. Free vibrations of zero-curvature shells.

IzVUZ, AvT no. 1 48-57

Axially symmetrical free vibrations of arbitrary cylindrical and conical shells are discussed under the assumption of multiwave deformation. The differential equations of V. Z. Vlasov for arbitrary shallow shells with a large index of variation are simplified for the case of zero curvature and used to analyze the vibrational behavior of noncircular cylindrical and circular conical shells.

822. Rabinskiy, N. L. Designing cantilever plates by Vlasov's variational method.

IzVUZ, AvT no. 1 58-65

An approximate method of designing cantilever plates of constant cylindrical rigidity is developed. Plates with planforms of the type used chiefly for airplane wings — rectangular, tapered, and triangular — are discussed.

823. Kurshin, L. M. On derivation of variational equations for a shallow cylindrical shell with thermal stresses taken into consideration.

IzVUZ, AvT no. 1 151-156

The principle of virtual displacements with introduction of two potential functions (in forces and in displacements) is used in the derivation of variational stability equations for the force-deflection relationships (including thermal buckling) of a heated thin shallow cylindrical shell under final deflections. The fundamental relationships of

shallow shell theory are used as initial equations.

824. **Kan, S. N., and D. Ye. Lipovskiy.** Load carrying capacity of stiffened, thin, circular cylindrical shells under [axial] compression.

The article concludes the work of the authors which was published in IzVUZ, AT, no. 4, 1962 [79], and no. 1, 1963 [33], by presenting a simple method for predicting the load-carrying capacity of a thin compressed circular cylindrical shell stiffened by a system of frames and stringers and discussing the effect of various constructional parameters on the shell strength.

825. **Kogan, B. I., and A. F. Khrustal'yev.** The temperature field in an infinite shallow cylinder.

The problem of determining the stationary temperature field in an infinite shallow cylinder is studied. The inner surface of the cylinder has a constant temperature; half the outer surface has a different constant temperature, while the other half radiates heat into the surrounding medium according to Newton's law.

626. **Kan, S. N.** Load carrying capacity of circular cylindrical shells under flexure.

The determination of the load carrying capacity of a circular cylindrical shell from the view point of the local strength of its material (not of buckling as a whole) is presented. Problems of a horizontal plain cylindrical shell subjected to pure flexure combined with uniform radial pressure are discussed.

827. Kaplan, Yu. I. Analysis of axisymmetrical
      state of stress in cylindrical shells
      with discretely spaced elastic frames.

IzVUZ, AvT
no. 4
70-78

The effect of discretely spaced transverse
frames on the strength stability, and
free vibration of cylindrical shells is
examined. It is assumed that the end
frames are either rigid or elastic, and
the intermediate ones are elastic in
their plane and perfectly pliable out of
it. The strength of shells under axi-
symmetrical loading and under flexure
combined with compression, is investi-
gated.

828. Ivanyuta, E. I., and R. M. Finkel'shteyn.
      Investigating the axisymmetrical vibration
      of cylindrical shells.

LGU, MMe
IslUpPro, Sb
no. 2
90-104

The possibility of simplifying the initial
equations for axisymmetrical vibrations of
cylindrical shells is studied in order to
obtain the engineering dynamical-shell-
design formulas. A system of homogeneous
algebraic equations is derived from which
the whole frequency spectrum of torsional
and combined longitudinal-flexural vibra-
tions can be determined.

829. Chernykh, K. F., and V. A. Shamina (Shell
      Theory Laboratory, Institute of Mathematics,
      Leningrad State University). Designing
      toroidal shells.

LGU, MMe
IslUpPro, Sb
no. 2
247-346

Work is being carried out to systematize
and further develop design methods for
toroidal shells. In this presentation of
the first part of the planned work, the
basic general methods for designing tor-
oidal shells under conditions of symmetri-
cal loading are discussed. A chronological
critical review of Soviet and non-Soviet
works in the field of toroidal-shell
design showing the development of the art
is presented, and a list of 46 Soviet and
36 non-Soviet references is given.

830.   Karavanov, V. F. (Candidate of Technical   MoAvI
        Sciences). On large deflections of a   Voprosy pro.
        clamped cylindrical light-core-sandwich   no. 1
        panel under uniform normal pressure.   97-109

        Large deflections of a rectangular, cylin-
        drical, shallow, symmetrical light-core-
        sandwich panel, built-in on all edges, are
        determined in the first approximation.
        The panel is under uniform normal pressure
        acting on its convex side; the materials
        of its faces and core are isotropic, homo-
        geneous, and elastic.

831.   Nazarov, M. O. (Leningrad Technological   PMe
        Institute). Free vibrations of circular   v. 9, no. 3
        cylindrical and shallow stiffened shells.   249-258

        The vibrations of shells stiffened by
        stringers and transverse ribs or frames,
        the tangential rigidity and torsion of
        which are neglected, are investigated.
        The Ostrogradskiy-Hamilton variational
        principle is applied, and an equation for
        determining the natural frequency is
        derived.

832.   Karnaukhov, V. G. Analytical solutions of   PMe
        free-vibration and stability problems of   v. 9, no. 3
        conical shells.   259-263

        Simplified Mushtari-Donnell-Vlasov stress-
        strain equations are used to establish exact
        theoretical solutions in the analysis of
        free vibration and constructional stabil-
        ity of cylindrical conical shells under
        combined axial compression and external
        normal pressure.

833.   Karpov, M. I. (Institute of Mechanics,   PMe
        UkrSSR). Stress and strain analysis of   v. 9, no. 3
        a shell with unequally spaced stringers.   270-274

The problem of the stress of a circular cylindrical shell stiffened by arbitrary spaced stringers having different geometric and elastic parameters is treated as a contact problem of the theories of shells and beams.

834. Kan, S. N.(Khar'kov Higher Aeronautical Engineering School). Load carrying capacity of stiffened and corrugated circular cylindrical shells under compression.

PMe
v. 9, no. 5
465-472

An attempt is made to develop a relatively simple method for determining the load carrying capacity of constructionally orthotropic (stiffened or corrugated) circular cylindrical thin-walled shells under axial compression. The L. C. C. is determined not from buckling conditions, but from crushing stresses of the material. Symmetrical and asymmetrical manufacturing irregularities are taken into account.

835. Komisarova, G. L. (Institute of Mechanics, Academy of Sciences UkrSSR). Longitudinally corrugated cylindrical shells of the optimum profile.

PMe
v. 9, no. 5
473-479

The problem of finding that form of corrugations which will ensure a maximum buckling load for a corrugation-cross-section cylindrical shell of a given weight is discussed.

836. Lur'ye, A. I. Free fall of a mass point in the cabin of a satellite.

PMe
v. 27, no. 1
3-9

The path and velocity in a free fall of a mass point in the cabin of a satellite performing a free flight (in the presence of gravity only) and in a flight when nongravitational forces (such as those caused by aerodynamic drag of the satellite) are present, are discussed.

837. Tokarev, V. V. The effect of random devia-   PMMe
tions from the optimum-thrust program on   v. 27, no. 1
the motion of a variable-mass body with a   27-32
constant power expenditure moving in a
gravitational field.

The problem is reduced to determining the
minimum averaged value of the increment
of a characteristic acceleration (due to
the thrust) functional. The random errors
(stipulating this increment) incurred in
realization of the optimum-thrust program
which cause deviations from the calculated
trajectory are discussed as well as the
corrections of the thrust, their number,
and distribution.

838. Chernyshov, G. N. Thin elastic shell of   PMMe
arbitrary shape subjected to concentrated   v. 27, no. 1
forces and moments.   126-134

The characteristic features in stress-strain
relations are studied in the vicinity of
points where concentrated forces or moments
are applied. The results of previous in-
vestigations by other authors are general-
ized.

839. Suvorov, Yu. P. Spreading of thermal stresses   PMMe
in an elastoplastic bar.   v. 37, no. 2
383-389

Propagation of stress waves in a semifinite
elastoplastic bar caused by sudden heating
of its free end was studied. Time-depen-
dent thermal-stress distribution was as-
sumed. A nonlinear heat-conductivity equa-
tion was used. Elastic and plastic regions
in the bar were noted. The shock-wave ac-
tion is described.

840. Gol'denveyzer, A. L. (Moscow). Development   PMMe
of an approximate shell theory by asymp-   v. 27, no. 4
totic integration of the elasticity-theory   593-608
equations.

An asymptotic method of integrating the
differential equations of elasticity theory
is proposed, by means of which an approxi-
mate theory of shells can be established
with the desired degree of accuracy in a
way analogous to that used for developing
an approximate theory of flexure of plates
in the author's article published in PMM,
v. 26, no. 4, 1962.

841. Karavanov, V. F. (Candidate of technical   RaPro, Sb
     sciences). Stability and large deflec-   no. 9
     tions of oblong shallow cylindrical   280-301
     light-core-sandwich panels under uniform
     continuous transverse load.

     An exact solution to the equilibrium problem
     of an oblong, shallow, cylindrical, sandwich
     panel under normal uniform pressure over
     its convex surface is presented, based on
     the theory of shallow sandwich shells with
     a light-weight core layer. The flexural
     rigidity of the face layers is not con-
     sidered.

842. Vol'mir, A. S. Problems in elastic-system   UstoychivUpSis
     stability.   Monogr.
                                                       1-879
     In his recent book, *Stability of Elastic
     Systems*, A. S. Vol'mir summarizes modern
     methods of investigating the elastic and
     plastic buckling of columns, plates, and
     shells (mainly thin-walled) and presents
     an extensive Soviet and non-Soviet bib-
     liography (468 items). In the concluding
     article, "Some Problems for Further Inves-
     tigations" (pp. 837-840), he enumerates
     the "urgent problems in the theory of
     stability of elastic-systems."

843. Volkov, A. N. Conference on the theory of   VeAN SSSR
     shells and plates.   no. 1
                                                       123
     The Fourth All-Union Conference on the

Theory of Shells and Plates, called by the Presidium of the Academy of Sciences, Armenian SSR, was held in Yerevan', 24 to 31 October 1962, and was attended by 437 representatives of academic, departmental, and industrial scientific research institutes, and planning and design bureaus. The work of the conference was carried out by five commissions devoted to the following topics: 1) general problems of the theory of shells and plates; 2) stability and nonlinear problems; 3) dynamics; 4) thermoelasticity, creep, and plasticity; and 5) structural mechanics. A total of 181 papers were presented in the sessions.

844. Ivanov, G. V. (Novosibirsk). On plastic stability of a cylindrical shell under axial compression.

ZhPMeTF
no. 3
111-116

The axisymmetrical buckling of a cylindrical shell subjected to axial compression is examined under the assumptions that the material of the shell is incompressible and the strain-hardening process is linear.

845. Chernous'ko, F. L. (Computing Center, Academy of Sciences, USSR). Motion of a solid with a cavity containing a perfect liquid and air bubble.

1964
PMM
v. 28, no. 4
735-745

The motions of a solid, of a perfect incompressible liquid filling out a cavity in the solid, and of the center of a spherical, nondeformable, movable air bubble formed in the liquid are studied. The motion of the solid-liquid-bubble system is described by energy equations using its momentum and kinetic energy. Particular cases of translatory and rotary motions are analyzed as well as the effect of forces and moments suddenly applied to this system on its motion.

846. **Rumyantsev, V. V. Motion stability of a solid filled with liquid possessing surface tension.**

PMMe
v. 28, no.
746-753

The motion of a solid having a cavity filled with two non-mixing perfect incompressible liquids possessing surface tension is investigated. Given potential forces are acting on the solid, and mass forces on the liquids. The Hamilton-Ostrogradskiy principle of least action is used in deriving the equations of the motion of the system with the boundary conditions. The application of the results obtained to the viscous liquids filling the cavity is indicated.

847. **Petrov, A. A.** (Computing Center, Academy of Sciences, USSR). Variational formulation of the motion of liquid in a finite-dimension vessel.

PMMe
v. 28, no.
754-758

The nonlinear problem of oscillation of an ideal incompressible liquid in a vessel of finite dimensions is discussed in variational formulation. The liquid partially fills the vessel; the rest is filled with gas. The kinetic and potential energies of the system are considered in determining the Lagrange function and the Hamilton action integral from which the solution of the problem is obtained.

- 262 -

GROUP E MISCELLANEOUS

Acoustic and Sonic Boom
Auxiliary Devices

848.   Rybakov, A. I. The rotational motion of a celestial
       body around its center of mass.

       Results are given of the numerical integration of
       differential equations of the rotational motion of
       a homogenous mass segment when the length of the
       segment is sufficiently small.

849.   .Novozhilov, V. V. (Leningrad). Dis-
       placement of a perfectly rigid body
       under action of an acoustic pressure
       wave.

       A pressure wave propagated in an infinite
       fluid strikes a body at rest (immersed in
       the fluid) with a finite impulse, and
       causes its finite displacement. The body
       is perfectly rigid and its density can
       be higher, equal, or lower than that of the
       fluid (displacements due to the buoyancy
       are neglected). The body has two ortho-
       gonal planes of symmetry (as related to
       its shape and mass distribution) which
       are perpendicular to the wave front. The
       possibility of solving this problem
       for a body of arbitrary shape is briefly
       discussed.

850.   Fayzullov, F. S. (Physics Institute, Academy of Sciences
       USSR), N. N. Sobolev, Ye. M. Kudryavtsev. A spectro-
       scopic investigation of the state of gas behind a shock
       wave. III.

       The results of an investigation using the generalized
       spectrum-line reversal method to measure the tempera-
       ture of nitrogen and air behind a shock wave in the
       range of shock-wave velocities from 1.9 to 4.3 km/sec,
       and for gas pressures in the plug from 0.1 to 4 atm are
       presented. The distribution of temperatures along the
       plug is studied for various shock wave velocities.

851. Stanyukovich, K. P. A phenomenon in meteor
       aerodynamics.

       Equations are given which define phenomena of the
       motion of meteors at a speed of 18 to 20 km/sec
       and an altitude of 100 km.

852. Sayasov, Yu. S. The kinetics of ionization behind a
       normal shock wave in air.

       A theoretical study is made of the kinetics of elec-
       tron processes taking place behind a shock wave
       propagating in air.

853. Kuznetsov, N. M. (Institute of Chemical Physics, Acad-
       emy of Sciences USSR, Moscow). Kinetics of chemical
       reactions during air expansion.

       The kinetics of chemical reactions occurring in ex-
       panding air (with subsequent adiabatic cooling) in
       the wake of hypersonic blunted bodies is discussed.

854. Vinogradov, R. I. Similitude and the oscillations of
       bodies in liquid flows.

       Complete similitude in the development of self-
       induced oscillations in an elastic body in an incom-
       pressible liquid is obtained.

855. Dronov, A. P., A. G. Sviridov, and N. N. Sobolev. Con-
       tinuous emission spectra of krypton and xenon behind
       a shock wave.

       The brightness and energy distribution of the con-
       tinuous spectra of krypton and xenon behind a shock
       wave were studied at Mach numbers from 11.5 to 15.

856. Krivtsova, N. V., and Yu. P. Lun'kin (Leningrad Physico-
technical Institute). The excitation of molecule
rotations behind a shock wave.

    ZhTF
    v. 33, no. 1
    67-73

The effects of variations in gas flow parameters on
the excitation of rotational degrees of freedom of the
molecules beyond a shock wave are analysed. It is
shown that the width of the relaxation region is
sharply reduced with increasing Mach numbers of the in-
cident flow. A monatomic impurity has only a slight
effect on the width of the relaxation region.

857. Malkes, L. A., and N. V. Kirsanov.
    Release system for a deceleration
    parachute.

    1963
    BIzobr
    no. 17
    100

A patent was issued for a mechanism for
releasing a braking parachute with
forced opening of the container
compartment door in case of an emergency
(accumulation of dirt or freezing)
by using air cylinders connected with
the compressed-air circuit of the air-
craft.

858. Popov, Ye. I. (Institute of Physics of the Earth,
    Academy of Sciences USSR). Results of experimental
    airborne determinations of gravity acceleration.

    IzAN, IFZe
    no. 5

The purpose of the experiment was to determine the
difference between the gravity acceleration on the
ground and that in the air. In 1960 measurements
were taken from an Il-14 aircraft equipped with three
highly-damped GAL gravimeters suspended in gimbals, a
gyrostabilized aerial camera with a 70-mm focal-length
lens, two statoscopes, a radio altimeter, and two rang-
ing devices (flight line indicators).

859. Grigolyuk, E. I. (Novosibirsk), and V. L.
    Prisekin (Novosibirsk). Dynamic interaction
    between an orthotropic cylindrical shell
    and an acoustic shock wave.

    Iz AN MeMa
    no. 6
    25-35

Displacements in an infinite, constructionally orthotropic, thin, elastic, cylindrical shell due to interaction with a plane acoustic shock wave are discussed. The shell consists of a homogeneous isotropic elastic skin stiffened by an orthogonal system of identical, equidistant, elastic rings and stringers. The front of the incident acoustic shock wave is parallel to the generatrices of the shell.

860. **Ivanov, Yu. N. (Moscow). Motion of a variable mass body with limited power and given active time.**

Several authors have studied optimal working conditions for motion of a variable mass body with limited power of the reactive jet to find the optimal running time of the engines. The author generalizes these results by proposing a general method for solving the variational problem with given active time which is less than optimal. He formulates the variational problem for the case cited in the title and illustrates the general results by analyzing optimal motion in a plane-parallel gravitational field. He investigates two limiting cases for regulating a propulsion system: an ideally regulatable system (variable optimal thrust) and a nonregulatable system (constant thrust).

861. **Krasovskiy, Yu. P.; M. A. Lavrent'yev; N. N. Moiseyev; A. M. Ter-Krikorov; A. B. Shabat (Novosibirsk, Moscow). Mathematical problems of the hydrodynamics of a liquid with free boundaries.**

The article reviews Soviet publications of the last four years dealing with investigations in the theory of motion of a liquid with free boundaries. Data available from the authors' survey reports presented at the IV Vsesoyuznyy matematicheskiy s"yezd (Fourth All-Union Mathematical Congress) in Moscow in 1958 are used in this paper.

Abbreviations of Sources Used in This Report

1. AkZh — Akusticheskiy Zhurnal (Journal of Acoustics)

2. AN GruzSSR, Soob Sb — Soobshcheniya, Sbornik, Voprosy dinamiki i prochnosti (Academy of Sciences Georgian SSR. Communications. Collected Articles. Problems of Dynamics and Strength of Materials)

3. AN LatSSR, Sb IAvtMe, OFTN — Sbornik, Voprosy dinamiki i prochnosti (Academy of Sciences of Latvian SSR, Institute of Automation and Mechanics. Collected Articles. Problems of Dynamics and Strength of Materials)

4. AN UkrSSR IMe — Academy of Sciences Ukranian SSR Institute of Mechanics

5. AN Vych Ts — AN SSSR. Vychislitel'nyy Tsentr, Raschet osesymmetrichykh tel (Academy of Sciences USSR. Computing Center. Calculation of Axisymmetric Bodies)

6. ApM — Aplicace Matematiky (Applied Mathematics, Polish)

7. Arch BMa — Archiwum budowy maszyn (Records of Machine Building)

ᴜ. Arch Me Sto — Archiwum Mechaniki Stosowanej (Records of Applied Mechanics, Polish)

9. ASA SSSR I Str Kn, Tr — Academiya Stroitel'stva i Arkhitektury SSSR, Institut Stroitel'nykh Konstruktsiy, Trudy. (Academy of Construction and Architecture SSSR. Institute of Constructions, Proceedings)

10. As Zh — Astronomicheskiy Zhurnal (Astronomical Journal)

11. AvKos — Aviatsiya i Kosmonautika (Aviation and Astronautics)

12. Avt Te — Avtomatika i Telemekhanika (Automation and Remote Control)

13. AW — Akademie der Wissenschaften, Monatberichte, Berlin (Academy of Sciences, Monthly Report, Berlin. German)

14. **BIzobr** Byulleten' izobreteniy (Bulletin of Inventions)

15. DAN SSSR Doklady Akademii Nauk SSSR (Transactions of the Academy of Sciences USSR)

16. DopAN, **UkrSSR** Dopovidi Akademii Nauk (Transactions of the Academy of Sciences, Ukranian SSR)

17. EnI, ANSSSR, Energetichesk'y Institut. Academiya Nauk SSSR. Fizicheskaya Gazodinamikn: Teploobmen (Power Engineering Institute, Academy of Sciences of USSR, Physical Gasdynamics and Heat Exchange)

18. G Ast I Gosudarstvennyy Astronomicheskiy Institut, Soobshcheniya (State Astronomical Institute, Moscow State University, Communications)

19. IPMMe, ANSSSR Sib. O. Sb. Institut Prikladnoy Matematiki i Mekhaniki Sbornik (Institute of Applied Mathematics and Mechanics, USSR Academy of Sciences, Sibirian Branch, Collected Articles)

20. IKhm. Ma Institut Khimicheskogo Mashinostroyeniya (Institute of Chemical Machine Building)

21. InFI Inzhenerno-fizicheskiy institut. (Engineering Physics Institute)

22. InFZh Inzhenerno-fizicheskiy Zhurnal (Engineering Physics Journal)

23. In Zh Inzhenernyy Zhurnal (Engineering Journal)

24. In Sb Inzhenernyy Sbornik (Engineering Review)

25. IslTp Issledovaniye teploobmena

26. ISZ Iskusstvennyye Sputniki Zemli (Earth Artificial Satellites)

27. IzAN ArmSSR Izvestiya Akademii Nauk Armyanskoy SSR (News, Academy of Sciences Armenian SSR)

28. IzAN ArmSSR FMN Izvestiya Akademii Nauk Armyanskoy SSR, Seriya Fiziko-Matematicheskikh Nauk (News, Academy of Sciences Armenian SSR, Physics and Mathematics Series)

29. IzAN AzerSSR   Izvestiya Akademii Nauk, Azerbaydzhanskoy
    FMN   SSR. Seriya Fiziko-Matematematicheskikh
                   Nauk (News, Academy of Sciences Azerbai-
                   jain SSR, Physics and Mathematics Series)

30. IzAN EnAvt   Izvestiya Akademii Nauk, Energetika i
                   Avtomatika (News, Academy of Sciences
                   USSR, Power Engineering and Automation)

31. IzAN Me   Izvestiya Akademii Nauk, Mekhanika (News,
                   Academy of Sciences USSR, Mechanics)

32. IzAN MeMa   Izvestiya Akademii Nauk, Mekhanika i
                   Mashinostroyeniye (News, Academy of
                   Sciences USSR, Mechanics and Machine Building)

33. IzAN OTN   Izvestiya Akademii Nauk, Otdeleniye
                   Tekhnicheskikh Nauk (News, Academy of
                   Sciences USSR, Department of Technical
                   Sciences)

34. IzAN SibO   Izvestiya Akademii Nauk, Sibirskoye
                   Otdeleniye (News, Academy of Sciences
                   USSR, Sibirian Branch)

35. IzVUZ AvT   Izvestiya Vysshikh Uchebnykh Zavedeniy,
                   Aviatsionnaya Tekhnika (News of the Higher
                   Learning Schools, Aeronautical Engineering)

36. IzVUZ M   Izvestiya Vysshikh Uchebnykh Zavedeniy.
                   Matematika (News of the Higher Learning,
                   Mathematics)

37. IzVUZ Ma   Izvestiya Vysshikh Uchebnykh Zavedeniy,
                   Mashinostroyeniye (News of the Higher
                   Learning Schools. Machine Building)

38. IzVUZ Pb   Izvestiya Vysshikh Uchebnykh Zavedeniy.
                   Priborostroyeniye (News of Higher Learning
                   Schools. Instrument Building)

39. KAvI, Tr   Kazanskiy Aviatsionnyy Institut. Trudy
                   (Kazan' Aviation Institute. Proceedings)

40. KosIsl   Kosmicheskiye Issledovaniya (Space Research)

C

41. Kon. Tpkas Konferentsiya po teploobmeny i masso-
obmenu (Conference on Heat and Mass
Transfer)

42. "PoI Kievskiy Politekhnicheskiy Institut
(Kiev Polytechnic Institute)

43. LPoI Leningradskiy Politekhnicheskiy Institut.
TGi Tr Tekhnicheskaya Gidrodinamika Trudy (Lenin-
grad Polytechnic Institute. Technical
Hydro-dynamics, Proceedings)

44. LU MMeMa Leningradskiy Universitet Matematichesko-
Sb. Mekhanicheskiy Facul'tet (Leningrad
Universityk Department of Mathematics
and Mechanics. Collected Articles)

45. LU NIslIMMe Leningradskiy Universitet Nauchno-Is-
sledovatel'skiy Institut Matematiki i
Mekhaniki (Leningrad University. Scien-
tific Research Institute of Mathematics
and Mechanics)

46. Mo Av I, Tr Moskovskiy Aviatsionnyy Institut, Trudy
(Moscow Aviation Institute, Proceedings)

47. MoFTI, Tr Moscovskiy Fiziko-Tekhnicheskiy Institut,
Trudy (Moscow Institute of Physics and
Technology, Proceedings)

48. MoU, Vych Ts Moskovskiy Universitet, Vychislitel'
Sb. nyy Tsentr, Sbornik (Moscow University,
Computing Center, Collected Articles)

49. MoVTU, Tr. Moskovskoye Vysshe-Tekhnicheskoye Uchi-
lishche, Trudy (Moscow Higher Technical
Technical School, Proceedings)

50. OpSpe Optika i Spektroskopiya (Optics and
Spectroscopy)

51. PMe Prikladna Mekhanika (Applied Mechanics)

52. PMMe Prikladnaya Matematika i Mekhanika (Ap-
plied Mathematics and Mechanics)

53. Rev Me Ap Revue de Mecanique Appliquee (Revue
of Applied Mechanics, Ruman)

54. RaPrKon Raschety na Prochnost' Konstruktsiy
Sb. Teoreticheskiye i Eksperimental'nyye
issledovaniya Prochnosti. Sbornik
(Design for Strength, Theoretical and
Experimental Investigations, Collected
Articles)

55.	RZhM	Referationyy Zhurnal, Matematika (Journal of Abstracts, Mathematics)
56.	RZhMe	Referativnyy Zhurnal, Mekhanika (Journal of Abstracts, Mechanics)
57.	SibOAN MMe	Sibirskoye Otdeleniye Academii Nauk, Matematika i Mekhanika (Sibirian Branch of the USSR Academy of Sciences, Mathematics and Mechanics)
58.	S Phys (JETP)	Soviet Physics (English translation of Zhurnal Eksperimental'noy i Teoreticheskoy Fiziki see No. 75)
59.	StuCeMeAp	Studii si Cercetari de Mecanica Aplicata (Study and Research in Applied Mathematics, in Rumanian)
60.	Tp	Teploperidacha (Heat Transfer)
61.	Tpe	Teploenergetika (Heat Power Engineering)
62.	Tpf	Teplofizika (Thermophysics)
63.	TGi, Tr	Tekhnicheskaya Gidrodinamika, Trudy (Engineering Hydromechanics, Proceedings)
64.	TsAeGiI (TsAGI) Sb.	Tsentral'nyy Aerogidrodinamicheskiy Institut, Sbornik (Central Aero and Hydrodynamics Institute, Collected Articles)
65.	UsFN	Uspekhi Fizicheskikh Nauk (Progress in the Physical Sciences)
66.	UeMN	Uspekhi Matematicheskikh Nauk (Progress in Mathematical Sciences)
67.	UstUprSis	Ustoychivost' Uprugikh Sistem (Stability of Elastic Systems) (Monograph)
68.	VeAN	Vestnik Akademii Nauk (Herald of the USSR Academy of Sciences)
69.	VeLUMMeAst	Vestnik Leningradskogo Universiteta Seriya Matematiki, Mekhaniki i Astronomii (Herald of Leningrad University, Mathematics, Mechanics, and Astronomy)
70.	VeMoUMMe	Vestnik Moskovskogo Universiteta Seriya Matematiki i Mekhaniki (Moscow University, Mathematics and Mechanics)

71. VpMe, Sb.   Voprosy Mekhaniki, Sbornik (Problems of
                Mechanics, Collected Articles)

72. Vych M.   Vychislitel'naya Matematika (Computing
                Mathematics)

73. WJPrzT   Wojskowy Przeglad Techniczny (Polish)
                (Air Force Review)

74. ZhETeF   Zhurnal Eksperimental'noy i Teoreticheskoy
                Fizika (Journal of Experimental and
                Theoretical Physics)

75. ZhPMeTF   Zhurnal Prikladnoy Mekhaniki i Tekhni-
                cheskoy Fiziki (Journal of Applied
                Mechanics and Technical Physics)

76. ZhTF   Zhurnal Tekhnicheskoy Fiziki (Journal of
                Technical Physics)

77. ZVychMMF   Zhurnal Vychislitel'noy Matematiki i
                Matematicheskoy Fiziki (Journal of Com-
                puter Mathematics and Mathematical Phy-
                sics)

Glossary of Abbreviations Used in This Report

Abbreviation	Russian, Czekh, German, Polish, Rumanian (transliterated)	English (translated)
A	Akademiya, Akademicheskiy	Academy, Academic
Ae	Aerodinamika, Aerodimicheskiy	Aerodynamics, Aerodynamic
Ak	Akustika, Akusticheskiy	Acoustics, Acoustic
Ap	Appliquee (Fr.), Aplicata (Rum.), Aplikace (Polish)	Applied
Ar	Arkhitektura	Architecture
Arch	Archiwum (Polish)	Archives
Arm	Armeniye (SSR), Armyanskiy (aya)	Armenia, Armenian
As	Astronomiya, Astronomicheskiy, Astronautika	Astronomy, Astronautics
Av	Aviatsiya, Aviatsionnyy	Aviation
Avt	Avtomatika, Avtomaticheskiy	Automation
Azer	Azerbayazhan (SSR), Azerbaydzhanskiy	Azerbaijan
B	Byulleten'	Bulletin
Bd	Budowy	Building, design (Polish)
Ce	Cercetari (Rumanian)	Research
D	Doklady	Reports, Proceedings
Dn	Dinamika	Dynamics
Dop	Dopovidi (Ukranian)	Transaction
E	Eksperiment, Eksperimental' nyy (aya)	Experiment, Experimental
En	Energetica, Energeticheskiy	Energetics, Power Engineering, Energy Producing
Est	Estoniya, Estonskiy	Estonia (SSR), Estonian
F	Fizika, Fizicheskiy	Physics, Physical
Fa	Fakul'tet	Department (in University, especially physics & mathematics)
G	Gosudarstvo, Gosudarstvennyy	State
Ga	Gaz, Gazodinamika	Gas, Gasdynamics
Gi	Gidravlika, Gidrodinamika, Gidrodinamicheskiy	Hydraulics, Hydrodynamics
Gruz	Gruziya, Gruzinskiy	Georgia (SSR), Georgian
I	Institut	Institute
In	Inzhener, Inzhenernyiy	Engineer, Engineering

Isk	Iskusstvennyy	Artificial
Isl	Issledovaniya, Issledova-tel'skiy	Research
Iz	Izvestiya	Bulletin, News
Izd	Izdatel'stvo	Publishing House
Izobr	Izobreteniye	Invention
K	Kiev, Kievskiy	Kiev (city)
Kaz	Kazan', Kazanskiy	Kazan (city)
Khm	Khimiya, Khimicheskiy	Chemistry, Chemical
Kn	Konstruotsiya	Construction, Design
Konf	Konferentsiya	Conference
Kos	Kosmos, Kosmicheskiy	Space
L	Leningrad, Leningradskiy	Leningrad
Lat	Latviya, Latviyskiy	Latvia (SSR), Latvian
Lit	Literatura	Literature
Lot	Lotniczy (Polish)	Flight
M	Matematika, Matematicheskiy	Mathematics, Mathema-tical
Ma	Mashinostroyeniye	Machine building
Mas	Massobmen	Mass transfer, Mass flow rate
Me	Mekhanika	Mechanics
Mo	Moskva, Moskovskiy	Moscow
Mokolas	Mokolas ir Technike (Hun-garian)	Science and Technology
Monogr.		Monograph
N	Nauka, Nauchnyy	Science, Scientific
O	Otdeleniye	Department, Branch, Section
Op	Optika, Opticheskij	Optics, optical
P	Prikladnaya, Prikladnoy	Applied
Pb	Priborostroyeniye	Instrument building
Po	Politekhnika, Politekhniches-kiy	Politechnic
Pro	Prochnost'	Strength
Prz	Przeglad (Polish)	Review
R	Referativnyiy	Reference
Ra	Raschet	Calculation, Design
Rev	Revue	Review
S	Soyuz, Sovet, Sovetskiy	Union, Soviet
Scientia Sinica		Chinese Science
Sb	Sbornik	Collection, Collected Articles
Sib	Sibir', Sibirskiy, Sibir-skoye	Siberia, Siberian
Sis	Sistema	System
Soob	Soobshcheniye	Communication, Message Report

Sp	Sputnik	Satellite
Spe	Spectroskopiya	Spectroscopy
Sto	Stosowanej (Polish)	
Stu	Studium (Polish, Studii (Rumanian)	Studies
Str	Stroitel'stvo	Building, Construction
T	Tekhnika, Tekhnicheskiy	Technology, Engineering, Technical
Te	Teoriya	Theory
Tl	Telemekhanika	Telemechanics, Remote Congrol
Tm	Temperatura, Termicheskiy	Temperature, Thermal
Tp	Teplo, Teploenergetika, Teploobmen	Heat, Heat Power Engineering, Heat transfer
Tpr	Teplofizika	Heat physics
Tr	Trudy	Transactions, Proceedings
Ts	Tsentr, Tsentral'nyiy	Center, Central
U	Universitet, Uchilishche, Uchebnoye	University, School, Learning
Ukr	Ukraina, Ukrainskiy	Ukraine (SSR), Ukranian
Upr	Uprugost'	Elasticity
Us	Uspekhi	Progress
Ust	Ustoychinost'	Stability
V	Vysshiy, Vysshiye	High, Higher
Ve	Vestnik	Herald
Voe	Veyennyy, Voyennoye	Military
Vp	Voprosy	Problems
Voz	Vozdukh, Vozdushnyy (aya)	Air
Vych	Vychisleniye, Vychislitel'nyy	Computation, Computing
W	Wissenshaften (German)	Science, Scientific
Wj	Wojskowy przeglad Techniczny	(Air Force Review, Polish)
Z	Zavedeniye	Establishment, Institution, School
Ze	Zemlya	Earth
Zh	Zhurnal	Journal

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1.	Abramyan, B. L.	Institute of MME, A of Sci. ArmSSR, Erevan	744
2.	Adamskiy, V. B.	Moscow	63
3.	Adushkin, V. V.	Moscow	227
4.	Akhmed'yanov, I. S.		765
5.	Akim, E. L.		671
6.	Aksel'rad, E. L.	Leningrad	726, 815
7.	Aksenov, A. P.	Leningrad University	270, 271
8.	Aleksakhin, B. N.		315
9.	Aleksandrov, A. Ya.		759
10.	Aleksandrov, G. V.	Moscow	798
11.	Aleksenko, I. I.	Leningrad University	185
12.	Alekseyev, V. M.		95
13.	Alimov, R. Z.	Kazan' Aviation Institute	480
14.	Alishaev, M. G.	Moscow	551
15.	Ambartsumyan, S. A.	Director of Inst. of MMe, A of Sci. ArmSSR, Erevan	713
16.	Andryankin, Ye. I.	Institute of Chem. Physics, Moscow	461
17.	Anfimov, N. A.		148, 152
18.	Anisimov, S. I.		232
19.	Ankudinov, A. L.		172
20.	Antipov, O. O.	Nikolayev Shipbuilding Inst.	797
21.	Antonov, A. M.		447
22.	Arkhimov, V. N.	Moscow	120, 410

23.	Artamonov, K. I.	Moscow	544
24.	Artyukh, L. Yu.	Kazakh State University	604
25.	Arutyunyan, N. Kh.	Academician, A. of Sci. ArmSSR, Erevan	745
26.	Aslanov, S. K.		251, 252, 256, 393
27.	Avduyevskiy, V. S.	Moscow	71, 149, 155, 158
28.	Babayev, D. A.	Moscow	412, 416
29.	Babenko, K. I.	Prof. Math. Inst., A. of Sci. USSR, Moscow	143
30.	Babichev, A. I.	Inst. of Me., A. of Sci. USSR, Moscow	594
31.	Babloyan, A. A.	A. of Sci. ArmSSR, Erevan	747
32.	Badyagin, A. A.		209
33.	Bagdasaryan, Zh. Ye.	A. of Sci. ArmSSR, Erevan	713, 747, 808
34.	Bakulev, V. I.		112
35.	Balabukh, L. I.	Moscow State University	754
36.	Bam-Zelikovich, G. M.	Moscow State University	331
37.	Barabanov, A. T.		621
38.	Barantsev, R. G.	Leningrad University	185, 369
39.	Barglazar, A.	Rumanian A. of Sci., Bucharest	51
40.	Bashkin, V. A.	Moscow	521
41.	Batrakov, Yu. V.	Gorkiy State University	624
42.	Baush, G.	Leningrad University	222, 223, 870
43.	Bazhenova, T. V.	Power Engineering Inst. Moscow	99, 147
44.	Bazzhin, A. P.		428
45.	Belotserkovskiy, O. M.	Computing Center, A. of Sci. USSR, Moscow	193, 243, 257, 282, 292, 337, 375, 378

141.	Galkin, V. S.	Moscow	114, 124, 177, 205, 359, 400
142.	Gaushus, E. V.		646
143.	Gavrilov, Yu. V.		683
144.	Generalov, N. A.		234
145.	Gerasimov, I. S.	Inst. of Mech, A. of Sci. USSR, Moscow	682, 697, 771
146.	Ghia-Nastase, A.	Inst. of Appl. Mech. Bucharest, Rumania	403
147.	Ginevskiy, A. S.	Moscow	29, 49, 200, 323
148.	Ginzburg, I. P.	Leningrad University	126, 437
149.	Gladkov, A. A.	Moscow	124, 241
150.	Glikman, V. F.		456
151.	Godunov, S. K.		27, 142
152.	Godzevich, V. G.		821
153.	Gol'denveyzer, A. L.	Moscow	840
154.	Golitsyn, G. S.	Inst. of Atmospheric Physics, A. of Sci. USSR	52, 217
155.	Golubev, V. A.	Moscow Aviation Institute	109, 499, 619
156.	Golubinskiy, A. I.	Moscow	432
157.	Goncharenko, V. M.	Kiyev Polytechnical Inst.	794
158.	Gonor, A. L.	Inst. of MMe, Moscow State University	218, 262, 275, 296, 303, 340
159.	Gorban', N. F.		589
160.	Gorelov, Yu. A.	Moscow	657
161.	Goroshchenko, L. B.		12
162.	Gorskaya, N. M.	Inst. of Mech. A. of Sci. USSR	542
163.	Gozdovskiy, G. L.	Inst. of Mech. A. of Sci. USSR	236

212.	Karavanov, V. P.	Moscow Aviation Institute	678, 701, 830, 841
213.	Karlikov, V. P.		196
214.	Karpenko, P. D.		349
215.	Karpov, M. I.	Inst. of Mech., A. of Sci. USSR, Moscow	796, 833
216.	Karnaukhov, V. G.		832
217.	Karnozhitskiy, V. P.		718, 799
218.	Karpov, M. I.		779, 833
219.	Kashkarov, V. P.	Kazakh State University	601, 604
220.	Kastelin, O. N.	Power Engineering Institute, Moscow	526, 527, 591
221.	Keldysh, V. V.	Inst. of Mech., A. of Sci. USSR, Moscow	110, 281
222.	Kellin, S. S.		476
223.	Kerimgaziyev, E.		113
224.	Khaldeyev, V. M.		210
225.	Kharchenko, V. N.		225, 238, 563
226.	Khaskind, M. D.	Odessa	285
227.	Khodyko, Yu. V.		232
228.	Kholyavko, V. I.	Aviation Inst., Kharkov	391, 425
229.	Khomenko, V. S.		285
230.	Khoroshko, K. S.		410
231.	Khristyanovich, S. A.	Director of Inst. of Mech., A. of Sci. USSR, Siberian Branch, Novosibirsk	10, 14, 47
232.	Khrustal'yev, A. F.	Kharkov	825
233.	Kil'chyns'ka, G. A.		791
234.	Kim, Ye. I.	Kharkov	455
235.	Kireyev, V. T.		160

306.	Larish, E.	Institute of Applied Mech. Bucharest	75, 103
307.	Lashkov, A. I.	Inst. of Mech., A. of Sci. USSR	449
308.	Lavrent'yev, M. A.	Novosibirsk	625, 861
309.	Lazarev, A. I.		600
310.	Lazareva, Ye. V.		245
311.	Lebedev, A. A.	Moscow Aviation Institute	676
312.	Lebedev, V. N.		648
313.	Lebedev, Yu. A.		730
314.	Leonas, V. B.	Moscow State University	188
315.	Leont'yev, A. I.	Novosibirsk	492, 576, 578, 581
316.	Leont'yeva, T. P.		515
317.	Levinson, Ya. I.		2
318.	Librescu, L.	Physics Inst. Rumanian A. of Sci. Bucharest, Rumainia	783
319.	Lipovskiy, D. Ye.		820, 824
320.	Litvin-Sedoy, M. Z.		545
321.	Livanov, K. K.	Inst. of Mech., A. of Sci. USSR	800
322.	Loscu, S. A.		234
323.	Losev, S. A.		181
324.	Loshkina, V. P.		407
325.	Loytsyanskiy, L. G.	Leningrad Polytechnic Inst.	364, 484
326.	Lozgachev, V. I.		192
327.	Lubonski, J.		145
328.	Lugovtsov, B. A.	Novosibirsk	186

329. Lunev, V. V.	Moscow	25, 83, 133, 161, 255, 302, 321, 332, 346, 368, 389, 392, 398
330. Lun'kin, Yu. P.	Leningrad Physico-Technical Institute	24, 94, 137, 139, 856
331. Lur'ye, A. I.		647, 836
332. Lyakhov, G. M.	Moscow	58
333. Lyakhov, V. K.		507, 566
334. Lyamshev, L. M.	Acoustics Institute, A. of Sci. USSR	681
335. Lyashenko, S. S.	Novosibirsk	686
336. Lyubimov, G. A.	Moscow State University	57, 293
337. Lyubimov, V. M.	Moscow	711
338. Madejski, J.		525
339. Magomedov, K. M.	Moscow	420
340. Makariavichus, V. I.	Kaunas	516
341. Makarov, B. P.		683
342. Makarov, O. F.		639
343. Makhovikov, V. I.		737
344. Malakhovskiy, R. A.	Gomel	702
345. Malkes, L. A.		857
346. Malkina, R. I.	Urals Polytechnic Institute	706, 760, 821
347. Malykhin, V. I.		784
348. Malyshev, G. P.		491
349. Manevych, A. I.		795
350. Manokhin, D. G.	Kazan Aviation Institute	705
351. Marenkova, A. F.		291

397. Nemchinov, I. V.	Moscow	227, 487
398. Nesgovorov, L. Ya.		618
399. Nevzglyadov, V. G.		483
400. Neyland, V. Ya.	Moscow	171, 206, 430, 431, 498, 614
401. Nigul, U. K.		782
402. Nikitenko, N. I.		572
403. Nikitin, Ye. Ye.	Inst. of Chem. Physics, Moscow	471
404. Nikolayev, V. S.	Moscow	382
405. Nikol'skiy, A. A.	Inst. of Mech., A. of Sci., USSR	7, 115, 169, 267, 352, 449
406. Nowak, Eugeniusz		418
407. Novozhilov, V. V.	Leningrad	849
408. Obremskiy, S. V.		734
409. Obroskova, Ye. I.		158, 216
410. Ogibalov, P. M.	Moscow State University	727
411. Onufriyev, A. T.	Novosibirsk	224, 559, 616
412. Osipov, A. I.		181, 234
413. Osipov, Yu. V.		108, 539
414. Ostapovich, O. N.		332
415. Ostoslavskiy, I. V.	Moscow Aviation Institute	278, 642
416. Ozerinin, V. N.		422
417. Palatnik, I. B.	Power Inst.,A. of Sci. Kazakh SSR	515
418. Palley, I. Z.		729
419. Pal'mov, V. A.	Leningrad	814, 818
420. Panevin, I. G.		577

421.	Pashchenko, N. T.	Moscow	64, 519
422.	Pavlov, K. B.	Moscow	80
423.	Pavlova, L. M.	Moscow	239
424.	Perel'man, T. S.	Power Engineering Inst., A. of Sci., BelorSSR, Minsk	511
425.	Perepukhov, V. A.		440
426.	Peshkova, A. I.		661
427.	Petrazhitskiy, G. B.		553
428.	Petre, A. C.	Physics Inst., Rumanian A. of Sci. Bucharest	724
429.	Petrosyan, L. G.		199
430.	Petrov, A. A.	Computing Center, A. of Sci. URSS	847
431.	Petrov, V. V.	Saratov Polytechnic Institute	776
432.	Petrov, Yu. N.		351, 602, 603, 629
433.	Petukhov, I. V.	Moscow	69, 70, 172
434.	Petukhov, B. S.		481
435.	Petukhov, V. G.		732
436.	Pirumov, V. G.		385
437.	Pitayevskiy, L. P.		146
438.	Pleshanov, A. S.	Power Engineering Inst., A. of Sci. URSS	617
439.	Polezhayev, V. I.		553
440.	Polkovnikov, V. I.		165
441.	Pol'skiy, N. I.	Heat of Power Eng. Inst., A. of Sci. UkrSSR, Moscow	62, 655
442.	Poluboyarinov, A. K.		28

611.	Valilenko, M. V.	Inst. of Cermets & Special Alloys, UkrSSR	793
612.	Val'kov, Yu. A.		426
613.	Vallander, S. V.	Leningrad State University	128, 129, 184, 215
614.	Váni, V.	Peking	348
615.	Varzhanskaya, T. S.		216
616.	Vasil'yev, V. V.		738
617.	Vasitsyna, T. N.		755
618.	Vatazhin, A. B.	Moscow	593
619.	Vaulin, Ye. P.	Moscow State University	560
620.	Veluko, V. I.	Power Engineering Inst., Moscow	537
621.	Vereshchagin, I. F.	Perm State University	634
622.	Vereshchagina, L. I.		439
623.	Vetlutskiy, V. N.		616
624.	Vil'ker, D. S.		96
625.	Vil'nit, L. N.	Novosibirsk Electrotechnical Inst.	314
626.	Vinogradov, B. S.		212
627.	Vinogradov, R. I.		854
628.	Volkov, A. N.		843
629.	Vol'mir, A. S.		842
630.	Volodina, M. V.	Moscow	476
631.	Volosevich, P. P.	Moscow	583
632.	Vorob'yev, O. S.		35
633.	Vorobyev, N. F.	Novosibirsk	298, 330, 675
634.	Voskresenskiy, G. P.		143
635.	Voyshel', V. V.		88