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OPTIMIZATION OF THE TRAJECTORY OF MULTISTAGE FLIGHT VEHICLES

by Leonas Kacinsk

SUMMARY: The optimal flight of a multistage flight vehicle is analyzed in the case when the curvature of the earth and its rotation are taken into account and the constraints imposed on the control function are of the inequality type. Necessary and sufficient conditions under which the determined trajectory minimizes the performance functional are investigated.

The optimal motion of flight vehicles has been studied by many aut However, the majority of these studies were concerned with determinin optimal trajectories of single-stage flight vehicles which satisfy only th first necessary optimality condition——the Euler equations, or the nece: sary optimality conditions formulated in the form of the maximum princi of Pontryagin——and were not concerned with other necessary and suffi- cient optimality conditions.

In the study reviewed here [1], A. A. Bolonkin analyzes the optima flight of a multistage flight vehicle in the case when the curvature and th rotation of the earth are taken into account and the constraints on the co functions are expressed by inequalities. All necessary and sufficient oj mality conditions (the Euler equations, Clebsch, Weierstrass, and Jaco conditions) are analyzed on the basis of a general study of necessary an sufficient optimality conditions in the variational problem of optimizing discontinuous control processes with inequality-type constraints impose upon the control function presented in the appendix of the article. To simplify the presentation of the general results, the optimal control is divided into the following two problems: 1) analysis of necessary and su ficient conditions for the strong relative minimum of the performance fu tional in the case when the domain in which the control function varies i: bounded, the control function is discontinuous at certain points, and the phase trajectory has corner points (so-called discontinuous variational problem of the first kind); 2) analysis of necessary and sufficient conditi for the multistage problem (the discontinuous variational problem of the second kind, or the variational problem with discontinuous right-hand si when, in addition to the conditions formulated in the first problem, the motion of a body is described at various stages by various differential equations.

The first type of problem is reduced to the ordinary problem of Bol: determining the minimum in the class of curves with corner points——an

the second type of problem, to determining the minimum in the class of curves with corner points which intersects the given switching surfaces. The conditions of Euler, Weierstrass, Clebsch, and Jacobi, the Erdman-Weierstrass corner condition, and the transversality condition, which are necessary conditions for the normal nonsingular curve (extremal) to minimize the performance functional, are analyzed in the discontinuous variational problems of both the first and the second kind. The sufficient conditions of its strong relative minimum are obtained from an analysis of the second variation of the performance functional. Simple algorithms for verifying the sufficient conditions are presented.

Since the thrust, mass, aerodynamic, and other characteristics of the separate stages of a multistage flight vehicle are different, the problem of optimizing the flight trajectory is considered as the discontinuous variational problem of the second kind. The optimal flight problem is analyzed under the following conditions: 1) the flight vehicle moves in the plane of a great circle of the earth; 2) the design of the flight vehicle is known (the number of stages, the amount of propellant in each stage, and other parameters); 3) stages separate without shock at the instant that the propellant is burned out; and 4) the flight vehicle is considered as a mass point and the earth as a sphere.

In the orthogonal coordinate system with its origin in the mass point and the x-axis in the direction of flight, the equation of motion of the vehicle, with the curvature of the earth, the components of the Coriolis acceleration, and the variation of the gravitational acceleration with the altitude taken into consideration, is set up, using the following simplifying assumptions: 1) the centrifugal force due to rotation of earth is to be neglected; 2) the component of the Coriolis acceleration perpendicular to the plane of the flight is to be neglected; and 3) the exhaust velocity of combustion products does not depend on the altitude.

In the equations of motion, functions $L(t)$, $H(t)$, $V(t)$, $\theta(t)$, and $m(t)$ (flight range, flight altitude, flight velocity, the angle of inclination of the trajectory with the local horizon, and the mass of the vehicle, respectively) are considered as phase coordinates and functions $\alpha(t)$, $\omega(t)$, and $\beta(t)$ (the angle of attack, the angle between the thrust vector and the velocity vector, and the fuel consumption, respectively) as control functions constrained by certain inequalities. The phase coordinates $L(t)$, $H(t)$, $V(t)$, and $\theta(t)$ are continuous and piecewise differentiable functions, $m(t)$ is a continuous and piecewise differentiable function in each stage but has a finite jump at the instant the stages separate; control functions $\alpha(t)$, $\omega(t)$, and $\beta(t)$ have discontinuities of the first kind.

With the above-formulated conditions, the optimum trajectory of the flight vehicle is sought from the optimality condition of the given phase coordinate. The minimum propellant consumption, the maximum terminal

velocity, or others can be taken as the optimizing coordinate. The boundary conditions at the ends of the trajectory are considered as fixed, but the case of variable boundary conditions is also analyzed. In this way, the formulated optimal flight problem is considered as the Mayer variational problem; the results of the general theory presented in the appendix are applied to its analysis. The necessary and sufficient conditions for the existence of the weak and strong relative minima of the performance functional are verified.

It is concluded that when the Euler conditions and the strengthened Clebsch and Jacobi conditions are satisfied on a nonsingular curve, this curve ensures the weak relative minimum of the performance functional, and when the Euler and the strengthened Weierstrass and Jacobi conditions are satisfied, this curve ensures the strong relative minimum of the performance functional. Some peculiarities of the optimal path of a multistage flight vehicle are presented in connection with the study of necessary and sufficient optimality conditions.

REFERENCE

1. Bolonkin, A. A. Optimization of a trajectory of multistage flight vehicle. IN: Ostoslavskiy, I. V. Issledovaniya po dinamike poleta; sbornik statey, vyp. 1 (Studies on flight dynamics; collection of articles, no. 1). Moskva, Izd-vo Mashinostroyeniye, 1965. 20-78.

A METHOD OF INCREASING DIGITAL DATA TRANSMISSION SPEED

by Boris Doncov

SUMMARY: A discrete data coding method related to A. Lender's duobinary technique is described which compresses the baseband spectrum of a binary signal by a factor of three. The coding exhibits the same noise immunity as is characteristic of the duobinary technique. Inherent in the process of coding is an error detection feature which does not depend on data redundancy.

According to A. Lender's duobinary method [1], the bandwidth of a train of binary digits is compressed by converting the random sequence of binary digits into a correlated stream of digits through application of the following coding rules:

1) Binary ZERO in the new sequence remains a ZERO.

2) Binary ONE can assume either a positive (+) or negative (-) polarity, depending on the number of ZEROS intervening between the ONES; the polarity of a given ONE is the same as that of the preceding ONE if the number of intervening ZEROS in the binary sequence is even, and opposite to that of the preceding ONE if the number of intervening ZEROS is odd.

3) If no intervening ZEROS are present between the ONES, the polarity of a given ONE is the same as that of the preceding ONE.

4) The polarity of the first ONE in the duobinary sequence is arbitrary. It can be shown that by this transformation the spectral density of the original binary signal is compressed by a factor of two.

If the spectrum of an alternating train of ZEROS and ONES is expressed as:

$$G_1(f) = T \frac{\sin \pi fT}{\pi fT},$$

then the spectral densities of binary and duobinary pulse trains are

$$W_B(f) = \frac{T}{4} \left(\frac{\sin \pi fT}{\pi fT} \right)^2,$$

and

$$W_D(f) = \frac{T}{4} \left(\frac{\sin 2\pi fT}{2\pi fT} \right)^2,$$

respectively.

M. I. Pelekhatyy [2] suggests an alternate method of coding which he refers to as the triobinary method and which differs from Lender's method only with respect to part (2). Pelekhatyy's method stipulates that each succeeding ONE in the coded train must change its polarity in the new sequence, irrespective of the number of ZEROS intervening between ONES in the binary stream. The comparison between binary sequence (A), duobinary (B), and the new method (C) may be illustrated by the following sequences:

```
A   1 1 0 0 0 1 0 0 1 0 0 1 0 0 1 1 1 0 1 0 0 0 0 1 1 1
B   — —0 0 0 +0 0 +0 0 +0 0 + + +0 — 0 0 0 0 — — —
C   — —0 0 0 +0 0 —0 0 +0 0 — — —0 +0 0 0 0 — — —.
```

The spectral density of the triobinary stream is derived in [2] and is shown to be

$$W_{TB}(f) = \frac{1}{8T}\left(\frac{\sin \pi fT}{\pi fT}\right)^2 \frac{15 + 14\cos 2\pi fT - 4\cos 6\pi fT}{17 + 8\cos 8\pi fT}.$$

The normalized spectral densities of the binary, duobinary, and triobinary signals are shown in Fig. 1. It can be seen that, with the same number of
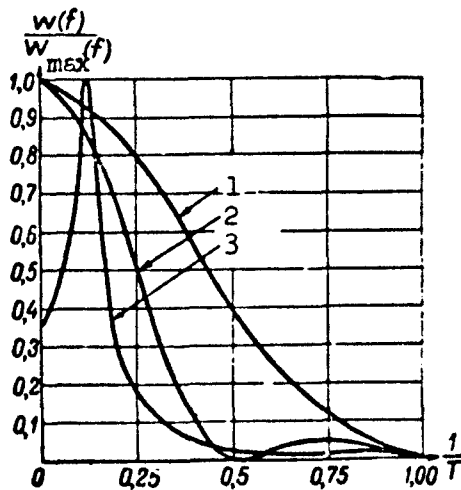
Fig. 1. Comparison of spectral densities of binary (1), duobinary (2), and triobinary (3) signals

discrete signalling levels as used in the duobinary system, the triobinary signal spectrum is reduced by a factor of 1.5. This fact may be demonstrated by considering the spectrum bandwidth in which 90% of the energy is concentrated. The figure shows that for the binary signal this spectrum is contained in the band between 0 and 1; for the duobinary signal it is between 0 and 0.5; and for the triobinary signal it is between 0 and 0.33.

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Unlike multilevel systems, the triobinary system does not require complex equipment to accomplish the coding transformation at the transmitting end and the decoding at the receiver. The coding scheme is an insignificant modification of equipment used in duobinary coding and the decoding is analogous to duobinary decoding, i.e., full-wave rectification and subsequent sampling.

As in the duobinary transmission, the triobinary coding is such that a certain amount of *a priori* information is available at the receiver, and detection of certain odd-numbered and even-numbered errors is therefore possible. For example, after the appearance of a negative level in the triobinary data stream, assuming intervening ZERO(s), it is not permissible to receive another negative level as a valid bit. The error detection implementation in the triobinary system differs from that used in the duobinary equipment.

REFERENCES

1. Lender, A. The duobinary technique for high-speed data transmission. IEEE Transactions on Communication and Electronics, 1963, 214-218.

2. Pelekhatyy, M. I. Certain new possibilities of increasing the transmission speed of discrete information. Elekrosvyaz', no. 3, 1966, 33-41.

RESEARCH IN PHYSICS OF THE TERRESTRIAL ATMOSPHERE

by Edward Gelins

SUMMARY: This paper is a review of the works of Soviet-Bloc scientists reported at the Seventh COSPAR Conference in Vienna in May 1966. Short abstracts of reports on the physics of various phenomena in the terrestrial atmosphere, dealing with the following topics, are presented: 1) ion and molecular interactions; 2) ozone influence on radiation exchange; 3) electron fluxes in the upper atmosphere; 4) positions of mirror points of high-energy electrons; 5) ionization and recombination in the ionosphere; 6) absorption of solar ultraviolet radiation in the upper atmosphere; 7) night sky emission into space; and 8) proton radiation belts. These works cover investigations of the whole atmosphere, including phenomena of the reflection of solar light on atmospheric molecules, the absorption of solar radiation, ionization processes, and the blackout of radio waves. The abstracts of the reports are systematized according to the classification of physical atmospheric layers as follows: 1) troposphere and stratosphere; 2) stratosphere and ionosphere; 3) mesosphere; 4) thermosphere and exosphere; 5) ionosphere and airglow; 6) magnetosphere and aurora; and 7) polar cap absorption.

Section 1. Troposphere and Stratosphere

This section contains abstracts from two reports dealing with ultra-violet light reflection from the earth's atmosphere and infrared emission. V. A. Iozenas, V. A. Krasnopolsky, A. P. Kuznetsov, and A. I. Lebedinsky [1] studied 2500 spectra obtained by a special ultraviolet spectrophotometer mounted on Kosmos-65 satellite. The change in energy distribution in the ultraviolet spectrum depends not only upon solar zenithal distance, but also upon atmospheric ozone content . Observed spectra contained numerous details which were not found in calculated spectra. The atmospheric albedo decreases gradually with the wavelength because of ozone absorption. The intensity of the wavelength $\lambda = 3016$ Å increases highly at 30° latitude and depends upon the ozone distribution and the albedo of the lower atmospheric layers and clouds. This report follows an earlier study by the same authors, published in the collection *Issledovani; kosmicheskogo prostranstva* (Space Exploration). (Moskva, 1965, 77-88).

A. I. Lebedinskiy, V. G. Boldyrev, V. I. Tulupov, C. N. Kudinova, A. D. Lovchenko, and T. K. Shvidkovskaya [2] studied 10,000 spectra of outgoing terrestrial radiation in the far-infrared range. These spectra wer

obtained by a grating spectrophotometer mounted on the Kosmos-45, Kosmos-65, and Kosmos-92 satellites. The measured outgoing radiations at selected points were compared with those computed theoretically for the same points and moments. The agreement was good. The ozone absorption band was found to be weaker when computed than when measured directly.

Section 2. Stratosphere and Ionosphere

This section contains four abstracts of reports dealing with ion and molecular interaction processes in the ionosphere.

A. D. Danilov [3] discusses the main ion and molecular reactions in the ionosphere, basing the discussion on his earlier works, published in *Kosmicheskiye issledovaniya*, v. 2, 1964. The diurnal variation in ion concentration in the F2 layer at heights of 100—200 km is analyzed. Numerical values of the ion concentration are given in tables in the original report and compared with data obtained in laboratory experiments.

A. D. Danilov and A. A. Pokhunkov [4] studied data obtained by the flight of a geophysical rocket in November 1961 at heights of 130—430 km. The absolute distribution of neutral and ionized atmospheric gases and pollution of the atmosphere by the rocket were determined. Ionized gas contents are given in Table 1. This result was obtained by mass-spectrometric measurements. Water ions were recorded at the height of 100 km

Table 1.

H in km	170	190	210	240	270	300	340	370	400	430
Ne, 10^4 cm^{-3}	7.2	17	40	68	57	42	25	19	14	10.8
O^+, 10^4 cm^{-3}	1.7	6.8	26.6	58	51	40.7	24.3	18.2	13.1	9.5
NO^+, 10^4 cm^{-3}	4.2	6.8	9.3	5.8	2.2	0.6	—	—	—	—
O_2^+, 10^4 cm^{-3}	1.3	3.4	5.1	3.9	3.3	—	—	—	—	—

which could be formed by ion-molecular reaction between atmospheric ions, neutral atmospheric molecules, and gas released from the rocket. Hydroxyl ions were also recorded at the same height.

V. V. Rybin [5] studied collisions between neutral particles and ionized gas particles in the ionospheric layers. Gases are slightly ionized in the ionospheric D layer and the lower part of the E layer. In these layers the collision frequency between charged particles is less than between neutral particles. The possibility of collisions is discussed theoretically using the impulse conservation equation and simplifying real conditions. Investigation shows that collisions of charged particles do not cause the plasma movement to any appreciable extent. This movement may be caused only by

collisions between neutral particles. The electric fields in ionospheric irregularities are determined only by collisions between neutral particles and do not depend on electron-ion collisions.

K. Ya. Kondrat'yev and G. M. Shved [6] studied the problem of heat distribution in the atmospheric layers from 30 to 100 km. The radiative heat flux was computed and its divergence determined in the upper atmosphere. The state of radiative heat depends upon the spectral composition of solar radiation, the distribution of absorbing gases, the temperature field, and the absorption ability in infrared and ultraviolet ranges. Computation of the temperature field is carried out and approximated to the relative equilibrium.

Section 3. Mesosphere

This section includes three abstracts of reports dealing with the followir. topics: 1) water vapor concentration, atomic oxygen, and total density in the mesosphere; 2) determination of the ozone profile above the level of maximum concentration; and 3) the mean particle size at heights of 70—450 k These topics were studied theoretically and experimentally by rocket flights.

A. V. Fedynsky, S. P. Perov, and A. F. Chizhov (Cheezhov) [7] made preliminary measurements of water vapor concentration, of atomic oxygen, and of the total gas density in the mesosphere from data recorded by the rocket launched in August 1965. Measuring instruments consisted of a set of glass gages with sensitive tungsten wires for measuring water vapor concentration. The atomic-oxygen gage was based on the heat effect of surface recombination. Parameters of undisturbed atmosphere were determined using the Rayleigh equation for shock waves. The maximum water vapor concentration was found to be at heights of 78–82 km. The concentratic of atomic oxygen steadily increased from 75 km up to 95 km. The method used yielded adequate results and can be used for upper-atmosphere investigations.

S. M. Poloskov, A. A. L'vova, and A. E. Mikirov [8] studied the behavior of ozone density, especially its profiles above the level of maximum concentration at sunrise and sunset. The change of the ratio I/I_0 within the interval of heights from 40 to 70 km was determined. I is the brightness of a source in the ozone layer and I_0 is the brightness of the same source outside the ozone layer. The change of the ratio was within the limits 1.5—2.0. Measurements above the level of 70 km may be carried out only in the ultraviolet range from 3000 to 3200 Å. A geophysical rocket was launched into the lunar shadow, where its instrument container separated from the rocket, made automatic measurements, and telemetered them to the ground. The ultraviolet photometer operated as a photon counter. The

ozone density in the shadow region deviated from the exponential law and up to the 77-km level it decreased more rapidly than the exponential law would indicate.

A. E. Mikirov [9], referring to his earlier publication in *Kosmicheskiye issledovaniya*, determined the mean size of particles at heights of 70—450 km from rocket measurement data. The brightness of the upper atmosphere has been studied in the spectral ranges 5300 and 5577 Å. The brightness of the daytime sky consists of Rayleigh scattering of atmospheric lumines-cence, of background radiation, and of aerosol scattering. The analysis of data made it possible to conclude that the brightness of the upper atmosphere at altitudes from 70 to 100 km is generated by molecular and aerosol constituents, and at altitudes higher than 100 km by aerosols alone. The maximum mean size of aerosol particles was found at altitudes of 120 to 160 km. Fig. 1 shows the distribution of sizes.
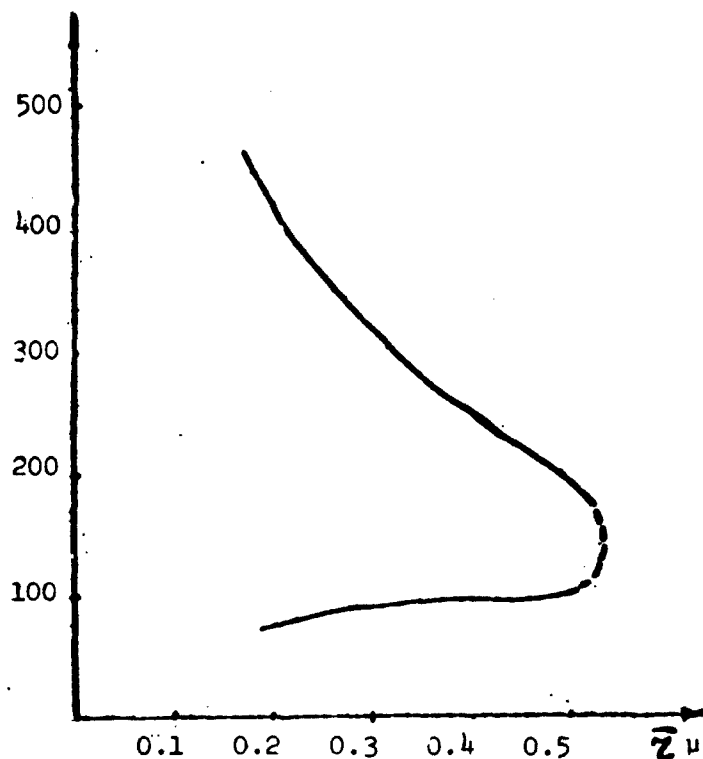

Fig. 1. Mean optical aerosol particle size.
Altitude range of 102—170 km - extrapolation.

Section 4. Thermosphere and Exosphere

This section contains seven abstracts of reports dealing with different aspects of upper-atmosphere phenomena. Two abstracts deal with the composition of the upper atmosphere; the others contain data on mass-spectrometric investigations, electron flux at heights of 200—500 km, a thermospheric gas as a mixture of two gases with different temperatures, neutral hydrogen distribution in the geocorona, and photometric measurements made by satellite instruments while in the Earth's shadow.

I. Taubenheim [10] studied atmospheric composition and ionization using rocket data obtained at a height of 200 km. The level of 200 km, including the F-layer, is a surface which characterizes the distribution of ions of O^+, NO^+, and O_2^+. Two sets of electron densities are discussed. The first set includes daytime variations in electron density at 180, 200, and 220 km as determined by vertical sounding in Bulgaria on 14 February 1961 during a solar eclipse. The other set includes forenoon electron density obtained in Germany on 30 September 1957. Using the COSPAR International Reference Atmosphere, a reduction factor D = 0.45, and the reaction coefficients γ_1 and γ_2, the calculated results are compared with Hinteregger's data.

V. G. Kurt [11] studied the distribution of neutral hydrogen in the geocorona at distances up to 20 Earth radii. Data on hydrogen distribution were obtained from the Venera-2 interplanetary probe. The density was computed using the exponential formula. Hydrogen density at the distance of 10 Earth radii was found to be 15 cm^{-3}, and was found to be concentrated near the ecliptic plane.

E. G. Shvidkovsky, A. I. Ivanovsky, and A. I. Repnev [12] studied the behavior of electrons and neutral particles in the terrestrial thermosphere. Their temperatures in this sphere are different and they may be considered to be a binary gas. The properties of such a gas may be investigated using the Boltzmann equation. Formulas for transfer coefficients during elastic collisions have been developed and applied to the general case of a binary gas mixture and also to constituents of large ionospheric particles. Electrons contribute more to viscosity and heat conduction when the degree of ionization exceeds 0.05%. If the ratio of the temperatures is equal to 2, the constant of thermodiffusion is three times that of the simple binary gas.

V. A. Krasnopolsky and A. I. Lebedinsky [13] determined night-glow brightness on the basis of eight spectral ranges. Data for the brightness determination were taken from the colorimeteric records of the Kosmos-9 satellite made during twelve orbits. The colorimeter was described previously *(Issledovaniya kosmicheskogo prostranstva)*. The radiation intensity

was greater during the first four revolutions of the satellite, attaining 0.35 rayleighs/Å in the 1650—2500 Å range. Numerical values of night glow intensity are presented in a table. The highest intensity of the night glow was found to be from 168 to 425 rayleighs in the emission of the 5577 Å line.

L. A. Antonova [14] studied the electron fluxes in the upper atmosphere at heights from 200 to 500 km. Data for studies were taken from satellite records obtained on 6 and 18 June 1963, with the sun in a low position above the horizon. On 6 June a small increase in flux intensity was found, but on 18 June it was not observed to change with height. These measurements relate to electrons with energies above 50 kev. The analysis of the registrograms showed a periodic oscillation with periods of 20 and 30 sec.

A. A. Pokhunkov [15] studied the temperature of the upper atmosphere by assuming the presence of a diffusive gas in the terrestrial gravitational field and the local Maxwell distribution. This method is described by the author in his earlier publications. Variation in the partial pressure of one component of the gas with height is discussed using the barometric exponential formula. Mass-spectrometric measurements in the ion current in September 1960 yielded the following results:

h, km	110	120	130	140	150	160	170	180
$T^\circ K$	265	325	395	490	600	715	785	825

F. Link [16] discussed light curves obtained in the L_α (1216 Å) and the violet (4200 Å) ranges on a satellite at sunrise and sunset. Studies of the L_α range showed an absorption of molecular oxygen at heights from 80 to 160 km, the zone in which transition from molecular to atomic oxygen occurs by dissociation. Measurements in the violet range showed that aerosols are present in the 10—50 km atmospheric layer.

Section 5. Ionosphere and Airglow

This section covers eight abstracts of reports dealing with the effective recombination coefficient and variations in the ionosphere, variations in ion composition at altitudes of 400—1000 km, mirror points of high-energy electrons, the absorption of ultraviolet solar radiation in the upper atmosphere, formation of the lower ionospheric layers by corpuscular radiation, the ion concentration in the stratosphere and mesosphere, and the night sky luminescence. Data for investigations were obtained from rockets and satellites.

G. S. Ivanov-Kholodny [17] computed the ionization in the ionospheric E layer under the action of solar x- and UV-radiation at altitudes of 100 to 200 km. The formation of O_2^+ ions in the 100—150 km altitude zone is very high and that of N_2^+ is very low. This phenomenon is explained by the variation in spectral composition of solar radiation during the passage through the atmospheric layers. The main contribution to ion production is made by UV-radiation of 911—1038 Å, which produces O_2^+ ions at the solar zenithal distance of 55°. The maximum ion production increases with solar zenithal distances above 150 km altitude. The O_2^+ and N_2^+ ion concentration depends upon the effective recombination coefficient and its variations.

V. G. Istomin [18] studied ion distribution and variation in ionic concentration at heights from 400 to 1000 km on the basis of mass-spectrometri records obtained from the Elektron-2 satellite. The ion concentration depends upon time. The hydrogen H^+ ions attain concentrations of 8—10% during the morning and evening hours at the heights of 400—500 km and 2—3% in the afternoon. The concentration of oxygen O^+ ions is 20% at a height of 900 km, and it increases to 70—80% at 2 pm. The ion concentration in the upper atmosphere is asymmetric at noon, attaining the maximum value at 2 or 3 pm. The concentration of nitrogen N^+ ions increases gradually from 3% to 6% in the daytime at the satellite's perigee and from 1% to 10% at distances from 900 to 1000 km.

O. L. Vaysberg [19], continuing his earlier investigations, analyzed data obtained by the Kosmos-5 satellite with special sensors consisting of th scintillators shielded with aluminum foil. Electrons of energies greater than 40 kev were measured. The rotating satellite had a period of 3—4 min in which the electron pitch-angle distribution could be measured. An LB diagram (Fig. 1) shows the mirror point distribution of electrons determined
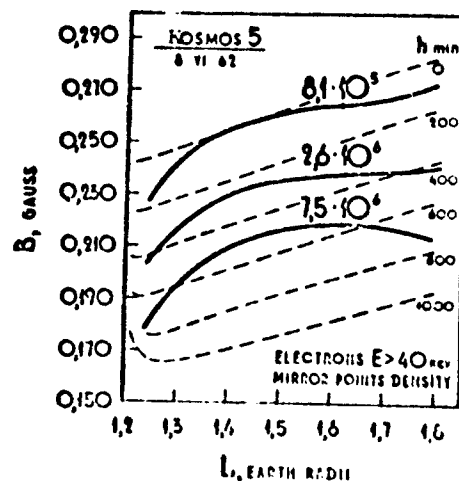

Fig. 2.

from three revolutions of the satellite. Data obtained were classified into three groups. The first group included measurements to the west from the South Atlantic magnetic anomaly with electron flux intensities from $8.1 \cdot 10^5$ to $2.6 \cdot 10^6$ el $cm^{-2} sec^{-1} ster^{-1}$, and the second and third group involved measurements obtained in the region of the South Atlantic anomaly and east of it, with the flux intensities from $2.6 \cdot 10^6$ to $7.5 \cdot 10^6$ el $cm^{-2} sec^{-1} ster^{-1}$ (for the second group) and $8.1 \cdot 10^5$ to $2.6 \cdot 10^6$ el $cm^{-2} sec^{-1} ster^{-1}$ (for the third group). The "Starfish" explosion limited the study of natural electrons in the magnetosphere.

B. N. Gorozhankin, K. I. Gringauz, and N. M. Shutte [20] studied the absorption of ultraviolet solar radiation in the upper atmosphere. The absorption of solar radiation was measured from saturated photoelectron currents emitted from flat metallic photocathodes of three photoelectron analyzers which were mounted on an artificial satellite. The satellite rotation was such that it was possible to assume that the maximal values of photocurrents occurred when the two normals to the photocathodes of the analyzers were directed toward the sun. Measurements of photo-currents were made at altitudes of 550 km and 220 km. The decrease in the photocurrent occurred with the satellite's entry into the ionosphere. The absorption coefficient was determined from the photocurrent intensities at various heights and the atmospheric thickness through which solar light passed.

V. F. Tulinov [21] studied the role of corpuscular radiation in forming the lower ionospheric layers. Rocket measurements were made to detect electron streams at altitudes up to 100 km. Electrons of energies above 35—40 kev were recorded. A significant increase in electron flux intensity was found at a height of 70 km. The absorption of electrons of energies above 40 kev was found at a height of 100 km and ion production at heights of 70—95 km. Ionization caused by corpuscular radiation may be considered to occur chiefly in the layer between 70 and 90 km.

Yu. Bragin [22] analyzed the concentration of charged particles measured by rockets from the research ship "Y. M. Shokalskiy." A special method was developed for measuring ion and electron concentration up to a height of 80 km. Profiles of charged particle concentration were determined and the existence of a maximum ion concentration in the stratosphere was demonstrated. The ion concentration at middle latitudes is greater than at the Equator. In daytime two or more regions of greater ion concentration are found, at the Equator and at the middle latitudes, but at night there is only one maximum at each location.

K. I. Gringauz, G. L. Gdalevich, V. F. Gubskiy, I. A. Knorin, V. A. Rudakov, and N. M. Shutte [23] analyzed measurements of the electron concentration and temperature in the ionosphere. The measurements were made with instruments mounted on geophysical rockets launched

in the early morning. Preliminary data are processed and represented graphically. Fig. 3 represents the vertical electron concentration with height. The curve a is drawn on the basis of data obtained from the rocket
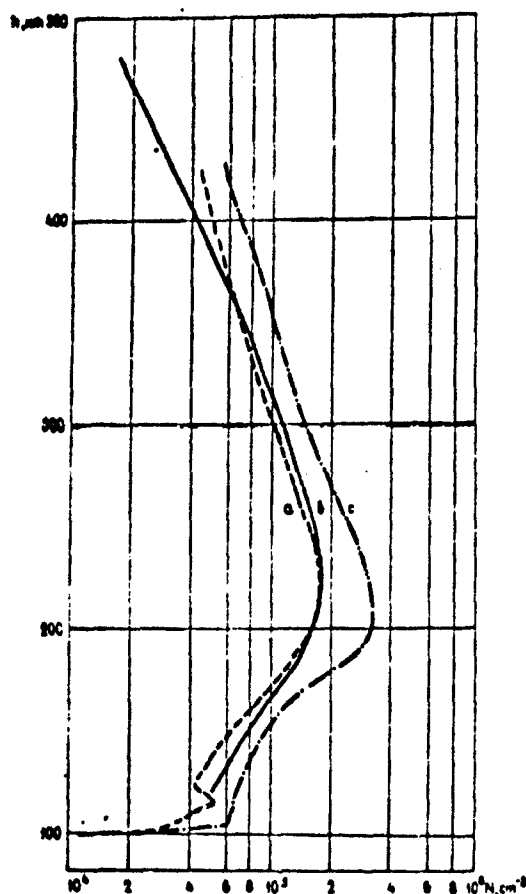
Fig. 3.

descent on 20 September 1965 by the dispersion interferometer; the curve c from similar data obtained on 1 October 1965; and the curve b from data obtained on 20 September 1965 by the Langmuir probe. Fig . 4 represents the electron temperature distribution with height obtained by the Langmui probe during the rocket's descent on 20 September 1965. The absorption of solar ultraviolet radiation in the upper atmosphere is represented by the curves in Fig. 5. obtained during the rocket's ascent on 20 September 1965.

T. M. Tarasova [24] studied emission lines of sodium luminescence with heights, continuing her former investigations. Variations in night-sky emission intensities were measured by rocket photometer with a complex rotational movement at heights from 64 to 200 km in the ascending branch of the trajectory. Maximum intensities were recorded at heights

of 108 and 165 km when the photometer axis was near the horizontal position and its sight beam passed the thickness of a luminous layer. No correlations were found between sodium, hydroxyl, and molecular and

Fig. 4.

Fig. 5.

atomic oxygen emissions in space. This indicates that the vertical distribution of sodium and other elements differs in individual layers. Only the ratio of lines 6300 Å/5893 Å in the total luminous flux was constant. This result was unexpected, becaus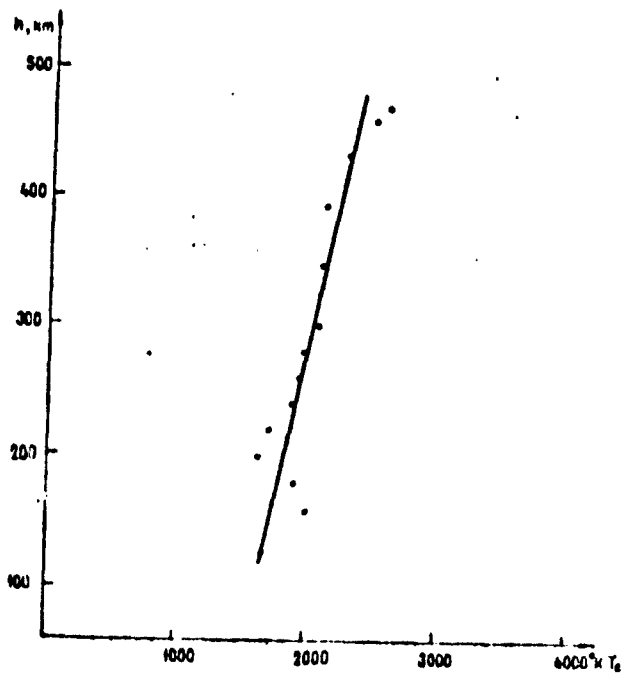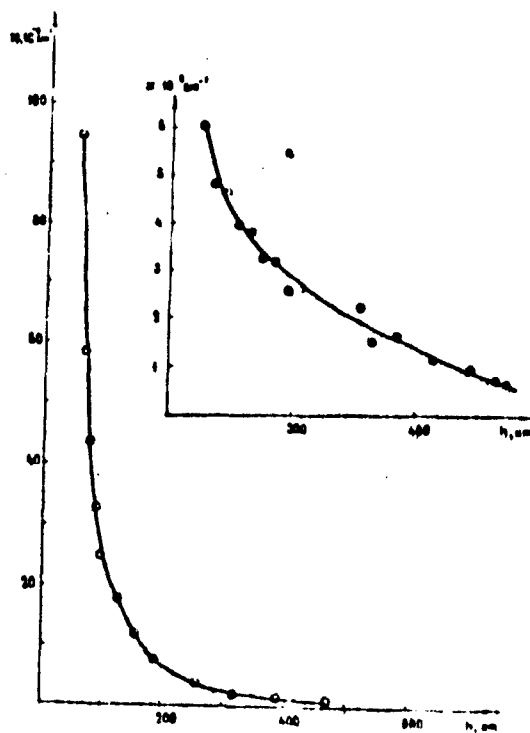e nocturnal luminescence of sodium is associated with altitudes of 70 –90 km and the luminescence of oxygen with altitudes above 200 km.

Section 6. Magnetosphere and Aurora

This section contains three abstracts of reports dealing with the electron distribution in the radiation belts above the regions of magnetic anomalies, the structure of the terrestrial proton radiation belts according to measurements made by the Elektron satellite series, and the structural model of the magnetosphere.

E. V. Gortchakov, A. V. Gurevich, and G. A. Timofeev [25] studied the electron distribution in the radiation belts under Coulomb interaction with the medium at low altitudes above the regions of magnetic anomalies. The geomagnetic field, especially its anomalies, exerts an influence on electron distribution at low altitudes. The electron mirror point in the drift depends upon the longitude. The Coulomb interaction frequency on electrons of energies less than 1 Mev in the magnetic shell L = 1.5 was studied using the kinetic equation and taking the scattering and deceleration of electrons into consideration. Results of computations show that electron distribution in the shell of L = 1.5 at fixed drift trajectories smaller than 200 km depends upon altitudes. This result agrees with experimental data.

S. N. Vernov, S. N. Kuznetsov, Yu. I. Logatchev, A. G. Nikolayev, E. N. Sosnovets, V. G. Stolpovsky, and P. V. Vakulov [26] studied the terrestrial proton radiation belts from data obtained by the Elektron satellites. Data were obtained in 1964 and the processing yielded the energy spectrum of trapped protons with probable energies above 1 Mev. The integral energy spectrum of protons shows a dependence upon the distance and the geomagnetic latitude. The position of the belt in space and its intensity depend upon proton energy. The integral energy spectrum of protons becomes softer with an increase in the distribution parameter- L level and harder with an increase in geomagnetic latitude. Experimental data agree with theoretical computations.

Yu. S. Sigov [27] formulated a model of the magnetosphere based on the equilibrium between rarefied plasma and the magnetic field of a two-dimensional dipole. This model describes the motion of charged particles from a cylindrical surface over a magnetic dipole. Particles move to the cylindrical center and are reflected from the boundary of the magnetosphere.

Such motion of solar particles occurs behind the front of a stationary shock wave. The mean velocity of the corpuscular stream may be varied by changing the particle distribution. Within the limits of this model the structure of a closed volumetric space with a magnetic field within it may be obtained for various parameters of the surrounding plasma.

Section 7. Polar Cap Experiments

This section contains only one abstract from a report presented to the Seventh Meeting of COSPAR concerning polar cap activities. Z. Svestka [28] from the Astronomical Institute of the Czechoslovak Academy of Sciences discussed records of polar cap activity associated with proton flare occurrences from 1956 to 1963. Proton flares were accompanied by type-IV bursts. Data from ionospheric soundings at high latitudes are available from 1938 to 1955. Not all of these data can be related to polar cap activities which are associated with blackouts for a longer interval. The ratio of the yearly polar cap activity N to the Wolf relative number R is variable during the solar cycle.

COMMENT: Reports of the Soviet Bloc scientists presented at the Seventh COSPAR Session in Vienna in May 1966 were concerned with physical phenomena in the terrestrial atmosphere. Detailed investigations of outgoing radiation of the terrestrial atmosphere, on the role of ozone in atmospheric radiation, on the distribution of neutral and ionized gases and the pollution of the atmosphere by rocket eruptions, on the constituents of the geocorona, and on a special method for determining the temperature of the upper atmosphere were reported. Results of investigations on the absorption of solar light in the Earth's atmosphere and the terrestrial proton radiation belts were presented. The scientific approach to the problems mentioned above is on the level of Western investigations, although parallelism is observed in few cases. These short abstracts are based on the theses of the reports. It may be hoped that the data of these reports will be processed and published in scientific periodicals.

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GROWING YTTRIUM-ALUMINUM GARNET CRYSTALS

by John Kourilo

Soviet achievements during the period 1963-1965 in growing yttrium-aluminum garnet crystals have been reviewed. Different trends were noted in the development of the growth technique from fluxed melts. Major progress was achieved by adding boron oxide to the flux. As a result of this improvement, larger YAG single crystals having an estimated linear dimension of about 2 cm were obtained. Some progress was made in defining the criteria for the growth of quality crystals, although conflicting conclusions were reached by two different teams of Soviet scientists. A comparison was made between Soviet and Western research data.

After numerous Soviet studies on the growth of rare earth-iron garnet crystals,* information was recently published in the Soviet literature on research into the growth of rare earth-aluminum garnet crystals, isomorphous with the rare earth-iron garnets. The only previous indication of Soviet interest in the rare earth-aluminum garnet crystals was found in a 1964 article by V. A. Timofeyeva and co-workers, already reviewed the FSB.*

New information on this subject was contained in two articles which a reviewed here in view of recent American reports on the luminescence property of rare earth-aluminum garnet crystals. Particularly interestir are the reports on high-power coherent emission from Ho^{3+}- and Nd^{3+}-doped yttrium-aluminum garnet (YAG) crystals, which promise a continuous laser operation at room temperature.** In the Soviet literature, in addition to vague hints of unspecified origin on the luminescence proper ty of certain garnets,*** the only references to the lasing potential of YAG crystals are of Western origin. A review of the most recently available Soviet research data on the growth of YAG crystals may provide some clu to Soviet progress toward the development of this new host material for solid-state lasers.

The primary research interest of the authors of both articles reviewe was the study of crystal growth techniques from a molten flux with the evi dent purpose of perfecting the techniques to grow exclusively single crysti

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* See FSB, v. 1, no. 5, 1965, 24-29 and v. 2, no. 2, 1966, 37.
** Bell Laboratories Record, v. 42, no. 8, 1964, 280; Applied Physics Letters, v. 8, no. 8, 1966, 200-202.
***Timofeyeva, V. A., T. V. Lebedeva, and T. S. Kon'kova. Peculiarity of the morphology of garnets grown from PbO and PbF_2 molten flux. Kristall grafiya, v. 10, no. 1, 1965, 92-95.

of adequate size and free of defects. The authors of these two articles, however, had differing approaches and used different techniques. S. Sh. Gendelev and A. G. Titova, who is associated with the Leningrad Institute of Semiconductors, AS USSR, used spontaneous crystallization from a lead oxyfluoride flux to grow the $Y_3Al_5O_{12}$ crystals and studied the morphology of the grown crystals as a means of defining the growth conditions which lead to the formation of various defects (inclusions, cracks, etc.) in the crystals [1]. The article contains data presented at the Third Conference on Crystal Growth, held in Moscow from 18 to 25 November 1963. The growth technique used by the authors was essentially the same as that developed for $Y_3Al_5O_{12}$ crystals by R. A. Lefever, J. W. Torpy and A. B. Chase* and conceived earlier by I. W. Nielsen** for $Y_3Fe_5O_{12}$ crystals. The starting composition of the melt used by the authors was (in mol.%): Y_2O_3, 3.4; Al_2O_3, 7; PbO, 41.5; and PbF_2, 48.1. In a normal operation, the rate of heating to 1200°C was 8 hr, retention time at that temperature was 15 hr, the initial cooling rate was 5°/hr, then 3°/hr to 950°C, and final cooling with the furnace shut off.

Under these conditions single crystals up to 2 cm in size were obtained in a 150—200 cc crucible. The YAG crystals were smaller than the ferrogarnets and, in contrast to YIG crystals, were predominantly formed by [110] faces. In addition to YAG, the crystals of solid solutions $Y_3Al_xFe_{5-x}O_{12}$ were grown from the melts having a composition intermediate between those used for YAG and YIG. The [110] form was also predominant in these crystals. The morphological difference between YAG and YIG was explained principally in terms of the absence of a deficiency of Y^{3+} ions in relation to Al^{3+} ions, since the starting Al_2O_3/Y_2O_3 ratio in the melt (2.06) was much closer to the stoichiometric ratio than in the case of YIG preparation by the Nielsen technique, where the Fe_2O_3/Y_2O_3 ratio was 2.75. It should be noted in this connection that V. A. Timofeyeva and co-workers*** using a similar growth technique but a stoichiometric Al_2O_3/Y_2O_3 ratio in the melt obtained two types of YAG crystals in the same experiment: one colorless and predominantly formed by [211] faces, the other greyish-yellow and formed exclusively by [110] faces (rhombic dodecahedron). This morphological difference was explained by the presence of impurities in the second type of crystals. Usually, small YAG crystals which were prepared by Gendelev and Titova [1] were homogeneous, but larger ones contained multiphase inclusions which were preferentially concentrated in the parts of the crystal adjacent to the crucible. The source of these inclusions, clearly visible in a transparent crystal, was crystallization of the impoverished melt entrapped

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* J. Appl. Phys., 32, 1961, 962
** J. Appl. Phys., Suppl., 31, 1960, 51
***See FSB, v. 1, no. 5, 1965, 24-29.

between the layers of the garnet material, which grow in opposition to each other in the second, prolonged, dendritic growth phase (the first phase is a normal nucleation). Dendritic growth is explained by a high degree of supersaturation of the melt because of significant supercooling before the beginning of crystallization. A decrease in supersaturation toward the end of crystallization determined the beginning of the last phase—the growt of plane faces forming the crystal.

Practical conditions of crystallization determine the relative importan of the growth phases. For instance, an increase in viscosity of the melt would favor dendritic growth. In contrast, a minimum cooling rate durin₉ the second growth phase would minimize dendritic growth. The growth rate can be increased again during the final phase without any damage to the quality of crystals. The authors observed various defective forms on the [110] and [211] faces of $Y_3Al_5O_{12}$ crystals, which they discussed in terms of growth conditions (supersaturation and viscosity of melts, solvent vaporization, etching by fluorine). Defective growth was interconnected with internal strain which, in case of a rapid growth, caused formation of cracks on [211] faces.

In a more recent study [2], V. A. Timofeyeva and Y. Kvapil also used a molten flux technique to grow YAG single crystals, but employed a different flux (solvent) and oriented (on seed) instead of spontaneous crystallization. The authors, who are associated with the Institute of Crystallography, AS USSR, studied comparatively the most commonly used fluxes: lead oxide, PbO and lead oxyfluoride, with the addition of a small amount of B_2O_3. The idea of using B_2O_3 additions was borrowed from a 1964 U.S. study.* B_2O_3 was added to the fluxes to minimize the high vapor pressure of PbO and PbF_2, which in the past had hindered establishing the phase diagrams by differential thermal analysis and determination of YAG solubility in the common fluxes. For these reasons, in the past oriented crystallization from PbO or PbF_2 was seldom used. Solubility criteria guided the authors in selection of the most appropriate solvent for growing YAG crystals on seed.

The authors described in detail two apparently original methods of determining solubility of $Y_3Al_5O_{12}$ in $PbO-B_2O_3$ and $PbO-B_2O_3-PbF_2$ melts. One, tempering of the melt, made it possible to evaluate approximately the equilibrium of the system and also to define the temperature limits of crystallization of the stable phases in the $Y_2O_3-Al_2O_3-PbO-B_2O_3$ PbF_2 system. Another method, experimental seeding of the melt, enablec the authors to determine the saturation point of the melt with $\pm 10°C$ accurac Solubility data indicated that the $PbO-B_2O_3-PbF_2$ flux is the most appropr:

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* Bell Laboratories Record, v. 42, no. 8, 1964, 280.

for growing YAG crystals, since at 1290°C the solubility of $Y_3Al_5O_{12}$ in $PbO-B_2O_3-PbF_2$ was 21.9% versus 16.6% in $PbO-B_2O_3$ at the same temperature. Extrapolation of data into a higher temperature region showed an even greater difference in solubility in the two solvents studied.

Once a solid scientific base for YAG crystallization with seeding was established, the authors attempted to grow YAG crystals by this technique. One advantage of oriented over spontaneous crystallization was seen in the possibility of overcoming the chief obstacle to control of crystal growth, which is presented by the existence of a large metastable region with undetermined limits. The apparatus for growing YAG crystals comprised a platinum cylinder and a resistance furnace with a rhodium heating element for temperatures up to 1500°C and a thermoregulator to maintain temperature in the cooling period with $\pm 1°$ accuracy. This set-up made it possible to maintain a uniform temperature along the height and diameter of the cylindric crystallizer. The absence of even a small temperature gradient was a basic requirement for preventing the formation of the parasitic crystals. The seed crystal was placed near the bottom of the crystallizer to insure a uniform crystal growth. Under these experimental conditions, the seed crystal increased 10 times in weight and 4 times in linear dimensions, as shown in Fig. 1. Further growth was difficult
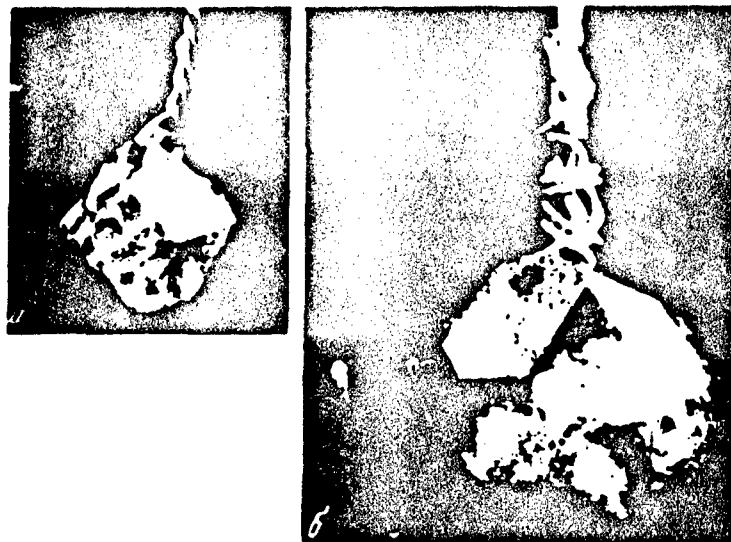
Fig. 1.   Original $Y_3Al_5O_{12}$ seed crystal (a) and grown crystal (b)

because of the formation of parasitic crystals in the upper part of the melt.

Exclusive crystallization of $Y_3Al_5O_{12}$ occurred at 1255°C, which is the saturation point of the melt as determined by air tempering of a drop of melt at the end of a platinum wire. Above that point, in the superheated melt at 1260—1270°C $Y_3Al_5O_{12}$ crystals coexisted with Al_2O_3 and $YAlO_3$

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crystals. At 1270—1280°C the melt yielded only Al_2O_3 and $YAlO_3$ crystals.

COMMENT: The Soviet effort at growing YAG single crystals for laser application as late as the middle of 1965 appears to be still in the exploratory research stage. This effort was divided between two teams of scientists, one headed by Gendelev and Titova [1], the other by V. A. Timofeyeva [2]. Basically, only one crystal growth technique, growth from solution (flux), was explored by both teams. Their efforts produced relatively small crystals of an estimated maximum linear dimension of about 2 cm. Crystal growth even under the most favorable conditions was limited by parasitic growth [2]. A measure of progress was achieved in perfecting growth technique and establishing the growth criteria of quality crystals. In comparison with Western achievements in the same field, Soviet research appears to be lagging behind in respect to the size and, in particular, the quality of the crystals. Also, the Western growth techniques are more diversified than the Soviet techniques.

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SCIENCE & TECHNOLOGY NOTES

VLF TRANSMISSION THROUGH THE IONOSPHERE

V. I. Aksenov [1] has undertaken to determine accurately the coefficients of transmission and reflection of low-frequency electromagnetic waves propagating through the ionosphere. In the general case, where the transmitted wave vector makes an arbitrary and possibly variable angle with the earth's magnetic field vector, mathematical difficulties arise which have precluded solution of this problem, even when the effect of earth curvature is disregarded.

In practice it is an acceptable approximation to use an optical model to find transmission coefficients, provided that the following inequality is satisfied:

$$(c / \omega) \left(|d\tilde{n} / dz| \big/ |\tilde{n}|^2 \right) \ll 1$$

where $\tilde{n} = n - j\varkappa$ is the complex index of refraction and ω is the signal frequency. However, below the VLF range this criterion is clearly not met. Calculations show that at frequencies of a few kilocycles, the left-hand side of the expression rises to the order of 1 in the ionosphere, under both day and night conditions; hence the optical model breaks down.

Aksenov therefore attempts a rigorous solution for propagation at ELF-VLF frequencies through a simplified magnetoactive ionospheric plasma. His model assumes that plasma parameters vary only in the z (vertical) direction, and that a plane wavefront signal is generated, also vertically. Effects of ionic and molecular motion are neglected. An arbitrary layer of plasma $z_0 \leqslant z \leqslant z_1$ is investigated, whose lower boundary z_0 is taken to be the upper limit of free-space propagation conditions, i. e., where $\tilde{n}$ ceases to be unity. Proceeding from the wave equation for propagation through the interval from z_0 to z_1, and from the expression for $\tilde{n}$ in the usual terms of plasma frequency, electron gyrofrequency, and electron collision frequency, the author derives expressions

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for the desired transmission and reflection coefficients over the assumed
interval.

The derived equations were integrated on a BESM-2 computer, assum:
height intervals of 50—100 km for daytime and 80—200 km for nighttime
conditions, at frequencies from 1.5 to 100 kc. The geomagnetic latitude
was assumed to be 50°. Electron density and effective collision frequency
as functions of altitude were taken to be as in Fig. 1, which agrees closely
with the figures reported by Fligel' [2, 3] and others. The transmission
coefficient (D) for both day and night conditions could then be calculated
(Fig. 2, solid lines). The broken lines in Fig. 2, obtained using the
optical model, demonstrate the discrepancies at low frequencies; the
optical model does not reveal, for example, the peak of D at 4 kc at night,
which is in the optimum whistler mode range.
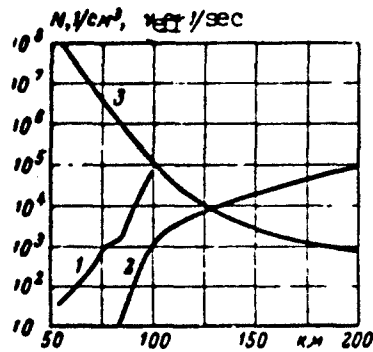
Fig. 1. Density and collision
frequency

1 - Electron density, day;
2 - electron density, night;
3 - collision frequency.
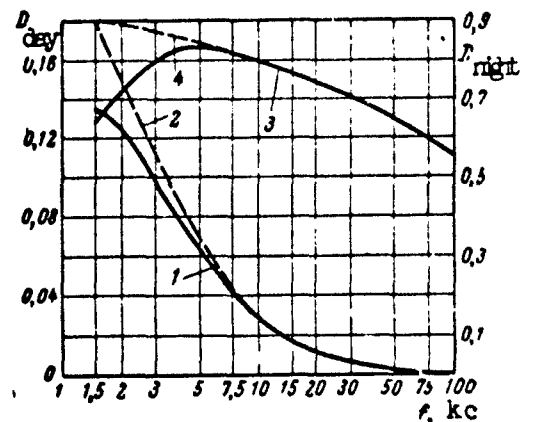
Fig. 2. Ionospheric transmission
coefficients

1, 2 - Day; 3, 4 - night. Curves
2 and 4 from optical model.

Aksenov emphasizes that the curves in Fig. 2 are for extraordinary
waves only. Absorption of the ordinary wave component by the ionosphere
is so great that it is meaningless to analyze it in the foregoing manner.
Calculations show that at 1.5 kc, ordinary waves in daytime are more than
40 db down upon reaching 100 km altitude, and this factor rises rapidly
with higher frequency.

Calculated reflection coefficients for incident signals were also obtained, and are shown in the three curves of Fig. 3. The similarity of the three curves is apparently due to the fact that the reflective layer occurs near the lower ionosphere boundary, where there is little difference between day and night refractive behavior.
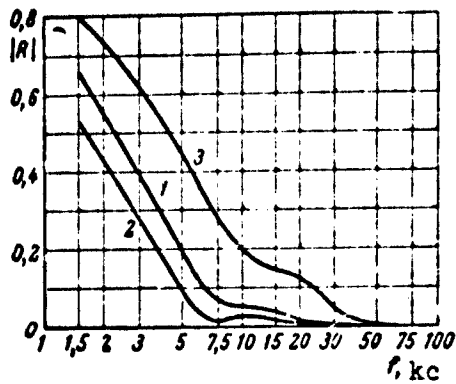
Fig. 3. Ionospheric reflection coefficients

1 - Extraordinary wave, day;
2 - extraordinary wave, night;
3 - ordinary wave, day.

In summarizing his findings, Aksenov reiterates the main point: that for signal frequencies below about 5 kc, the optical model becomes increasingly erroneous for analyzing propagation through the ionosphere.

[SH]

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BROADBAND DIPOLE ARRAY WITH AN ACTIVE REFLECTOR

A unidirectional cophased dipole antenna array with an active reflector fed by a directional coupler is analyzed. It is shown that, with certain chosen parameters (coupling coefficient, dipole and feeder characteristic impedances), this antenna maintains high directivity with good matching and efficiency characteristics in a wide frequency band without re-adjustments.

Cophased dipole antenna arrays are usually constructed in two sections, an active section fed by the transmitter and a passive reflector section in which the amplitude and phase of the currents are stub tuned to adjust the reactive part of the antenna impedance. Antenna current components from the active and passive sections add in the forward direction and cancel each other in the opposite direction, giving rise to antenna directivity. In other types of systems the reflector may also be active, but special transformers must be used to insure proper amplitude and phase relationships between the currents. In both types the antennas are directional at the operating frequency only. At frequencies slightly removed from the optimum, the front-to-back directivity ratio deteriorates, the antennas are no longer properly matched to the feed system, and the efficiency decreases accordingly.

The authors report on a new driven cophased dipole antenna system comprising two arrays, each containing two sections of four horizontal two-section dipoles placed one above another. Each dipole section consists of four conductors which form the corners of a parallelepiped. Individual antenna down-leads are used for each dipole array, and the current phases are therefore equal. The opposite ends of these down-leads are connected to a directional coupler which channels the currents with proper amplitudes to corresponding dipoles.

This antenna system may be analyzed by assuming that each array may be replaced by an equivalent dipole with a corresponding radiation impedance equal to the sum of all actual dipole impedances, including the effect of mutual interaction between the main dipoles and the directors. For purposes of analysis, the reflector dipoles may also be analogously treated as one dipole. The calculations performed by the authors apply to an antenna system with the following parameters: distance (t) between the center lines of adjoining four-dipole columns, 430 mm; diameter of each conductor used to form a dipole arm, 0.00093 t; diagonal of the transverse cross section of the parallelepiped formed by the conductors, 0.0745 t; length of each dipole arm, 0.42 t; vertical distance between dipoles, 0.581 t; distance between the two arrays, 0.337 t; characteristic impedance of each dipole feeder, 300 ohm; directional coupler length, 0.3 t; maximum directional coupler current splitting factor, 0.2.

The authors develop expressions for the resistive and reactive components of self- and mutual impedances of the equivalent dipoles as functions of $1/\lambda$ (where 1 is the dipole arm length and λ the wavelength). From these expressions and the directional coupler parameters, the basic antenna performance factors such as the antenna radiation patterns, the input traveling wave ratio, the antenna efficiency, and the back-to-front ratio are determined. The deviations are based on a previous work on a driven cophased two-dipole antenna fed through a directional coupler. * The theoretical and experimental curves for the traveling wave ratio (TWR), efficiency (η), and back-to-front ratio (B/F) are shown in Figs. 1, 2, and 3, respectively. The experimental results were obtained for the
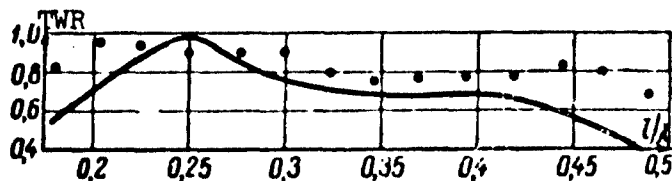
Fig. 1. Traveling wave ratio as a function of $1/\lambda$

Solid line - theoretical; dots - experimental.

Fig. 2. Efficiency as a function of $1/\lambda$

Solid line - theoretical; dots - experimental.
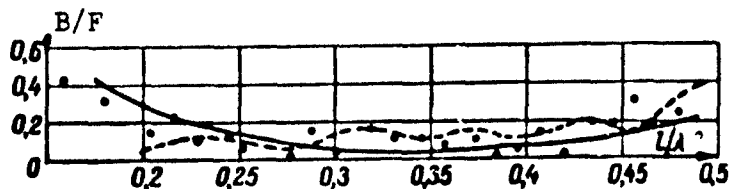
Fig. 3. Back-to-front directivity ratio as a function of $1/\lambda$

Solid line - theoretical; dots - experimental; broken line - antenna with nonperiodic reflector.

antenna whose dimensions were given above. Each array in the experimental setup was fed by a coaxial cable, and the dipoles were driven through a symmetric 300-ohm KATV cable. The frequency range used in the test was limited to the band between 300 and 900 Mc. Both the general pattern shape and the half-power beam widths of the radiation patterns [not supplied] are said to conform to the theoretical patterns. It is apparent from the theoretical curves that the antenna is highly unidirectional (the B/F ratio does not exceed 0.1, 0.2, or 0.3 in the 1.6:1, 2.1:1, or 2.5:1 frequency ranges, respectively). A good match between the

* Kuznetsov, V. D., and V. K. Paramonov. Dipole with a reflector, fed by a directional coupler. Elektrosvyaz', no, 3, 1966, 26-32.

antenna proper and the feed system is evident from the high TWR (0.7 for most of the range). The efficiency is 90% at short wavelengths and 70% at longer wavelengths.

One of the salient features of the antenna system is its ability to maintain its performance level even when the parameters of its components are sub-optimal. For example, the length of the directional coupler does not affect the basic antenna characteristics. The dipole array dimensions are not critical and may be made equal to the corresponding dimensions of typical cophased dipole arrays, i.e., distance between arrays, $\lambda_0/4$; vertical distance between individual dipoles, $\lambda_0/2$; and dipole arm length, $0.42\lambda_0$ (where λ_0 is the fundamental antenna wavelength). The only relatively critical parameter is the dipole impedance, which tends to extend the antenna frequency range and assures a good match between components if it is low.

For comparison, the broken line in Fig. 3 represents the B/F directivity ratio of a cophased antenna with nonperiodic reflector, i.e., a reflector in the form of a curtain of parallel conductors separated by a distance of 0.035 t. From this and other comparisons, it was concluded that the performance of the new antenna is equal to or better than that of an array with nonperiodic reflector or a cophased dipole antenna array in which the reflector is tuned at each frequency. (Kuznetsov, V. D., and V. K. Paramon Cophased antenna with an active broadband reflector. Elekrosvyaz', no. 6, 1966, 20-27)   [BD]

EXPERIMENTAL INVESTIGATION CF ATMOSPHERIC TRANSMITTANCE AT WAVELENGTHS IN THE SUBMILLIMETER RANGE

An experimental study of radiation absorption in the submillimeter region was made under field conditions. Measurements were conducted in the atmospheric windows of relative transmittance centered at $\lambda = 0.2$, 0.29, 0.36, 0.45, 0.73, and 0.87 mm. The absorption coefficient of atmospheric water vapor was measured by varying the humidity. The radiation source was a mercury-quartz lamp mounted in the focal plane of a parabolic reflector (diameter, 900 mm; focal length, 365 mm) and having a continuous emission spectrum in the entire range of wavelengths considered. A field spectrometer containing a monochromator with diffraction grating and an optical-acoustical radiation indicator was used at the receiving end.

The absorption coefficient was determined from the dependence of the received signal on humidity at the following distances between the radiation source and the receiver: 25 m for λ = 0.2 and 0.29 mm; 150 m for λ = 0.36 and 0.45 mm; and 250 m for λ = 0.73 and 0.87 mm. The humidity was recorded by aspiration psychrometers simultaneously at both points.

The dependence of signal strength on humidity is illustrated in Fig. 1. Values of the absorption coefficient were obtained by statistically processing
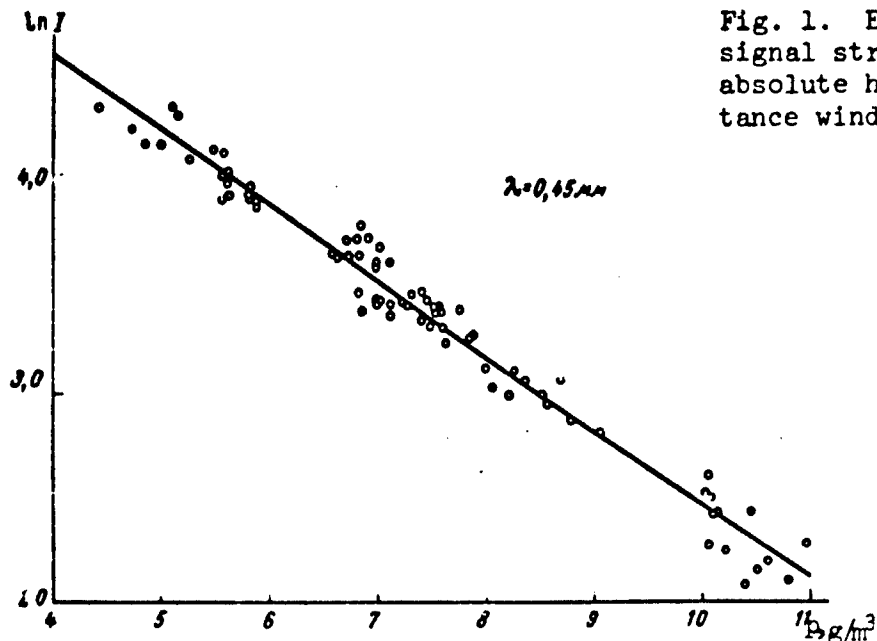

Fig. 1. Experimentally obtained signal strength as a function of absolute humidity for transmittance window λ = 0.45 mm

the experimental data by the method of least squares. The measured values of the coefficient represent an averaged absorption $(\bar{\gamma}_{exp})$ in a frequency range determined by the frequency characteristics of the receiving equipment.

The values of $\bar{\gamma}_{exp}$ for various atmospheric transmittance windows, together with the width of the transmission band (Δv) and the average wavelength for each window, are given in Table 1. The averaged values of the

Table 1. Experimental and theoretical values of the absorption coefficient at standard humidity ρ_0 = 7.5 g/m^3 (T = 293°K, p = 760 mm Hg)

λ, мм	v, cm^{-1}	Δv, cm^{-1}	$\bar{\gamma}_{exp}$ db/km	γ_{theor} db/km	$\dfrac{\bar{\gamma}_{exp}}{\bar{\gamma}_{theor}}$	$(\gamma_{exp})_{min}$ db/km	$(\gamma_{theor})_{min}$ db/km	$(\gamma_{exp})_{min}$ according to data of N.I. Furashov, db/km[*]
0,20	50,0	2,67	334±16	245	1,36	254±24	186	267±6
0,29	34,25	1,24	336±17	262	1,28	263±25	205	270±9
0,36	27,78	1,65	66,7±5	41	1,63	62±6	38	75±8
0,45	22,22	1,60	73±4	41,5	1,76	65±5	37	84±10
0,73	13,70	1,12	23,2±1,7	15,4	1,51	17,8±2	11,8	—
0,87	11,49	0,84	17±1,4	8,2	2,08	12,5±1,8	6	—

* Furashov, N. I. Optika i spektroskopiya, v. 20, no. 3, 1966, 427.

absorption coefficient were also determined theoretically and compared with those obtained in the experiments. As the table indicates, the measured values exceed the theoretical by a factor of 1.3—2.

Since the averaged values of $\bar{\gamma}_{exp}$ depend on the actual measurement conditions and, in particular, on the transmission band and frequency characteristic of the equipment used, they cannot give a true picture of absorption in the atmospheric windows considered. Minimum values of the averaged coefficient $(\gamma_{exp})_{min}$ were therefore computed. Both the values of $(\gamma_{exp})_{min}$ in the atmospheric windows and the corresponding theoretical values for the minimum absorption coefficient are tabulated. For comparison purposes, the results obtained by N. I. Furashov under laboratory conditions using a vacuum spectrometer are also included in the table. (Ryadov, V. Ya., and G. A. Sharonov. Experimental investigation of transmittance in the Earth's atmosphere for waves in the submillimeter region. Radiotekhnika i elektronika, v. 11, no. 6, 1966, 1037-1045) [JR]

LEAD METANIOBATE PIEZOELECTRIC VIBRATION PICKUP

After long study, two East German scientists from the Institute of Electro- and Structural Acoustics of Dresden Technical University have developed an experimental sonic transducer for high-temperature applications. Extension of the working temperature range of the transducer to 570°C was made possible by the use of lead metaniobate as a material for the ceramic component of the transducer. The idea of using lead metaniobate in transducers originated in view of the fact that the ferroelectric Curie point (570°C) of lead metaniobate is much higher than the upper limit (250°C) of the working temperature range of presently used transducer materials. The authors described preparation of the lead metaniobate ceramic material, determination of its electromechanical characteristics, the experimental sonic transducer with built-in lead metaniobate ceramic disks, and the working parameters of this transducer.

The starting point in the preparation of lead metaniobate was the reaction:

$$PbSO_4 + Nb_2O_5 \rightarrow PbNb_2O_6 + SO_3,$$
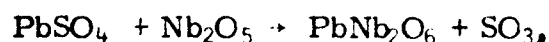
which was carried out in two steps. First the compacted mixture of the

reactants was sintered at 1240°C in air, and then the 15 x 3 mm disks of the sintered and plastified material were sintered again at 1320°C. This high sintering temperature was required to obtain the exclusively ferro-electric phase which, on cooling to room temperature, crystallized into an orthorhombic system. Hygroscopicity of $PbNb_2O_6$ was minimized by the addition of small amounts of fluxing materials which yielded $Pb(Zr_{0.5}Ti_{0.5})O_3$ on sintering.

The disks thus prepared were electrically polarized by applying a field of 20 kv/cm at 200°C. The applicability of the lead metaniobate system in sonic transducers or vibration pickups was deduced from comparable values of the electromechanical coupling factor in a mode of thickness vibration of lead metaniobate and of the known piezoelectric ceramics, such as barium titanate and lead zirconate-lead titanate. The coupling factor of lead metaniobate was about 30% and the measured piezoelectric stress constant g_{33} was relatively high. The plots of temperature dependence of the fractional changes in dielectric permeability, $\varepsilon_{33}^T/\varepsilon_{33\ 20C}^T$, and in piezoelectric stress constant, $g_{33}/g_{33\ 20C}$, indicated a steady increase or decrease, respectively, with increasing temperature of lead metaniobate.

The experimental sonic transducer was equipped with two 12 x 1 mm disks of polarized lead metaniobate with a perforation 3 mm in diameter. Total capacitance of the disks was about 200 pF. The transducer was made of nonscaling chromium steel, thermally insulated with the ceramic and provided with a shielded high-temperature cable. Total capacitance of the cable was 80pF. The total mass of the transducer, without cable, was 52 g and the seismic mass 10 g. For room-temperature (25°C) experiments, the transducer was screwed onto an electrodynamic vibrator and shaken to vibration frequencies from 20 cps to 9 kc. The voltage transmission coefficient Ba_0 of the transducer, complete with the cable and an amplifier, was 4.8 mv/ms^{-2}. For experiments at higher temperatures, the transducer was screwed onto a short piece of tube which was attached to the vibrator and the tube with the transducer was placed in an electric furnace.

At temperatures below 350°C the voltage transmission coefficient of the transducer was largely independent of vibration frequency within the above-indicated frequency range, but at temperatures above 350°C the transmission coefficient Ba_T/Ba_0 decreased rapidly with increasing temperature. This decrease was caused by the simultaneous linear decrease in resistivity of the insulator of the lead metaniobate disks, as shown on an experimental plot. Endurance tests at 430°C, at three different frequencies (120, 250, and 400 cps), indicated that the transmission coefficient remained constant for 2 hr at a given frequency.

The authors anticipate that further improvement of the piezoceramic vibration pickup of the type described will ultimately make possible its

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use at higher temperatures. (Walther, L. and G. Beister. Lead metaniobate piezoelectric vibration pickup. Hochfrequenztechnik und Elektroakustik, v. 74, no. 5-6, 1965, 204-205).　　　　　　　[JK]

CONFERENCES

CONFERENCE ON RESEARCH REACTORS

The Fourth Working Conference on Physics and Engineering of Research Reactors, held in Budapest in November 1965, was attended by representatives from Bulgaria, Hungary, East Germany, Poland, Rumania, USSR, Czechoslovakia, the Chinese People's Republic, and the Joint Institute of Nuclear Research. A total of 102 papers dealing with the modification of existing research reactors, reactor dynamics, and critical assemblies were presented. The highlights of scme of these papers are given below.

S. M. Feynberg (USSR) presented a paper on the future development of research reactors. He reported that during the past decade, the thermal neutron flux intensity in research reactors has increased from 3×10^{14} to 3×10^{15} n/$cm^2 \cdot$sec, and present trends indicate a further increase to $2-5 \times 10^{16}$ n/$cm^2 \cdot$sec. The specific power in the core ten years ago amounted to only about 50 kw/1 as compared with the present 2500 kw/1 (SM-2 reactor). Feynberg also discussed some problems associated with the development of "loop-" and "beam"-type reactors and presented some data on the MIF beam-type reactor which generates a neutron flux of 10^{11} n/$cm^2 \cdot$sec at the beam-tube exit. He also disclosed certain design features of a neutrino generator which, during operation in high-power pulsed regimes, can produce a favorable relationship between the cosmic and radioactive background and the useful effects; this would permit the use of research reactors in a new field -- research on the properties of neutrinos.

The paper "Physical problems in the development of fast power reactors" presented by M. N. Nikolayev (USSR) aroused great interest at the conference. He discussed the present status of reactor and neutron physics and the basic problems which have arisen in the development of the current fast power reactors.

V. V. Goncharov and V. A. Tsykanov reported on the operation of the MR and SM-2 research reactors. They described the results of the testing of individual reactor components, the operation of experimental loops and channels, and the radiation stability of reflector materials and other internal structures. Considerable attention was devoted to the problem of increasing the power of currently operational IRT and VVR reactors to 5—10 Mw and higher.

G. N. Zhemchuzhnikov and P. M. Yegorenkov (USSR) presented new methods of increasing the power of a typical IRT reactor by employing new types of fuel elements and new methods of heat removal from the reactor core.

A plan for modernizing the VVR-M reactor in order to expand its experimental capabilities was presented by K. A. Konoplyev (USSR). He proposed installing a special hot chamber above the reactor; this would be equipped with a viewing system and manipulators.

Ye. Aleksandrovich (Poland) reported on the work being done to modify the EVA reactor to raise its power from 4 to 10 Mw by installing fuel element assemblies similar to those used in VVR-M reactors. Similar efforts were described by representatives from Czechoslovakia and Hungary. Reports were also presented on the current status of experimental research being conducted on IRT and VVR reactors.

The representatives from Hungary and Bulgaria described some methods of measuring fuel element temperatures. A number of papers were devoted to the development of modern control and measuring equipment for the reactor control and safety systems. The Rumanian representative in his paper on an "Automatic control system for the VVR-S reactor" described the use of standard time functions for setting the power level and insuring that it varies exponentially, thus eliminating the process of taking logarithms and differentiating. The unit of the standard time functions consists of two operational amplifiers - an integrating and a summing amplifier. The feedback of the integrating amplifier circuit, and the initial conditions and the gain are different for different operating regimes.

The paper entitled "New simplified semiconductor-type control and measuring equipment for a control and safety system for an experimental nuclear reactor" (Poland) outlines the dynamics of the operations of the new system under various regimes. This system makes it possible to increase starting reliability and improve static accuracy and the dynamic characteristics.

A Hungarian paper described the use of a pulse counter for period measurements. D. Al'bert et. al. (GDR) reported on the measurement of neutron gas temperatures in the reactor core using Lu^{176}, Eu^{151}, and Pu^{239} resonance detectors.

S. Ishmayev (USSR) presented the experimental results of neutron thermalization in respect to time in hydrogenous moderators.

A number of papers dealt with the results of measuring neutron noise in a reactor in connection with the determination of the transfer function and other reactor characteristics. One of the Polish papers described the possibility of controlling (with $\pm 3\%$ accuracy) the reactor power level based on the activity of N^{16} formed in the water coolant. (Zhemchuzhnikov, G. Conference on physics and engineering of research reactors. Atomnaya energiya, May 1966, 450-451)   [AS]

FIFTH SCIENTIFIC CONFERENCE ON THE PROBLEMS OF EVAPORATION, COMBUSTION, AND GAS DYNAMICS OF DISPERSED SYSTEMS (USSR)

The Fifth Scientific Conference on Evaporation, Combustion, and Gas Dynamics of Dispersed Systems was held at Odessa State University from 27 September through 2 October 1965. The conference was convened by the University; the Council for High-Temperature Thermodynamics and Thermal Physics of the Ukrainian Academy of Sciences also participated. Some 216 scientists representing various institutes and more than 100 scientists and students of Odessa State University took part in the work of the conference.

The conference was divided into two sections: one on phase transitions in aerodispersed systems and the other on combustion and gas dynamics. At the plenary session of both sections, 51 papers dealing with the theory and practice of the formation and stability of aerosols, heat exchange, and gas dynamics of two-phase flows and 58 papers on theoretical and experimental studies of combustion and evaporation of dispersed materials at high temperatures were presented.

In the section on dispersed systems, B. V. Deryagin, Corresponding Member of the Academy of Sciences USSR, reported on new progress in the study of course-dispersed aerosols, and professor M. S. Shishkin reported on the conditions of the growth of snow, sleet, and hail particles in supercooled clouds. Deryagin's paper and Yu. A. Yalamova's paper on the theory of diffusiophoresis and thermophoresis of large aerosol particles were discussed in great detail.

I. M. Yur'yev, V. M. Volushchuk, and E. M. Ovchinnikova presente papers on the calculation of the coefficients of capture of aerosol particle and I. I. Paleyev, F. O. Agafonova, and M. Ye. Lavrent'yev reported or results of experimental studies of the flow of aerodispersed systems. Re sults of experimental studies were also presented on the motion of dispersed materials in vertical closed tubes by S. M. Reprintseva and M. Fedorovich.

V. G. Khorguani described the results of studies of uniform particle motion under gravitational forces in a viscous medium, and G. M. Gavril and A. A. Smirnov reported on the outflow and propagation of aerosol streams. The effect of perturbations in a liquid on its outflow from a noz was discussed by V. P. Belyakov, M. L. Dranovskiy, S. I. Sul'shenko, and I. I. Malyavin.

M. L. Mikhel'son and I. Ya. Kolesnik reported on the formation of aerosols and the kinetics of oversaturation during bulk and surface coolii Results of theoretical and experimental investigations of the processes of condensation were reviewed by M. V. Buykov, V. P. Bakhaı et. al. Mass transfer processes in aerosols were described in papers pr sented by B. V. Deryagin, Yu. S. Kurgin, B. Sh. Beritashvili, and Yu. Dovgalyuk.

I. I. Gayvoronskiy and his coworkers discussed the formation of aero sols with ice crystals, while A. S. Zhikhar'ov reviewed the formation of aerosols with ice crystals during an explosion. P. G. Kuntsevskiy and L. M. Royev reported on the calculation of an ice crystal generator.

A. D. Malkina, and his colleagues disclosed the results of using organic compounds for crystallization of water in clouds, and a series of papers on the evaporation of a drop of solution were read. The behavio: of a drop of solution on a hot surface in an acoustic field was discussed by I. I. Paleyev and his colleagues.

In the section of the conference dealing with combustion and gas dynam Ya. B. Zel'dovich, A. G. Istratov, and V. B. Librovich discussed the pre sent state of the theory of combustion instability.

The instability criterion of a normal flame was reviewed by K. I. Shchelkin and S. K. Aslanov, and L. A. Klyachko reported on the ignition and combustion of metal particles. A. G. Istratov and V. B. Librovich presented a paper on spherical flame stability and diffusion effects on the stability of a laminar flame front.

G. A. Varshevskiy and D. V. Fedoseyev presented a paper on the ignition of a single drop of liquid fuel, while L. A. Klyachko gave a detailed analysis of the ignition of a cluster of drops.

The experimental results were given of a study of the effect of the form of a metal particle on the combustion of pyrotechnic mixtures by V. O. Fedoseyev and B. A. Altoyiz.

Papers dealing with oscillatory combustion of fuels were read by V. O. Khristich, Yu. M. Bashkatov, I. M. Zherebtsov, R. G. Galliulin, and N. K. Nikolayev. V. O. Khristich and his coworkers discussed the combustion of fuel jets in the circulation zone behind a trough-shaped flame holder.

F. I. Dubovitskiy reported on the mechanism of thermal explosions in condensed systems, and Ye. I. Maksimov and A. G. Merzhanov discussed the homogeneous combustion of nonvolatile liquids and melting substances.

Yu. M. Grigoryev, O. G. Merzhanov, and K. V. Pribitkov reported on the critical conditions of a thermal explosion with convective heat transfer in the reaction zone and surrounding media. Papers dealing with heat transfer in two-phase flows were read by G. L. Babukha, O. A. Shrayber, M. I. Rabinovich, B. A. Permakov, A. G. Serebryakova, and others. V. O. Antifeyev and his coworkers reported on heat transfer in a fluidized bed and on the gas dynamics of the combustion of hydrocarbons in a fluidized bed. (Polishchuk, D. I. The Fifth Conference on Evaporation, Combustion, and Gas Dynamics of Dispersed Systems. Ukrayins'kyy fizichnyy zhurnal, v. 11, no. 5, 1966, 575-578.) [PS]

THE SECOND ALL-UNION CONFERENCE ON AVIATION AND SPACE MEDICINE

The Second All-Union Conference on Aviation and Space Medicine sponsored by the Moscow Physiological Society and the Institute of Biomedical Problems of the Ministry of Health was held in Moscow on 24—27 May 1966, in accordance with the resolution adopted at the first such conference held in 1963. More than 600 specialists and interested laymen from various parts of the Soviet Union attended. The next conference is scheduled for 1969.

Abstracts of 276 papers presented at the conference were published in book form under the title, *Problems of Space Medicine; Proceedings of the Conference, 24 to 27 May 1966*. The book was on sale during the conference, and according to FBIS (no. 105, 27 May 1966, p. cc13), the entire edition of 1000 sold out in less than one hour.

In a keynote address, Academician V. V. Parin, the General Chairman of the conference, told the audience that the era of short-term manned spaceflights is now over and that the next stage — the conquest of nearby space — will require that men remain in space for periods of weeks and months. The primary task of space physiologists in this new era, Professor Parin told his listeners, will be the investigation of regulation of physiological functions for the purpose of determining the reliability of regulatory mechanisms, and of man himself, as a link in a complex man-machine system. Progress in this new area will depend on development of a medical monitoring system, and of automatic on-board data processing devices, which would ensure quantitative, as well as qualitative, analysis of the physiological reactions of the organism. Professor Parin predicted that among the problems that his audience may be called upon to solve, as spaceflights increase in duration, will be the development of controllable anabiosis and the creation of biologically controlled hardware.

Professor Parin stressed that, at present, the most important problem is study of the effects of weightlessness, prolonged isolation, and hypodynamia on the organism; that studies of the effects of spaceflight factors on the circulatory and central nervous systems, and on interaction of sensory analyzers (with special attention given to vestibular problems) should be continued; and that increased attention should be given to the effects of spaceflight factors on metabolic processes, on thermal regulation, on external respiration, on the neuroskeletal system, and on endocrine regulators.

Since the papers presented at the Second All-Union Conference on Aviation and Space Medicine represent a three-year progress report (the time elapsed since the first All-Union conference on this subject), contrast of the number of papers in each area presented at the two conferences provides an index of research trends.

The number of papers presented at the present conference (276 as compared with 158 at the previous conference) may be considered to be indicative of the overall increase in the amount of research time and money allocated to this area. At the same time the percentage of papers devoted to conventional aviation medicine dropped from 27.8% to 18.1%.

While the number of papers devoted to experiments in space (6) and effects of combined factors (15) has not shown a percentage increase, the number of studies of the effects of individual factors has shifted significantly. Thus, the number of papers in radiobiology has increased from 3 to 34. This increase has been due, principally, to studies devoted to pharmacological protection, shielding, dosimetry, and modeling of space radiation hazards.

On the other hand, the number of papers dealing with acceleration has dropped from 25 (15.8%) to 15 (5.4%). The number of papers devoted

to short-term weightlessness (parabolic flights in aircraft) also dropped from 8 to 1, while papers on such factors as noise and vibration rose from 1 to 8.

The number of papers devoted to gas environment and respiratory problems rose from 24 to 44 (papers dealing with helium mixtures rose from 2 to 5).

The number of papers dealing with such topics as optokinetic, vestibular, and motion sickness problems rose from 7 to 17. Increases have occurred in the number of papers on hypodynamia and isolation (8 to 11), temperature effects (2 to 4), and hypothermia (1 to 3).

A number of topics are presented in this collection which were not covered at the first conference. These topics are represented by a paper on the biological effects of magnetic fields, four papers on alpine acclimatization, four papers on orthostatic testing, and 14 papers on life-support systems. The first three topics represent increased interest in these areas, but the dramatic jump in the number of papers on life-support systems (0 to 14) must be interpreted as a policy decision.

In summary, it is felt that the collection of 276 abstracts contained in the monograph *Problems of Space Medicine* provides not only adequate coverage of the Second All-Union Conference on Aviation and Space Medicine but also a comprehensive overview of the state-of-the-art of space-oriented life sciences in the USSR. The table of contents of this volume has been translated and is available on request. In addition, a special report containing abstracts of more than 200 of the papers presented at the conference is being prepared by the Aerospace Technology Division and should be available in the very near future. (Konferentsiya po problemam kosmicheskoy meditsiny, 1966. Problemy kosmicheskoy meditsiny (Problems of space medicine); materialy konferentsii. Moscow, 1966.)   [BM]

ALL-UNION SEMINAR ON THE INTERACTION OF HIGH-TEMPERATURE MATERIALS WITH AMBIENT MEDIA

The All-Union Scientific Seminar on the interaction of high-temperature materials with ambient media was held 20-26 January 1966 in L'vov. The seminar was sponsored by the Scientific Council on the problem "The Physicochemical Fundamentals of Designing New Inorganic Heat-Resistant

Materials," by the Scientific Council on the problems "Physicochemical Mechanics, Surface Phenomena, and Surface-Active Substances," Academy of Sciences USSR, and by the Scientific Council on the problem "The Physicochemical Mechanics of Materials," Ukrainian Academy of Sciences. About 210 specialists representing 53 organizations presented 55 reports on the most diverse problems related to the effect of gaseous and liquid media on the properties of materials used in modern engineering.

The program of the seminar included four basic topics: 1) Heat and mass transfer in materials under the action of a high-velocity gas stream. 2) The effect of various types of radiation on materials. 3) The effect of low-temperature plasma on materials. 4) The interaction between high-temperature materials and molten metals. In his opening statement, I. N. Frantsevich reviewed the most important achievements in the fields of physical chemistry, the science of materials, and the physics of heat and mechanics in the solution of the complex problems of interaction between solids and the various media. In his introduction, G. V. Karpenko informed the participants on the development of the Physicomechanical Institute of the Ukrainian Academy of Sciences.

G. I. Petrov and N. I. Anfimov presented a review of the methods used in calculating the processes of heat and mass transfer in the interaction of materials with a high-velocity gas stream. The authors derived a system of equations describing heat and mass transfer in a gaseous boundary layer, in a solid body, and in the liquid film on a body surface. The effect of various complementary factors, such as the multiplicity of components, dissociation, ionization, radiation, absorption, and super-charging with individual gases and gas mixtures through a surface, on the state of the gaseous boundary layer was discussed in detail. The processes of heat and mass transfer within a disintegrating body were analyzed, and the conditions of operation of materials in a high-velocity gas stream and the criteria applied in evaluating the efficiency of materials used for protection of structures and equipment against heat were reviewed.

M. I. Chayevskiy spoke on the embrittling effect of impurities on a strained metal in contact with molten metal and established basic relationship which determine the selectivity of the reaction of liquid metals with strained solid materials.

G. A. Tirskiy reviewed the theory of the laminar boundary layer on the surface of disintegrating plastics. The author described the method of calculation and the mechanism of disintegration of graphite, quartz, and structural plastics, such as textolite, taking into account dissociation and ionization of the air.

Three reports were devoted to the problems of modelling extremely important processes of heterogeneous recombinations of gas atoms in the

interaction between a flying body and an ambient medium and between gases and catalyst walls. V. A. Lavrenko and G. M. Dzyubenko discussed the kinetics of the reaction of hydrogen atoms with a surface of aluminum oxide at a pressure of 25—80 μm Hg.

A. V. Rokhlenko and V. A. Lavrenko propounded a quantum-mechanical theory of the recombination of gas atoms on the surface of solid bodies, and derived the asymptotic solution for the problem of interaction between two structureless particles on the surface of a solid catalyst.

A. V. Rokhlenko, V. M. Smidovich, and V. A. Lavrenko developed a method of electron paramagnetic resonance for investigation of the recombination gas atoms on the surface of metals which possess strong nonresonant absorption of the energy of a high-frequency field. A. V. Zyrin and V. A. Dubok spoke on the dependence of electrophysical properties of metal oxides on the partial pressure of oxygen at high temperatures.

V. Ya. Kolot, V. F. Rybalko, G. F. Tikhanskiy, and Ya. M. Fogel' reported on an investigation of the corrosion film formed on a beryllium surface in high vacuum, in a hydrogen or oxygen atmosphere. Yu. I. Kozub discussed the effect of active gaseous media on the mechanical properties of refractory metals at high temperatures.

E. A. Abramyan, L. I. Ivanov, V. Ya. Yanushkevich, and N. S. Kudryavtsev discussed the high-temperature creep of niobium and zirconium, which is an important characteristic determining the behavior of these metals in space. A. N. Kushnirenko used a quantum-field method to determine the energy spectrum of a system of interacting particles, which makes it possible to study the changes in the physical properties of a solid body subjected to external radiation. A. Ye. Glauberman and M. A. Ruvinskiy reported on the theory of exiton formation in crystals during passage of fast electrons.

M. S. Koval'chenko and V. V. Ogorodnikov spoke of the damage to the crystal structure and the changes in physicomechanical properties of titanium and chromium carbides under the action of nuclear (primarily neutron) radiation. R. Basharov, Ye. S. Trekhov and Ye. N. Gavrilovskaya presented the results of microscopic and x-ray diffraction examination of metal surfaces damaged by a concentrated ruby laser beam with a pulse energy of up to 10 joule.

V. V. Gogosov discussed the boundary layers in a two-temperature plasma — ionized gas in which light and heavy particles have different temperatures — with special emphasis on the behavior of electron and ion temperatures near a solid surface. He spoke also of a specific boundary wall-adjacent layer which, in the case of fully ionized plasma, is much thinner than the dynamic boundary layer.

G. N. Dul'nev, N. A. Yaryshev, and R. A. Ispiryan reported on som results of an investigation of the heat and mass transfer in solid material under the action of plasma and light energies. A. K. Musin spoke on the effect of plasma-contacting surfaces (solid or liquid, walls or particles) on the ionized state of the plasma under nonequilibrium conditions.

A. K. Musin and M. A. Tyulina discussed the mechanism of the formation of a double electrical layer in plasma generated between two metal contacts when the circuit is broken. The investigation was based on the concept that thermoelectron emission from the solid, liquid, and gaseous surfaces restricts the plasma.

R. Basharov, Ye. N. Gavrilovskaya, O. A. Malkin, and Ye. S. Trek reported on copper cathode destruction in a strong-current discharge with the plasma pinch located along the parallel planes of the electrode. R. Basharov and Ye. S. Trekhov described an investigation of the destructio of the working surface of a material struck by gas discharge plasma. L. Yu. Abramovich investigated the mechanism of the formation of the cathode spot on the surface of a negative metal electrode placed in plasma

G. V. Levchenko, V. S. Potokin, and V. I. Rakhovskiy reported on the interaction between arc-resistant ceramics and the bases of rapidly moving electric arcs (up to 1000 amp). G. V. Levchenko, V. I. Rakhovsk O. K. Teodorovich, and I. N. Frantsevich described the erosion of sinter metalloceramic contact points under the action of a high-powered arc. V. V. Kantsel', T. S. Kurakin, V. S. Potokin, and V. I. Rakhovskiy reported on the resistance of refractory metals to the action of an arc discharge in vacuum.

A number of reports dealt with reactions between solids and molten metals. Ye. D. Shchukin discussed the role of interatomic reactions in the adsorption-induced lowering of the strength of materials. V. I. Likhtman, L. S. Bryukhanova, and I. A. Andreyeva established that the surface tension, whose magnitude could vary as a result of adsorption interaction between a strained body and the ambient medium, is the most important factor determining the effect of surface-active molten metals on the strength and ductility of solid metals. Yu. V. Naydich and G. A. Kolesnichenko stated that the nature of the bond between a metal and graph is a basis for evaluating experimental data on the interaction of liquid metals with graphite.

A. L. Burykina and M. T. Yevtushok reported on the development of coatings for protecting graphite articles from mechanical and erosive action of aggressive media. M. A. Maurakh, V. I. Kostikov, I. A. Pen'k and G. M. Sverdlov presented experimental data on carburization of liquid refractory metals of the IV, V, and VI groups in contact with

a graphite surface. These authors also proposed a theory of isothermal spreading of molten metals of the IV group on graphite, taking into account chemical reactions. Yu. V. Levinskiy, K. I. Portnoy, and S. Ye. Salibekov spoke on the kinetics of the reaction of carbon with borides, carbides and nitrides of metals of the IV—VI groups.

G. A. Yasinskaya described oxygen-free refractory materials stable in molten magnesium, copper, aluminum, silicon, cadmium, zinc, tin, lead, bismuth, manganese, and iron. M. A. Maurakh, V. I. Kostikov, V. A. Levin, and B. S. Mitin reported on the reaction of liquid oxides of the Al_2O_3-SiO_2 system with tungsten, molybdenum, and graphite. M. V. Dukarevich, S. I. Kontorovich, and Ye. D. Shchukin discussed the decrease in the strength of fine-pore structures resulting from the adsorption-induced lowering of free surface energy.

The proceedings of the seminar will be published and the second All-Union Seminar will be convened in 1967. (All-Union Seminar on the interaction of high-temperature materials with ambient media. Fizikokhimicheskaya mekhanika materialov, v. 2, no. 2, 1966, 241-243)   [MS]

BOOK REVIEWS

Mikhlin, S. G. Chislennaya realizatsiya variyatsionnykh metodov
(Numerical realization of variational methods).   Moskva, Izd-vo
"Nauka," 1966.   432 p.

    As the title suggests, this monograph deals with the numerical realiza-
tion of variational methods and can be considered as a continuation of the
author's previous book, *Variyatsionnyye metody matematicheskoy fiziki*
(Variational methods in mathematical physics) (Moskva, Gostekhizdat
1957. 476 p.), in which the general theory of variational methods was
presented. The book contains original results obtained by the author
and his co-workers and presents a systematic treatment of voluminous
results which have been accumulated in the scientific journals during the
past years. An exact definition and a complete solution of the problem
of stability of variational methods, in particular of the most important
Ritz method, are presented for the first time. It is claimed that the book
is highly original and unique in the world literature. The author reduces
the problem of numerical realization of variational methods to the following
problems: 1) selection of the system of coordinate functions: 2) formation
of the Ritz system; 3) solution of the Ritz system; 4) the effect of errors
accumulated in forming and solving the Ritz system on the approximate
solution of the problem. Since problems (2) and, partially, (3) (solution
of linear Ritz systems) are already well explored, the book deals mainly
with problems (1) and (4) and, to some extent, with the solution of non-
linear Ritz systems. The author discusses in detail studies of the stability
and instability of the Ritz and the Bubnov-Galerkin "processes." [He
refers to the procedures for the approximate solution of variational
problems as "processes" rather than "methods."] These studies and the
closely related problem of the rational selection of coordinate functions
occupy the principal place in the book. In addition, the problems of
mathematical physics in infinite domains are analyzed in detail and some
problems arising in the solution of integral equations, and, in particular,
of singular integral equations, are considered. The book is intended pri-
marily for engineers, physicists, and mathematicians working on solutions

of problems in which the application of variational methods is expedient. The book has an introduction, ten chapters, and an appendix.

Chapter 1 is of an introductory nature and deals with certain classes of systems of elements in Hilbert space. The author presents mostly already known facts and concepts which facilitate understanding the subsequent chapters.

Chapter 2 deals with the Ritz and the Bubnov-Galerkin processes for the approximate solution of stationary problems of mathematical physics. Comments are made concerning the Ritz process and the Ritz system from which the coefficients of the approximate solution (the Ritz coefficients) are determined. The limiting properties of the Ritz coefficients are also analyzed. Examples of solutions of the Ritz system which illustrate the concepts of the stability of the Ritz process and of the approximate solution are introduced and conditions imposed upon the coordinate functions to ensure the stability of the process are established. A similar stability concept of the Bubnov-Galerkin process for solving stationary problems is introduced and stability conditions are established.

In Chapter 3, the solution of the Cauchy problem for the nonstationary operator equation

$$\frac{d^2}{dt^2} Au + \frac{d}{dt} Bu + Cu = f(t).$$ (1)

(where A, B, and C are operators operating in a certain separable space) by the Bubnov-Galerkin method is considered. The scheme of the Bubnov-Galerkin process is described and the concept of its stability, different from that introduced for the stationary problem, is defined and stability conditions are established.

In Chapter 4, the residual Au_n-f is analyzed, where u_n is the approximate solution of the operator equation

$$Au = f,$$ (2)

constructed by the Ritz process, and A is a positive definite operator in a certain Hilbert space. A theorem is proved establishing the conditions imposed upon the operator A and the similar operator B (two self-adjoint positive definite operators A and B are considered as similar if they are defined in the same domain) under which the residual converges to zero at n → ∞. A particular class of operators satisfying the conditions established by the theorem is investigated.

Chapter 5 is dedicated to the most rational selection of coordinate functions for the Ritz process. The author outlines a scheme for selecting the coordinate functions in the case of the energy method for positive definite operators of the most important classes of problems of mathematical

physics, and the problems of selecting the coordinate functions in the case of the method of least squares and for the approximate solution of certain integral equations are considered.

Chapter 6 deals with the construction of coordinate functions in the case when the operator A is only positive but not positive definite. The cases of infinite domains and other singular problems are considered.

In Chapter 7, the stability of the Ritz process as applied to the approximate determination of eigen values and eigen-elements (eigensubspaces) of the positive definite operator is analyzed. The corresponding concepts of stability of the Ritz process in the spectrum problem of such operators are introduced and the necessary and sufficient stability conditions are established.

Chapter 8 deals with estimating the error in the solution of the problem when its operator is replaced by another one which, in a certain sense, is close to the given one and which simplifies the calculation of the problem. The error estimate is derived in an abstract form which was later specified for a series of problems of mathematical physics, in particular, of the theory of shells.

Chapter 9 is dedicated to the general theory of variational methods for nonlinear problems. The nonlinear operators transforming a Banach space into itself are analyzed and variational problems are reduced to minimizing a certain functional. The problems of the convergence of the minimizing sequence and its construction by means of the Ritz process are analyzed. The minimization of certain functionals of the theory of plasticity is considered.

Chapter 10 deals with the numerical realization of variational methods for nonlinear problems. The approximate solution of nonlinear Ritz system which is the most important part in the numerical realization of variation methods, is analyzed. Three methods for solving nonlinear Ritz systems are presented: the Newton-Kantorovich method, the method of differentiating with respect to the parameter, and the L. M. Kachanov method. The stability of the Ritz process is formulated for nonlinear variational problem and some results concerning sufficient stability conditions are presented.

In the appendix, written by T. N. Smirnova, the problem of realizing the Ritz process on high-speed electronic computers by using the method of automatic programming developed by L. V. Kantorovich and his co-workers is considereed. Peculiarities of the computing process on the M-20 computer using the universal program are analyzed. [LK]