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This report includes abstracts and bibliographic lists on contractual subjects that were completed in February, 1973. The major topics are: laser technology, effects of strong explosions, geosciences, particle beams, and material sciences. A section on biocybernetics and one on items of miscellaneous interest are included as optional topics.

Laser coverage is generally limited to high power effects; all current laser material is routinely entered in the quarterly laser bibliographies.

An index identifying source abbreviations and a first-author index to the abstracts are appended.
## Table of Contents

1. Laser Technology
   - Abstracts ............................................. 1
   - Recent Selections .................................. 11

2. Effects of Strong Explosions
   - Abstracts ............................................. 13
   - Recent Selections .................................. 30

3. Geosciences
   - Abstracts ............................................. 41
   - Recent Selections .................................. 94

4. Particle Beams
   - Abstracts ............................................. 96
   - Recent Selections .................................. 119

5. Material Science
   - Abstracts ............................................. 125
   - Recent Selections .................................. 140

6. Biocybernetics
   - Recent Selections .................................. 162

7. Miscellaneous Interest
   - Abstracts ............................................. 176
   - Recent Selections .................................. 180

8. List of Source Abbreviations ........................ 185

9. Author Index to Abstracts ............................ 191
1. Laser Technology

A. Abstracts

Anan'in, O. B., Yu. A. Bykovskiy, N. N.
Degtyarenko, Yu. P. Kozyrev, S. M. Sil'nov,
and B. Yu. Sharkov. Obtaining C and Al
nuclei in a laser source of multicharged ions.

This work is an extension of earlier spectrographic studies
by the authors (Effects of High Power Lasers, December 1971, 32) on laser
stripping of various metal atoms. A neodymium laser was again used
developing 10-15 ns pulses at a density of $5 \times 10^{13}$ w/cm$^2$; in the present case
Al and C targets were used. The spectrographic equipment used yielded a
clear resolution of highly-charged levels up through Al$^{13}$. Fig. 1 gives the
distribution of energy maxima obtained for Al and C; for Al$^{13}$ the spread is
seen to be from 18 to 50 kev. The integral number of registered ions $N(z)$
is given in Fig. 2; data show that the Al$^{13}$ portion was about $10^6$ ions, with
singly-charged ions an order of magnitude greater. Assuming an isotropic dispersion of singly-charged ions, the authors extrapolate the measured data to arrive at a figure of $10^{14}$ for total emitted plasma ions. The total number of ejected atoms, calculated from crater volume, was put at $10^{18}$; hence the relative ion yield was on the order of $10^{-4}$, which agrees with earlier findings by Bykovskiy et al (ZhETF, v. 15, 1972, 308).

Mirkin, L. I. Production of oriented structures on metal surfaces by laser beam. DAN SSSR, v. 206, no. 6, 1972, 1339-1341.

Experiments in producing strongly oriented surface structures on various metals by laser beam heating are briefly described. Tests have established that laser heating can generate temperature rises on the order of
$10^{10}$ deg/sec, with subsequent cooling at $10^6$ deg/sec in metals or other opaque materials; the author examines the resulting surface anisotropy in several materials including steel, nickel, nickel iron and some refractory carbides. Tests were run with an Nd glass laser at 1 millisecond pulses, using various degrees of spot defocusing. The resulting crystal structure and surface texture were measured by radiography and metallography as well as photography of the treated areas.

All measurement techniques confirm a strongly oriented surface structure following laser exposure. An example cited is for nickel, which prior to irradiation showed a normal intensity distribution in radiographs, e.g. the (111) and (200) line intensities were in a ratio of 3:1, whereas following exposure the (111) line dropped by a factor of 100 or more while the (200) line was practically unchanged. Figs. 1 and 2 show radiograms of exposed specimens; Fig 3 shows surface grain structure of an exposed nickel iron alloy. It was

![Fig. 1. Radiogram of Ni surface after laser irradiation.](image1)

![Fig. 2. Radiogram of Ni-iron alloy after laser exposure and cooling in liquid nitrogen.](image2)
also observed that the most pronounced orientation effect occurred in single-phase materials, where the number of crystallization centers is relatively low.

Golodenko, N. N., and V. M. Kuz'michev.

Pulsed laser heating and vaporization of metals. Radiotekhnika (Khar'kov), no. 23, 1972, 139-142.

This is a condensed version of the same study reported earlier by these authors (January 1973 Report, p. 1). Heating characteristics are analyzed of a metal surface exposed to laser pulses on the order of $10^5$ w/cm$^2$ or greater; the idealized model of the earlier report is again used. The laser effect is treated in two stages: a heat-up or lag stage with absorption but no vaporization, followed by an abrupt start of vaporization and rapid propagation of the temperature field into the surrounding target material. The fraction of energy absorbed in the target area is then expressed by $\epsilon = \frac{\Delta t}{t_0}$ where $\Delta t$ is
the lag time and \( t_0 \) is laser pulse duration. Fig. 1. shows \( \xi \) as a function of \( t_0 \) and energy density for a copper target. Characteristics of surface boundary motion, temperature and lag time are given in Fig. 2 as functions of laser power density, also for copper.

Fig. 1. Fraction of energy absorbed vs. \( t_0 \) and energy density.

Fig. 2. Boundary velocity, temperature and lag time vs. power density.
Kondrat'yev, V. N. *Vaporization from interaction of powerful energy sources with a material.* ZhPMTF, no. 5, 1972, 49-57.

An extended analysis is given of heating effects of a concentrated high-energy beam on a solid surface. The specific aim is to correlate the conditions for surface vaporization with those for internal vaporization, since each of these has been claimed by various authors to be the predominant mechanism in laser beam-target studies. The model assumes a constant flux $q_r^0$ impacting a surface and attenuating with penetration, as given by

$$q_r = q_r^0 (1 - K_r) \exp \left[ - (x - x_v) / l_0 \right]$$  \hspace{1cm} (1)

where $q_r = \text{beam flux density at depth } x; x_v = \text{the vaporization boundary}; K_r = \text{mean coefficient of reflection of incident flux}; \text{and } l_0 = \text{the characteristic depth of energy release in the solid}. \text{ A quasistationary case is considered, in which all reflection is assumed to be from the solid face.}

The model is analyzed in terms of a vaporization wave which proceeds inward from the impact area typically at a subsonic velocity. Characteristic temperature curves for fusion and vaporization of Al, Cu and Pb are derived on this basis. The correlation of surface to internal vaporization may be seen in Fig. 1 for these metals in terms of $q_r^0 (l_0)$, calculated for both stationary and fluctuating bubble formation.

A further examination shows that for target materials with relatively great depths of $l_0$, the presence of stationary bubbles will accelerate the transition from surface to internal vaporization. However for opaque bodies such as metals the bubble presence would appear to have a negligible
effect on transition. Based on the cited model, the transition intensities

![Graph showing incident flux density vs. depth of energy release.](image)

Fig. 1. Incident flux density vs. depth of energy release.
a) Al, Cu (dashes); b) Pb.
1 - fluctuating bubbles; 2 - stationary; I - surface vaporization region; II - internal vaporization region.

for Al, Cu and Pb are given respectively as $5 \times 10^9$, $3 \times 10^9$ and $10^7 \text{ w/cm}^2$.

Rarov, N. N., A. A. Uglov, and I. V. Zuyev.  

The theoretical case of liquid phase formation on a laser- or electron beam-irradiated target surface is analyzed briefly. The treatment is limited to surface intensities sufficient to generate deformation in the liquid phase owing to local vapor pressure and thermal gradients; it is further
assumed that beam penetration is negligible in comparison to dimensions of the melt zone. Liquid phase deformation can then be determined using the Navier-Stokes system

$$\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla) \mathbf{v} = -\frac{1}{\rho} \nabla p + \mathbf{v} \Delta \mathbf{v} + \mathbf{g} + \mathbf{F}_s,$$

where \( v = \) particle velocity and \( p = \) pressure in the liquid phase, \( \nu = \) viscosity, \( g = \) internal force vector, and \( F_s = \) surface force vector. Eq. (1) together with equations for energy balance, discontinuity and mass conservation, are sufficient to define fully the surface deformation in the liquid phase. For ease of solution \( v = \) const is assumed in Eq. (1). Two general cases are solved in terms of the characteristic dimension \( Z \) of the melt zone, namely for small deformation, \((Z')^2 \ll 1\), and large deformation, \((Z')^2 \gg 1\). Limitations imposed by the assumed simplifications are emphasized in conclusion.


The structure is studied of shock waves generated in a volatile explosion cloud from the effect of powerful radiant flux on a solid. Calculations are based on gas dynamic equations for an ideal gas with a constant heat capacity in a one-dimensional plane approximation, with allowance for gas radiative heat transfer in the presence of scattering.

Results show that laser radiation scattering not only increases the radiant flux deflected from the shock wave front but also substantially affects the radiation field within the wave.

This is a rework of two previously published articles by the same authors (cf. December 1972 Report, pp 4 and 6) on flare characteristics of laser-irradiated metals. Target materials included bismuth, lead, aluminum and brass. A neodymium laser was used at 1 millisecond pulse lengths, developing up to $10^7$ w/cm$^2$ over a 1 cm diameter target area; tests were done at ambient pressures up to several atmospheres. An extensive analysis of test results is given, with emphasis on a critical surface temperature at which a transition from liquid metal to liquid dielectric can be identified. The present article includes clearer pictures of flare development, as shown in Figs. 1 and 2.

Fig. 1. Flare from Bi target. $I = 5.5 \times 10^6$ w/cm$^2$, $\tau = 0.8$ ms, $p = 1$ atm; exposure time exceeds pulse duration.


An analysis is developed of the interaction of powerful polarized radiation with an arbitrary medium, in which the medium is for convenience assumed to be a resonant system of randomly ordered linear or circular dipoles. Proceeding from an expression for the vector field in the medium, the authors derive expressions relating radiation polarity to the absorption or amplification properties of the medium. An approximate solution is obtained for the case of limited radiation power, as well as a more general one applicable to any incident power level.
B. Recent Selections

i. Beam Target Effects


ii. Laser-Plasma Interaction


2. Effects of Strong Explosions

A. Abstracts


Parameters are calculated of a plane shock wave generated by detonation of an explosive charge on a material surface and propagating in a semi-finite solid layer. Parameters of a glancing detonation wave at the surface are also calculated. The materials are a series of three-component tungsten carbide-cobalt cermets. The shock adiabats of the three-component systems were calculated using known adiabats of each component. The shock adiabat calculated for a VK-8 alloy agreed satisfactorily with an experimental value determined in the 100 - 600 kbar pressure range. An x-ray diffraction analysis of the shock compressed specimens indicates that shock adiabats can be calculated for pressures to 2 Mbar.

Rakhuba, V. K. and N. N. Stolovich. Effect of geometric dimensions of an exploding conductor and discharge current parameters on energy conversion efficiency. IAN B, Seriya fiz-energ nauk, no. 4, 1972, 119-123.

The effect of a cylindrical exploding wire diameter and discharge circuit parameters on electrical energy conversion into mechanical energy is investigated. Aluminum membrane detectors were used for measuring the mechanical work. A simplified diagram of the experimental installation is given.
Experimental data are presented in Fig. 1 on the deformation

![Graph](image)

**Fig. 1.** Relationship of the deflection $\Delta_{\text{max}}$ of a membrane detector to the diameter of the exploding wire $d_i$ at the following discharge-circuit parameters:

- $C_0 = 3 \ \mu F$, $L_0 = (5 \ to \ 7) \times 10^{-7}$ henry (1-4)
- $C_0 = 900 \ \mu F$, $L_0 = 4 \times 10^{-6}$ henry (5):
  - 1 - 27, 2 - 32, 3 - 40, 4 - 32, 5 - 5 kv.

Curves 1, 2, 3, and 5 are for explosion of a copper wire; curve 4 is for an aluminum wire.

**Fig. 2** is derived from dimensionless variables of Fig. 1 data, in the form of a relative generalization of curves 1-4, dealing with membrane-detector data, along with the cylindrical-detector data of curve 5.

The deformation processes of the membrane sheet detectors and the cylindrical indicator detectors in terms of dimensionless variables are both characterized by the same relationship. Other conditions being equal, the diameter of the exploding wire is found to exert the greatest influence on the maximum deformation value.
Fig. 2. Effect of discharge-circuit parameters and diameter D of the exploding wire on the dimensionless deflection $\delta$ of a membrane detector:
1 - 27, 2 - 32, 3 - 40, 4 - 32, 5 - 5 kv.
I - Calculation results based on $\delta = 1.25D^{-1.1}$ for $1.25 < D < 3.0$; $\delta = 1.03D^{-0.37}$ for $1.0 < D < 1.25$;
II - Based on an alternate formula for $A = 2.6$, $B = 2.66$.


A model is constructed for porous medium deformation. The spherical part of the stress tensor is given as a specific volume and internal energy function, and the deviator part is determined by the condition...
of plasticity (Tresca or Coulomb) and the proportionality requirement of the
tensor deviator inelastic part of the deformation rate. The condition of
brittle destruction of the grains (elementary components) of the porous
medium is also introduced. Destruction of the medium from macrocrack
formation is discussed. Orthogonal to the cracks, the stress in this case
is considered to be equal to zero. Equations of motion are derived for the
spherically symmetrical motion. The equation system for the numerical
calculations is presented in finite-difference form. The calculation is
mentioned of the detonation in sand of an explosive pellet. The results are
presented in a graph of explosive cavity expansion (for the initial stages of
motion) in comparison with radiography data.

Kuznetsov, V. M. *Explosive demolition of rocks.* IN: Sbornik. Dinamika splosshnoy
sredy, Novosibirsk, no. 8, 1971, 71-77.
(RZhMekh, 9/72, no. 9V589)(Translation)

Views on the efficient use of explosives in the crushing of
rock are mentioned. A probability law on fragment distribution by size is
presented (in specific cases, this law reduces to normal or Poisson
distributions). A scheme of brittle failure is proposed to assist in identifying
the distribution parameters. The coefficient of stress intensity and the
maximum pressure in the compression wave are assumed to be characteristic
values of the brittle failure. The initial ordered network of cracks is unstable
and the spacing between cracks is proportional to the cube root of the explosion
energy. A semi-empirical formula is compiled based on the assumed distributio
parameters. The formula is correlated with data on the granulometric
composition of fragmented rock for a series of explosions.
Consideration is given to conditions for shock wave propagation in a massif. The massif properties are described by rheologic models with elastic and plastic properties. A theorem is proved which establishes an interrelationship between the dissipative processes irreversibility of the shock wave and the necessary conditions of existence for the wave transient layer structure. It is shown that by introducing the shock layer it is possible to determine all the shock wave thermodynamic limitations.


The interaction of detonation products with the wall of a deep bore-hole in rock is analyzed, based on the theory of elasticity using composite variables. The effect of the exposed surface at the hole mouth is neglected. Two complexes of characteristic quantities are derived from the initial and boundary conditions of a radially directed blast. The physical significance of the complexes is explained. The generalized explosion process is described by the ratio of the two complexes. This analysis makes it possible to evaluate the effect of certain factors previously neglected and unaccounted for in a formula derived by dimensional analysis of experimental data. The effect of sound velocity in the rock can accordingly be evaluated by introducing the sound velocity-fissility relation into the cited complex.
Klochkov, V. F. *Stress of a rock mass and its destruction characteristics from explosions near a free surface.* IVUZ Gorn, no. 7, 1972, 70-75.

Normal $\sigma_n$ and tangential $\tau_n$ stresses on a free surface from the underground explosion of a spherical or cylindrical charge at depths $w$ of 0.5 - 2m (line of least resistance) are calculated at the onset and during decay of the stress field. Destruction occurs at the onset mainly owing to $\sigma_n$. During the decay period, the relative $\sigma_n$ and $\tau_n$ values are functions of $w$ and the inclination $\alpha$ of the axial stress vector at a surface point. At increasing $w$, both $\sigma_n$ and $\tau_n$ decrease more rapidly from the explosion of the spherical than from the cylindrical charge. At a given $w$, $\sigma_n$ and $\tau_n$ become extremal for certain $\alpha$ values in the 0-90 degree range. The optimum charge depth corresponds to a $109^\circ30'$ apex angle of the explosion crater, i.e. the maximum crater volume $V_{\text{max}}$. Only the first sumping hole should consequently contain a reinforced charge to produce $V_{\text{max}}$. The sumping holes fired in the preformed cavity need not contain a powerful charge.


Q-switching experiments are described using an aluminum film on a poly (ethylene terephthalate) substrate, exploded by the electric discharge of a low inductance capacitor. The feasibility of Q-switched laser operation with various active media having large cross-sections is cited as the
main advantage of the system studied. Energy, time, and space characteristics are determined for ruby and Nd-glass pulsed lasers, Q-switched by the described system. The experimental set up (Fig. 1)

![Diagram of Q-switching time measurement:](image)

Fig. 1. Diagram of Q-switching time measurement:

1 - illuminating laser, 2 - telescope, 3 - exploding film, 4 - objective (f = 1,600 mm), 5 - diaphragm, 6 - photomultiplier, 7 - oscilloscope, 8 - optical delay line.

features an exploding film located outside the laser cavity and a delay mechanism for synchronizing the laser pulse with the film explosion. Oscilloscope traces show that the film clears up completely, when the energy input rate is increased and the total energy supplied exceeds the metal vaporization energy. The minimum clearing time $\tau_s$ is 60 nsec. A high voltage and small inductance in the discharge circuit, plus a sufficiently high ratio of discharge energy to the film surface area are required for rapid Q-switching. Time $\tau_s$ increases gradually with decreasing diaphragm apertures, because of light scattering by the explosion products.

Laser characteristics are also affected by radiation interaction with the exploding film. The interaction was studied by placing the film in the cavity. In this case, when $\tau_s$ is decreased (e.g., to ~2 nsec for a 300 Å thick film) a flare is observed on the film surface. The emission interaction with the explosion products results in increased losses in the cavity and decreased power output. The emission losses from the substrate vaporization correspond to 88% of the transmissivity of the open Q-switch and a 3-4 j/cm$^2$ emission power density. A critical power density ~1 j/cm$^2$ exists at which rapid vaporization of a 300 Å thick Al film produces a 50 ns single pulse, even at $\tau_s = 350$ nsec. Above this critical value the pulse is distorted by substrate vaporization, and Q-switching is
impaired. The angular distribution of the single-pulse laser emission indicates that the Q-switching film automatically compensates for mirror misalignment owing to plasma heating by laser radiation.


The monograph contains 13 chapters and deals with various aspects of the effects of those explosives which are used in construction work for the destruction and movement of rock.

The first chapter discusses the effect of an explosion on various rocks and soils. The flow rate of the explosion energy is examined, particularly the cavity role (air or water filled) around the charge in explosion efficiency. Chapter 2 is devoted to "fill" explosions on slopes. Features of a crater on a slope are mentioned and a simplified diagram of slope collapse from an explosion is presented. Factors governing fill formation and rock consolidation after collapse are compiled in Chapter 3. It is shown that the fill density is a function of the slope height and the component rock strength. Chapter 4 is on problems of rock motion during cratering and fill explosions by concentrated and flat charge systems. Charge setting for cratering explosions is considered in Chapter 5. It is concluded that the rock displacement rate is independent of the escape of explosion products through the charge hole when the hole cross section is two orders smaller than the charge chamber cross section. In Chapter 6 a theory of destruction of a rock mass by an explosion is developed together with methods for calculating compression wave displaceme
and stresses. It is shown that at the normal explosion effect indices of 1.5 - 2, split-off breakdowns merge with those around the charge. A method of calculating charges for the erection of embankments by loosening is presented in Chapter 7. Detailed consideration is given to a system of fragmented rock overflow under a linear increase of the coefficient of loosening to a maximum value at the free surface.

Current experience in the erection of earth dams by directed explosions is reviewed in chapters 8, 9, and 10. The types of dams erected by directed explosions are discussed as well as problems of dam filtration, stability, and sedimentation. Results of blasting in connection with the building of dams on the Terek river, near the city of Alma-Ata, the Baypazy hydraulic complex, and the upper cofferdam of the Nurek hydraulic complex are described. The cost effectiveness of constructing dams by the explosion methods is illustrated on the basis of the Baypazy dam. Data on explosion effects on the physicomechanical properties of soils and rock are presented in Chapter 1. Compression zone dimensions are given for sand, clay, and loam, as well as dose for destruction zones from an explosion in monolithic rock. Chapter 12 outlines the manner in which demolition method dams should be operated and studied. In the last chapter a theory of underground explosion modelling is described together with methods for simulating cratering explosions under laboratory and field conditions.


The problem of a confined explosion in an unbounded rock mass is considered. Test data are used to construct a mathematical model of rock behavior over a broad range of parameter variations. Methods are examined for calculating brittle failure of materials.

A method is proposed for the precise measurement of the embedding depth of explosive charges, based on recordings made by a single sensor and the pulsation period variation factor of the explosion-generated gas sphere.


Results are discussed of applying time-span control methods to minimize the air shock wave and fragment dispersion effects during massive blasting of quarry blocks. Methods include group charging, sequential blasting, sectional charge-ordering, maximizing explosion delay gaps, adjusting the charge column height, and simultaneous secondary crushing of boulders during massive blasting.

Conclusions are: (1) The duration of massive explosions in quarries can be increased up to 10 seconds using specified block alignments and blast sequencing based on given block mass conditions; (2) The maximum admissible delay factor between adjacent boreholes when arranging air-gap charge systems should be within the 165 to 270 msec range; (3) Blasting work on a series of quarry blocks piled one on top of the other should be done by using detonation fuses sequentially connected from the bottom block upwards.
A numerical analysis is presented of the free axisymmetric expansion of a supersonic nitrogen jet, with allowance for rotational relaxation. The earlier assumption of the negligible effect of rotational relaxation has led to a significant discrepancy between theoretical and experimental data for a sonic nozzle. Free nitrogen jet expansion from a round nozzle is calculated at moderate temperatures, e.g., 300° K. The effects of viscosity and thermal conduction are assumed to be negligible along with a Boltzmann energy distribution of rotational degrees of freedom. Rotational relaxation is described by the equation

$$\frac{d T_r}{dT} = \frac{T - T_r}{T}$$

where $T_r$ and $T$ are rotational and translational temperatures, $\tau_r = Z\tau$ is the rotational relaxation lifetime, $\tau$ is the mean free path, and $Z$ is the number of collisions until translational-rotational equilibrium is established. In addition to (1), a set of six equations in a cylindrical coordinate system describes the flow parameters. These equations are solved by the method of characteristics.

Finite difference equations of characteristics and relationships along the flow lines are used to compute the parameters at the initial nozzle exit section, in the flow, at the nozzle edge, and on the symmetry axis. The computed $T_r$ and $T$ data are compared with analogous data calculated without allowance for the rotational relaxation effect, and experimental data from the literature. The comparative $T_r$ and $T$ versus $x_1 = x/r_a$ plots ($r_a$ is the nozzle exit section radius) show that the discrepancy between the earlier calculated and experimental $T_r$ data is reduced significantly when the rotational relaxation effect is taken into account. At $p_o r_a = 7.5$ torr x mm ($p_o$ is the receiver pressure) $T_r$ calculated with allowance for rotational relaxation agreed more closely with the experimental data for $Z = 5$ than for $Z = 10$, whereas at $p_o r_a = 240$ torr x mm, the discrepancy between the data for $Z = 5$ and $Z = 10$ was insignificant. For a small number of collisions, $T_r$ is only slightly affected by the rotational-translational energy exchange.
An asymptote for the flow behind a shock wave front after impact on a metal cavity edge is determined assuming that this flow is divided into two regions. In region I, where
\[ \varepsilon r^{-2} \ll 1, \quad r = \sqrt{\frac{2\pi}{\varepsilon}} / \zeta_0, \quad x = \pi/2(\pi - \gamma) \quad (\eta_1 < z < 1) \]
the flow is described by an acoustic approximation on the assumption that the wave amplitude \( \varepsilon \ll 1 \). In region II, where
\[ \varepsilon r^{-1} \approx 0(1) \]
the flow at \( \varepsilon \to 0 \) is approximated by equations of an incompressible fluid.

Assuming symmetric flow with respect to the y-z plane, it is sufficient to formulate an asymptotic solution for the region between the symmetry axis and an unknown free boundary \( \eta_1 = \eta_1(\xi_1), \xi_1 \geq 0 \). For a given apex half-angle \( \gamma < \pi/2 \), the boundary problem solution is reduced to that of a nonlinear singular integral equation for the real function
\[ f(u) = \arg \xi'(u) + \pi/2 + \gamma \]
where \( \xi'(u) \) is a derivative of the \( \xi(u) \) complex function with \( \xi = \xi + \imath \eta \). A numerical solution of the integral equation is obtained by iteration for \( \gamma \) values in the 0 to \( \pi/2 \) range. The iteration procedure is outlined. The function \( f_n(u) \) was determined after \( n \) iterations. For ease of calculations, the function \( R_{nl} \) was substituted for \( f_n \) according to the formula
\[ f = R [1 + (1 - u)^{(1-\gamma)/(2\gamma)}] \]
where $\beta = \gamma - f(0)$ is the apex angle between the symmetry axis and the free boundary. The function $R_n(\tau)$ was used to formulate the free boundary profile $\eta(\xi)$ and the velocity $\eta_A$ at the free boundary apex. The $\eta(\xi)$ profiles (Fig. 1) and tabulated $\eta_A$, $\beta$, and $\gamma$ values were calculated for $\epsilon = 0.1$ and $C_o = 5.5 \text{ km/sec}$. The tabulated data suggest that an arbitrarily small deviation of $\gamma$ from $\pi/2$ results in a finite change of $\beta$.

![Free boundaries in the $\xi\eta$ plane.](image)

Fig. 1. Free boundaries in the $\xi\eta$ plane.
Broken line calculations were by the difference method for $\gamma = \pi/4$.

Bronshten, V. A. *Propagation of spherical and cylindrical blast waves in a heterogeneous atmosphere with allowance for counterpressure.* ZhPMTF, no. 3, 1972. 84-90.

An approximation method of parallel layers is introduced to calculate the characteristics of a weak spherical blast wave and cylindrical shock wave propagating in a downward direction in a heterogeneous...
exponential atmosphere. Such a problem arises, for example, in attempting to evaluate the flight and explosion of the Tunguska meteorite. Since the blast wave from an explosion at 5-10 km above the ground is greatly attenuated at the surface, counterpressure must be taken into account. The three-dimensional problem of cylindrical wave propagation at an angle \( \theta \) to the horizontal plane (Fig. 1) is initially reduced to a two-dimensional problem by applying the plane cross-section principle, i.e., neglecting propagation along the cylinder axis.

The two-dimensional problem is further reduced to a one-dimensional problem by parametrization in terms of the angle \( \theta \). Similarly, the two-dimensional problem of spherical blast wave propagation is made one-dimensional by parametrization in terms of the angle \( \theta \). In both cases, the one-dimensional problem is solved by the method of parallel layers, involving a division of the atmosphere into parallel, small-thickness layers. The atmosphere within each layer is considered to be homogeneous and wave transition across the inter-layer boundary is assimilated to the boundary transition between two media. Wave propagation within each homogeneous layer is described by
known approximation formulas. The effect of atmospheric heterogeneity on shock wave propagation is expressed by the parameter

$$\beta = \left( r_0 | \cos \theta | \right) / H^*$$

(1)

where $$r_0 = \left( E / p_{10} \right)^{1/2}$$, E is the blast energy, $$p_{10}$$ is the nonturbulent air pressure at the elevation $$H_0$$ of the explosion point B, and $$H^*$$ is the homogeneous layer height. Using an approximation formula the excess pressure $$q = (p_2 - p_1) / p_1$$ at the shock wave front propagating in a heterogeneous atmosphere from a moderately elevated point, and its propagation velocity, can be rapidly evaluated.


The effect of the propagation direction of a detonation wave front is discussed with respect to the rock surface. The formation and propagation characteristics of the reflected expansion and refracted shock waves are considered for the cases when the detonation wave strikes the rock surface at an angle $$\alpha = 90$$ degrees or $$\alpha = 0-90$$ degrees. In the 0-90 degrees range (the most common case) and at a detonation velocity $$D_d < D_{\text{refr}}$$, the angle $$\omega_1$$ satisfies the equality $$D_d / \sin \omega_1 = D_{\text{refr}}$$ When $$\omega_1 > \alpha < 90$$ degrees, the incident, reflected, and refracted waves do not intersect at one point and energy is transferred to the rock across a stressed zone. The calculations verify the advantage of using a priming charge distributed lengthwise over a concentrated charge.

A solution is presented to the problem of two-dimensional shock wave propagation in multicomponent soils and water at distances from the explosive charge for which the pressure $p$ is at least tens of thousands of atmospheres. It is assumed that a small thickness and large surface area explosive charge is instantly detonated in the medium. The medium is represented by a mathematical model developed earlier by one of the authors (Lyakhov) for a three-component medium containing solid particles, water, and gas. The model is only applicable at $p > p^*$ when skeleton compressibility is negligible. Wave propagation at a time $t = 1$, when the expansion wave front $R_1$ attains the initial cross-section, is described using the model

$$p = (1 - x)^n, \quad u = 1 - (1 - x)^n$$

(1)

in the region $0 \leq X \leq X_R$ and by

$$p = p_T, \quad u = u_T, \quad D = D_T = u_T V_0 (V_0 - V_T)^{1\alpha}$$

(2)

in the region $X_R \leq X \leq X_0$ (Fig. 1)

![Wave propagation diagram](image)

Fig. 1. Wave propagation diagram:
$R_1$ - expansion wave front, $R_2$ - expansion wave detonation products boundary, $R_3$ - reflected expansion wave, $S$ - shock wave front, $T$ - contact discontinuity (detonation products-medium interface).
The initial shock wave parameters $p_T$, $u_T$, and $V_T$ in (1) and (2) were calculated for the three media (Table 1).

Table 1. Characteristics of three-component media $\alpha_1$, $\alpha_2$, $\alpha_3$ - volumetric content of the gas, liquid, and solid components, respectively.

<table>
<thead>
<tr>
<th>Media</th>
<th>Medium characteristics</th>
<th>Dimensionless parameters</th>
<th>Dimensional parameters</th>
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<tbody>
<tr>
<td></td>
<td>$s_1$</td>
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<tr>
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</tr>
<tr>
<td>Second</td>
<td>0.02</td>
<td>0.33</td>
<td>0.65</td>
</tr>
<tr>
<td>Third</td>
<td>0</td>
<td>0.4</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Computation of $u$, $p$, and $D$ was done separately for five different regions by the method of characteristics. The $p$, $u$, and discontinuity shift $y$ versus $t$ plots at the gas chamber boundary (T) show the gas chamber relative dimensions in three media types studied. The $p$, $u$, and $D$ versus $x$ and $p(t)$ plots in the $S$ region indicate, in agreement with experimental data, that $p$, $u$, and $D$ in a water-saturated soil ($\alpha_1 = 0$) are higher than in water, but decrease significantly in the presence of even small amounts ($\alpha_1 = 0.02$) of air in water-saturated soil. The decrease in these parameters is accentuated at increasing distances from the explosion site.
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Makogon, L. I. Nomogram of an equation of state for an ideal gas. IN: Sbornik. Gorn. elektromekh. i avtomatika, no. 21, 1972, 39-43. (RZhMekh, 1/73, no. 1B375)

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A. Abstracts

Statistics on the earthquakes and morphological structure of eastern Central Asia. IN:

A correlation between successive earthquakes is analyzed, and the parameters describing the correlation are compared with morphological structure. The method is based on the comparison of the local statistics of the complete and randomly compiled earthquake catalogs. The following results are obtained:

1. There exists a positive influence for weak earthquakes \((E = 10^9 - 10^{12})\): their recurrence probability increases by some value \(p\) in the proximity of the initial earthquake. For normal earthquakes this increase is statistically significant at \(r = 30-40\) days and \(d < 50\) km. For intermediate earthquakes the positive influence is smaller, but still statistically significant at \(r = several\) days and \(d = 10-20\) km.

2. Sequences of weak normal earthquakes are identified for which \(d \leq d_o\) and \(r \leq r_o\). Assuming \(d_o = 15\) km and \(r_o = 3\) hours, then the first-order error (identifying a fictitious sequence of independent earthquakes) does not exceed 7%, while the second-order error (missing a sequence) reaches 43%. If \(d_o = 50\) km and \(r_o = 40\) days, the second-order error is too high. Strong earthquake sequences with thresholds of \(r_c = 10\) days and \(d_o = 25\) km have been identified.
3. A significant decrease of $p$ in the focal-depth range of 120-160 km is observed for intermediate earthquakes (see Fig. 1).

![Diagram showing positive influence $p$ of an initial earthquake on subsequent ones within the time interval $\tau \leq 15$ days and distance $d < 18$ km.](image)

Fig. 1. Positive influence $p$ of an Initial Earthquake on Subsequent Ones within the Time Interval $\tau \leq 15$ Days and Distance $d < 18$ km.

Analyzed earthquakes were: group V intensity for 1952-1956 and $E = 10^7 - 10^{12}$ for 1957-1961.

1 - estimated $p$; 2 - 90% confidence level of the estimation; 3, 4 - estimated $p$ for 1952-1956 and 1957-1961, respectively.

This depth interval corresponds approximately to an assumed waveguide.

4. The correlation between $p$ and $\gamma$ (recurrence graph slope) and morphological structure is analyzed. High $p$ (large number of sequences) is confined to regions with thick sedimentary cover (region V in Fig. 2),
as well as regions with exposed crystalline rock. High $\gamma$ is confined to regions with high tectonic stresses (Tien-Shan, Pamir).

5. Deviation of $p$ and $\gamma$ from average values can be attributed to the build-up of a strong earthquake. Thus, anomalous earthquake sequences were observed in the past at sites where subsequent strong earthquakes occurred.

6. The distribution of seismic activity in Central Asia with respect to morphological structures changed significantly during the 1895-1965 period;

7. The hypothesis that a strong earthquake induces "distant aftershocks" at the sites of future strong earthquakes was examined. The significant of the existence of "distant aftershocks" is found to be 99% at $\alpha = 0.05$.


Experimental deep seismic sounding studies were conducted for the purpose of developing field procedures and observation method for studying the upper part of the basement of the Siberian platform. A discrete observation system was developed, intended for the recording of the seismic waves from three major interfaces: layer I - within the sedimentary layer; layer F - basement surface; and layer III - within the basement.
The crustal model inferred from the experimental data, taking some earlier results into account, is shown below in Figure 1.

![Seismic Section Along the Bedoba-Karabula (Krasnoyarsk region) Profile.](image)

Fig. 1. Seismic Section Along the Bedoba-Karabula (Krasnoyarsk region) Profile.

1 - depths determined from reflected waves (1965); 2 - from reflected waves (1969); 3 - from reflected waves (1970); 4 - from refracted waves (1970); 5 - assumed fault; 6 - seismic interfaces; 7 - assumed seismic interfaces.


The results of a complex interpretation of geological and geophysical data on the crustal and upper mantle structure of the Altay-Sayan folded region are summarized. The relation between the deep structure and the tectonics of the region is considered.
The density discontinuities determined for the lower crust and the upper mantle are illustrated in Fig. 1. The low-density zone in the upper mantle (density decrement $0.05 \text{ g/cm}^3$) is related to a region of intense present uplifting (Gornyy Altay, western Sayan, etc). Zones of high and low
density in the lower crust, outlined in the western and southeastern part of the region are apparently related to differing crustal composition, fennic and sialic, respectively. Isopach maps for the crust and granitic metamorphic layer are shown in Fig. 2. It was established that the Moho discontinuity relief

Fig. 2. Isopach Map for the Crust and Granitic-Metamorphic Layer in the Altay-Sayan Folded Region (compiled by V. S. Surkov and P. T. Morsin).

1 - Isopachs for the granitic-metamorphic layer; 2 - isopachs for the crust.

reflects both the present and ancient tectonics of the region. Thus, a general sinking of the Moho discontinuity to the south is related to neotectonic surface structures, while local depressions and uplifts are related to ancient ones. The tectonic development of the Altay-Sayan folded region is considered in the light of new data on deep structure.
Smirnova, M. N. *Effect of weak earthquakes on the Pyatigorsk mineral springs.*


An analysis is given of the effect of the weak earthquake of 16 June 1946 on the mineral springs of Pyatigorsk in the Caucasus. The mineral springs are confined to two semicircular latitudinal and a meridional faults (see Fig. 1). The effect of the earthquake was manifested in the

Fig. 1. Locations of the Pyatigorsk Mineral Springs

Composition of the springs: 1 - carbonic acid springs; 2 - carbonic acid and hydrogen sulfide springs; 3 - ferrous carbonic acid and hydrogen sulfide springs; 4 - alkali salt springs, 5 - radon springs.
following ways:

1. The level of Proval Lake (see Fig. 1) rose from 2.95 to 1.8 m (sic) one month before the earthquake. Subsequently the level fell to 3.2 m (sic);

2. The discharge rate and temperature of the mineral springs underwent changes over 1-2 months before, and 2-3 months after the earthquake. The observed variations were diverse (see Fig. 2). In the upper group of springs (Pirogovskiye, Akademicheskiye, Pushkinskiy, Teplyy and Kholodnyy Narzan), which are confined to the intersection of the faults, the discharge increases preceding an earthquake, sharply increases or decreases during an earthquake, and decreases after an earthquake (Fig. 2a). In the inner Pirogovskiye and inner Akademicheskiye springs, a temporary

* This description applies to inner Pirogovskiye and inner Akademicheskiye while the illustration is shown for outer Pirogovskiye and outer Akademicheskiye (see Fig. 2).
The discontinuation of the discharge occurred after the earthquake. In the lower group of springs (Lermontovskiy No. 2 Lower Kabardinskiy, Teplosernyye No. 1, Radioshtol'nya No. 2), the discharge decreased sharply preceding the earthquake, increased during, and decreased or stabilized afterwards (Fig. 2c). The activity of the outlying springs of the upper group (Narodnyy, Krasnoarmeyskiy No. 1, No. 2, No. 3, Borehole No. 14, Naklonsya borehole) was not affected by the earthquake (Fig. 2b).

The temperature of the upper springs increased slightly before the earthquake, increased considerably during, and decreased subsequently (Fig. 2a, b). In the lower group of springs, the temperature did not change or changed very slightly in the 1-2° C range.


Results of estimates of the effect of earthquake energy on the attenuation of seismic waves from near earthquakes are presented. The records of 500 earthquakes (1965-67) with $E = 10^7 - 10^{11}$ j, $h = 3-5 - 15$ km, $\Delta = 15-170$ km by eight seismographic stations are analyzed. Observational data on the maximum amplitude of seismic waves were corrected for the local conditions at seismographic stations (correction factor $0.62 - 1.72$). Empirical expressions are derived for: a) the relation between the attenuation factor and energy class $K = \lg E(j)$

$$\eta = \frac{10^{1.8} \cdot 0.9K}{K^2}$$

and b) the relation between the maximum amplitude and hypocentral distance and energy class

$$A = \frac{10^{a + 0.03} \cdot K^{0.62}}{K^2}$$

where $a = 3.7 \pm 0.5; \beta = 0.03 \pm 0.1$ (derived from $\lg A = \lg q(K) - n_k \lg R$).

where $q(K) = a + \beta K$.

-50-
Kogan, A. L.  First attempt at a crustal study in Antarctica by deep seismic sounding.  
Geologiya i geofizika, no. 10, 1971, 84-89.

The first results of deep seismic sounding investigations in Antarctica performed in 1969 in the coastal zone of East Antarctica (Novolazarevskaya station area) are described. The observations were made along a 430-km-long profile and at two receiving stations north and south of the profile (see Fig. 1). The preliminary results of these investigations, as well as the observing system and instrumentation used were reported earlier.*

Instrumentation consisted of an SS-24P seismic system modified by V. M. Davydov and B. P. Mishen’kin, an OS-8 seismic-recording oscillograph, and a set of NS-3 vertical and horizontal seismometers.

Deep seismic soundings were performed using the point seismic sounding method and discrete correlation of seismic waves.

Fig. 1. Location of DSS Observation Points
1 - Recording points; 2 - resulting DSS points; 3 - shot points.

The observing system consisted of two fixed shot points 15.7 km apart in the middle of the profile (at the east and west ends of the Schirmacher Ponds). The maximum recorder-to-shot point separation was 225 km and the minimum, 54 km. The length of a linear array of six groups of vertical and horizontal (in the x-axis direction) seismometers was 1000. Each array consisted of three seismometers connected in parallel and buried 25-50 cm in ice or snow. Charges of 100 to 2000 kg were detonated at depths of 37 and 50 m, on the bottom of lakes located at the east and west end of Schirmacher Ponds. Both lakes were covered by 2.4 m of ice. It was established that the level of background noise was low. A special type of noise occurring on certain days was attributed to the formation of thermal cracks in the body of the glacier and was discovered during special observations of background noise. Intense shear waves were consistently recorded at long distances. In the initial part of horizontal seismograms, the horizontal component of compressional waves was recorded.

In the preliminary analysis of the records, refracted phase and wide-angle reflections from the Moho discontinuity, as well as crustal waves, were identified, and several records are given. Wide-angle reflections from the Moho discontinuity were absent from the records at recording point 10 on the Lazarev shelf. Very intense wide-angle reflections from intercrustal interfaces were recorded immediately prior to the reflected phase from the Moho discontinuity at recording points 3 and 4.

The crust in the coastal zone of East Antartica (15-150 km inland from the present coast line) is characterized by block structure (Fig. 2). Three large blocks, separated by deep seated faults, are identified. The existence of these faults has been established by gravity and magnetic data, as well. The western fault probably penetrates the upper mantle and is not evident on the day surface of the glacier, while the eastern fault is very distinctly evident. The depth to the Moho discontinuity in the central block is 38-40 km, which indicates continental type of crust. Within the western block, the crustal thickness decreases from 38 to 34 km. A crustal thickness of 32-33 km at the 50 km observation point of the profile was determined from gravity.
Fig. 2. Preliminary Section of the Earth's Crust in Queen Maud Land, East Antarctica.

1 - seismic interfaces; 2 - depths from reflected waves; 3 - depths from refracted waves; 4 - zones of deepseated faults; 5 - shot points; 6 - observing points; 7 - bottom of the glacier; 8 - ice; 9 - water; \( \Delta g \) - residual gravity anomaly, \( \Delta z \) - vertical component of magnetic field, I - boundary of equal layer velocities, II - assumed Conrad discontinuity, M - Moho discontinuity.

The crustal thickness decreases from 38 to 34 km. A crustal thickness of 32-33 km at the 50 km observation point of the profile was determined from gravity data. The crustal thickness (see Fig. 2) of the eastern block, as
data. The crustal thickness (see Fig. 2) of the eastern block, as revealed by gravity data, is equal to the thickness of the central block. The crustal thickness increases southward, reaching 41 km at recording point 9, while it decreases northward reaching 29 km at recording point 10 (Lazarev shelf). This decrease of the crustal thickness and absence of wide-angle reflections from Moho discontinuity in the shelf region leads to the assumption of a transitional type of crust. Within the central block, two reflection interfaces are found at depths of 18 and 28 km. The interface occurring at 18 km is interpreted as the top of the "basaltic" layer. It was established that the average crustal velocity is 6.4 km/sec, while the "basaltic" layer velocity is 6.65 km/sec and the Moho discontinuity velocity is 8.0 km/sec. The velocity distribution in the upper crust is shown in Figure 3. The layer velocities increase from 5.5 to 6.3 km/sec over a 15 km depth range.

![Fig. 3. Velocity Distribution from Data of Generalized Time Distance Curve of First Arrivals.](image)

The residual gravity anomalies are in agreement with seismic data on the Moho discontinuity along the profile, but not at recording points 9 and 10 (low and high values, respectively).

It is concluded that the DSS results verified the crustal thickness as predicted from gravity data and the relief of the bottom and top of the glacier.

The network of seismological observatories operating in the USSR during 1967 provided reliable determination of earthquakes with $M > 4 \frac{1}{2}$, originating in the USSR and adjacent regions. The coordinates of computer-determined epicenters and the magnitude of earthquakes summarized in this article were taken from the Seismological Bulletin of the Network of Seismograph Stations of the USSR (Seysmologicheskiy byulleten' seti seysmicheskikh stantsiy v SSSR). The article contains a catalog-type listing of the following data on 137 earthquakes with $M > 4 \frac{1}{2}$ originating in the USSR and adjacent region in 1967: date, origin time (GMT), epicenter coordinates, focal depth, magnitude and the name of the region where the epicenter originated. The distributions of the earthquakes in individual seismic zones with respect to magnitude is as follows:

<table>
<thead>
<tr>
<th>Earthquake magnitude</th>
<th>$M \geq 4 \frac{1}{2}$</th>
<th>$4 \frac{1}{2} \leq M &lt; 5$</th>
<th>$5 \leq M &lt; 6$</th>
<th>$6 \leq M &lt; 7$</th>
<th>$7 \leq M &lt; 8$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carpathia</td>
<td>3</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Crimea</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
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</tr>
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<td>23</td>
<td>14</td>
<td>8</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>subcrustal</td>
<td>30</td>
<td>15</td>
<td>14</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Altay Sayan</td>
<td>3</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Baykal</td>
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<td>-</td>
<td>2</td>
<td>-</td>
<td>1</td>
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<tr>
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<td></td>
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<tr>
<td>crustal</td>
<td>45 with $M \geq 5$</td>
<td>-</td>
<td>36</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>subcrustal</td>
<td>18 with $M \geq 5$</td>
<td>-</td>
<td>13</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Arctic</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* $M \geq 5$ for earthquakes in the Kurile-Kamchatka and Hindu Kush regions
Fig. 1. Epicenter Map of Earthquakes with M ≥ 4.1/2 in the Territory of the USSR in 1967

Magnitude: 1 - 7 ≤ M < 8; 2 - 6 ≤ M < 7; 3 - 5 ≤ M < 6; 4 - 4 1/2 ≤ M < 5. Focal depth
(in km) 5 - H < 60; 6 - 60 < H ≤ 300; 7 - H ≥ 300.
An epicenter map for the earthquakes is shown in Figure 1. A graph of cumulative strain energy released in individual seismic zones during 1967 and a graph showing the variation of strain energy released in the principal seismic zones in the USSR during 1957-1967 are given in the article. Similar to previous years, seismic activity in 1967 was at its highest level in the Far East seismic zone. It had been gradually decreasing after a significant increase in 1963, reaching a minimum in 1966 and increasing again in 1967. A brief description of seismic activity in individual zones in 1967 is given.


The earthquakes in Carpathia during 1967 originated mainly in the Vranchea region of the Carpathian chain in Rumania and in Transcarpathia in the USSR and Rumania. The earthquakes were located on the basis of records from the Soviet Carpathian network of seismographic stations (L'vov, Uzhgorod, Mezhgor'ye, Rakhov, Kosov, and the temporary station at Morshin), as well as data from other Soviet (Kishinev, Chernovtsy, Simferopol', Yalta, Alushta, Feodosiya) and non-Soviet (Hungary, Poland, Bulgaria, Czechoslovakia, Yugoslavia) seismographic stations. A catalog listing of the following data on 20 earthquakes in Carpathia in 1967 is given: date, origin time (GMT), epicenter coordinates, focal depth, accuracy class, energy class $K = \lg E(j)$ and the name of the region where the earthquakes originated. An epicenter map for the earthquakes in Carpathia during 1967 is shown in Figure 1. In 1967, as in previous years, the Vranchea region was the most active with 15 deep earthquakes ($H = 80-180$ km). Macroseismic
Fig. 1. Epicenter Map of Earthquakes in Carpathia in 1967.

Earthquake energy (in joules): 1 - $E = 10^{13}$; 2 - $E = 10^{12}$; 3 - $E = 10^{11}$; 4 - $E = 10^9$. Accuracy class: 5 - A, B; 6 - not classified. Focal depth (in km): 7 - $H \leq 60$ km; 8 - $100 \leq H \leq 180$ km; 9 - seismographic stations

data on three earthquakes with $E = 10^9$ originating in Transcarpathia are given.

Observations of earthquakes originating in the Crimea seismic zone during 1967 were conducted at the Alushta, Yalta, Feodosiya and Simferopol' seismographic stations. The stations were equipped to determine epicenter coordinates of earthquakes with $E \geq 10^7$ j. All 19 earthquakes observed originated in the Black Sea in a region between $44^\circ 1 - 44^\circ 6$ N and $34^\circ 3 - 35^\circ 0$ E.

A catalog listing given in the article contains the following data on 19 earthquakes: date, origin time (GMT), epicenter coordinates, focal depth (16 shocks), accuracy class, energy class $K = 10^{\lg E(j)}$ and the name of the geographical region where the earthquake originated. An epicenter map for earthquakes in the Crimea seismic zone during 1967 is shown in Figure 1. Seismic activity in this zone in 1967 was characterized by somewhat increased activity in the Yalta-Alushta group of hypocenters.

![Fig. 1. Epicenter Map of Earthquakes in the Crimea in 1967.](image)

Earthquake energy (in joules): 1- $E = 10^{10}$; 2- $E = 10^9 - 10^{10}$; 3- $E = 10^8$; 4- $E = 10^7 - 10^8$; 5- $E = 10^7$; 6- stations.
Tskhakaya, A. D., E. A. Dzhibladze, V. G.
Papalashvili, T. M. Lebedcva, Ts. A.
Tabutsadze, L. K. Darakhvelidze, L. A.
Kakhiani, L. V. Labadze, Z. Z. Sultanova,
and V. P. Alimamedova. Earthquakes in the
Caucasus. IN: Akademiya nauk SSSR. Institut
fiziki Zemli. Zemletryaseniya v SSSR v 1967
godu (Earthquakes in the USSR in 1967). Moskva,

A network of twenty nine seismograph stations was in
operation in the Caucasus in 1967. Twenty four of these stations were
equipped with high sensitivity seismographs. In addition to the records of
these stations, data from the Seismological Bulletin of the Institute of the
Physics of the Earth (Moscow), as well data from seismographic stations
in Poland, Turkey, and Finland, were used in the analysis of earthquakes.
A catalog listing is given for the following data on 759 earthquakes originating
in the Caucasus during 1967: date, origin time (GMT), epicenter coordinates,
focal depth, accuracy class, magnitude (11 shocks), energy class $K = \log_{10}(E)$
and the name of the region where the earthquake originated (with macro-
seismic data given for 13 shocks). The distribution of the earthquakes with
respect to energy is as follows:

<table>
<thead>
<tr>
<th>Earthquake energy (joules)</th>
<th>$10^5$</th>
<th>$10^6$</th>
<th>$10^7$</th>
<th>$10^8$</th>
<th>$10^9$</th>
<th>$10^{10}$</th>
<th>$10^{11}$</th>
<th>$10^{12}$</th>
<th>$10^{13}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of earthquakes</td>
<td>5</td>
<td>73</td>
<td>232</td>
<td>269</td>
<td>103</td>
<td>63</td>
<td>10</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

Two epicenter maps, one for earthquakes with $E \geq 10^9$ $j$ (Fig. 1)
and the other for $E < 10^9$ $j$ (Fig. 2), are given.

Seismic activity in the Caucasus seismic zone in 1967 was
significantly lower than in 1966. A brief description of the macroseismic
effects of several earthquakes is given.
Fig. 1. Epicenter Map of Earthquakes with $E \geq 10^9$ j in the Caucasus in 1967.

Earthquake energy (in joules): 1- \(10^{13}\); 2- \(10^{12}\); 3- \(10^{11}\); 4- \(10^{10}\); 5- \(10^9\). Accuracy class: 6- a, b, A; 7- B; 8- n/c; 9- seismograph stations. Numerals denote earthquakes with $E \geq 10^{11}$ (nos.1-13) and earthquakes for which macroseismic data exist (nos.14-26).
Fig. 2. Epicenter Map of Earthquakes with $E < 10^9$ j in the Caucasus in 1967.

Earthquakes energy (in joules): 1- $10^8$; 2- $10^7$; 3- $10^6$. Accuracy class: 4- a, b, A; 5- B; 6- n/c; 7- area of epicenter concentration, numerals denote the number of earthquakes with corresponding energy class $K = \lg E$ (j).
Nepesov, R. D., K. D. Lagutochkina, G. L.


Observations of earthquakes in the Kopet Dag seismic zone during 1967 were conducted at the Kizyl-Arvat, Ashkhabad, Vannovskaya and Krasnovodsk seismographic stations. The last two stations were equipped with high sensitivity seismographs. The location of the seismographic stations in Kopet Dag is unfavorable; thus, only earthquakes with $M \geq 4$ ($E \geq 10^{11}$ j) can be determined. However, some earthquakes with $M < 4$ were determined using additional data from the Turkmen geological-geophysical expedition which was equipped with "Zemlya" seismic recording systems. The article contains a catalog listing of the following data on 72 earthquakes with $E \geq 10^5$ j in Kopet Dag during 1967: date, origin time (GMT), focal depth (10 shocks), accuracy class, magnitude (16 shocks), energy class $K = \lg E$ (j) and the name of the region where the earthquake originated. An additional listing is given showing macroseismic data for 12 earthquakes with $E \geq 10^7$ j which were recorded in the Kopet Dag seismic zone. The energy distribution of the earthquakes in Kopet Dag during 1967, is as follows:

<table>
<thead>
<tr>
<th>Earthquake energy (in joules)</th>
<th>No. of earthquakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^5$</td>
<td>2</td>
</tr>
<tr>
<td>$10^6$</td>
<td>3</td>
</tr>
<tr>
<td>$10^7$</td>
<td>6</td>
</tr>
<tr>
<td>$10^8$</td>
<td>9</td>
</tr>
<tr>
<td>$10^9$</td>
<td>17</td>
</tr>
<tr>
<td>$10^{10}$</td>
<td>21</td>
</tr>
<tr>
<td>$10^{11}$</td>
<td>8</td>
</tr>
<tr>
<td>$10^{12}$</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>79</td>
</tr>
</tbody>
</table>

The distribution of local earthquakes with $(S-P) \leq 10$ sec recorded by one or two stations is as follows:
Earthquake energy (in joules) | $10^4$ | $10^5$ | $10^6$ | $10^7$ | $10^8$ | $10^9$ | $10^{10}$ | $10^{11}$ | Total |
---|---|---|---|---|---|---|---|---|---|
Vannovskaya station No. of earthquakes | 3 | 22 | 42 | 52 | 37 | 10 | - | - | 166 |
Ashkhabad No. of earthquakes | 1 | 2 | 5 | 9 | 6 | 7 | 1 | - | 31 |
Kizyl - Arvat No. of earthquakes | - | - | - | 1 | - | - | - | - | 1 |
Krasnovodsk No. of earthquakes | - | 2 | 2 | 1 | 1 | - | - | - | 6 |
Vannovskaya and Ashkhabad No. of earthquakes | - | - | 7 | 41 | 30 | 16 | 1 | - | 95 |
Ashkhabad and Kizyl - Arvat No. of earthquakes | - | - | - | 1 | - | - | - | - | 2 |
Vannovskaya and Kizyl - Arvat No. of earthquakes | - | - | - | 3 | - | 1 | 1 | 1 | 5 |

An epicenter map is shown in Figure 1. Most epicenters are concentrated in the Ashkhabad and Shirvan-Kuchan regions, where disastrous earthquakes occurred in the past. The remainder of the article contains macroseismic data on several earthquakes.
Fig. 1. Epicenter Map of Earthquakes in Kopet Dag in 1967.

Earthquake energy (in joules): 1 - $10^{12}$; 2 - $10^{11}$; 3 - $10^{10}$; 4 - $10^9$; 5 - $10^8$; 6 - $10^7$; 7 - $10^6$; 8 - $10^5$.

Accuracy class: 9 - A; 10 - B; 11 - n/c.
Azizov, T. S., Ye. G. Astaf’yeva, A. A.
Vlasova, K. Dzhanuzakov, A. I. Zakharova,
R. N. Ibragimov, V. K. Iodko, A. P. Katok,
T. A. Kinyapina, A. A. Kon’kov, R. I.
Kurochkina, V. K. Kuchay, K. Kurmanaliyeva,
V. A. Nechayev, M. P. Pavlovskaya, Ye. A.
Rozova, O. A. Romanova, P. G. Semenov,
E. M. Khaitov, V. N. Yakovlev, and D. Kh.
Yakubov. Earthquakes in Central Asia. IN:
Akademiya nauk SSSR. Institut fiziki Zemli.
Zemletryaseniya v SSSR v 1967 godu (Earth-
quakes in the USSR in 1967). Moskva, Izd-vo

The network of seismographic stations which operated in
Central Asia in 1967 was the same as in previous years and was capable
of determining epicenters of earthquakes with \( E \geq 10^9 \cdot 10^{10} j \) originating
within the Soviet part of the Central Asia seismic zone. The article contains
a catalog listing of the following data on 1236 earthquakes with \( E \geq 10^9 j \)
(580 crustal and 706 subcrustal) occurring in Central Asia in 1967: date,
origin time (GMT), epicenter coordinates, focal depth, accuracy class,
magnitude (73 events), energy class \( K = \lg E(\) and the name of the region
where the earthquake occurred. In addition to the catalog, a listing is
given of 50 strong earthquakes with \( E \geq 10^{12} j \) (a few with \( E = 10^{11} j \)). The
energy distribution of earthquakes in 1967 and 1966 originating in the crust
is as follows:

<table>
<thead>
<tr>
<th>Earthquake energy (in joules)</th>
<th>(10^9)</th>
<th>(10^{10})</th>
<th>(10^{11})</th>
<th>(10^{12})</th>
<th>(10^{13})</th>
<th>(10^{14})</th>
<th>(10^{15})</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of earthquakes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1967</td>
<td>256</td>
<td>219</td>
<td>70</td>
<td>23</td>
<td>6</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>1966</td>
<td>364</td>
<td>206</td>
<td>74</td>
<td>15</td>
<td>6</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

An epicenter map for earthquakes with \( E \geq 10^{10} j \) is shown in Figure 1.
Seismicity in Central Asia in 1967 was marked by high activity in the
southern Tien Shan region of crustal earthquakes and in the Pamir - Hindu-
Fig. 1. Epicenter Map of Earthquakes with $E \geq 10^{10}$ (7) Originating in Central Asia in 1967

Earthquake energy (in joules): 1- $10^{15}$; 2- $10^{14}$; 3- $10^{13}$; 4- $10^{12}$; 5- $10^{11}$; 6- $10^{10}$. Accuracy class: 7- class A, B; 8- n/c. Focal depth (in km): 9- $H \leq 60$; 10- $60 < H \leq 300$. 
Kush region of deep earthquakes. More than a third of all earthquakes in Central Asia occurred in the southern Tien Shan (1 event with $E = 10^{13}$ j; 6 with $E = 10^{12}$ j). Nineteen strong earthquakes occurred in Pamir - Hindu-Kush (6 crustal shocks with $E = 10^{12}$ j; 13 deep events - one with $E = 10^{14}$ j and twelve with $E = 10^{13}$ j). Descriptions of seismic activity in various regions of the Central Asia seismic zone and macroseismic effects of 17 strong earthquakes are discussed.


Observations of earthquakes in northern Tien Shan in 1967 were conducted at nine regional-type and three general-type seismographic stations. The Orta-Merke and Charyn stations did not operate in the second half of the year. A catalog listing of data on 336 earthquakes occurring in northern Tien Shan during 1967 is as follows: date, origin time (GMT), epicenter coordinates, focal depth (100 shocks*), accuracy class, and energy class $K = \log E(j)$. The distribution of the earthquakes with respect to energy is as follows:

<table>
<thead>
<tr>
<th>Earthquake energy (in joules)</th>
<th>$10^5$</th>
<th>$10^6$</th>
<th>$10^7$</th>
<th>$10^8$</th>
<th>$10^9$</th>
<th>$10^{10}$</th>
<th>$10^{11}$</th>
<th>$10^{12}$</th>
<th>$10^{13}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of earthquakes</td>
<td>3</td>
<td>43</td>
<td>162</td>
<td>90</td>
<td>26</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

An epicenter map for the earthquakes is shown in Figure 1. The most seismically active regions in 1967 were the Kungey-Alatau and Terskey-Alatau (western and eastern ends) ridges. The parameters of the recurrence

---

* The majority of these shocks originated in the regions of the Chilik and Charyn rivers where temporary stations were located.
Fig. 1. Epicenter Map of Earthquakes Originating in Northern Tien Shan in 1967.

Earthquake energy (in joules): 1- $10^{13}$; 2- $10^{12}$; 3- $10^{11}$; 4- $10^{10}$; 5- $10^9$; 6- $10^8$; 7- $10^7$; 8- $10^6$. Focal depth (in km): 9- $h = 0-5$; 10- $h = 6-10$; 11- $h = 11-15$; 12- $h = 16-20$; 13- $h > 20$; 14- undetermined.

Graphs plotted for the 1929-67 (entire period of instrumental observations) 1965, 1966, and 1967 periods are as follows:

<table>
<thead>
<tr>
<th>Period</th>
<th>1929-67</th>
<th>1965</th>
<th>1966</th>
<th>1967</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_{10}$</td>
<td>0.056</td>
<td>0.1</td>
<td>0.076</td>
<td>0.076</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.44</td>
<td>0.42</td>
<td>0.52</td>
<td>0.48</td>
</tr>
</tbody>
</table>

Seismic activity $A_{10}^\gamma$ in the last three years was higher than the average

---

\* Number of earthquakes of energy $E = 10^{10}$ j per year over an area of 1000 km².
for all periods of instrumental observations. Graphs of the cumulative strain energy release for the 1929-1967 and 1807-1967 (extrapolated from macroseismic data) are given in the article.

Tsibul'chik, I. D., and A. G. Filina.

Earthquakes in the Altay-Sayan zone.


Observations of earthquakes in the Altay-Sayan seismic zone in 1967 were conducted at nine seismographic stations equipped with SK-3M systems. The earthquake epicenters were determined using data from the Altay-Sayan network and additional data from the Baykal network of seismographic stations. The following data on 114 earthquakes with $E \geq 10^9$ j originating in the Altay-Sayan seismic zone in 1967 are given: date, origin time (GMT), epicenter coordinates, energy class $K = \lg E(j)$, accuracy class, and the name of the region where the earthquake originated. The distribution of all recorded earthquakes with respect to energy is as follows:

<table>
<thead>
<tr>
<th>Earthquake energy (in joules)</th>
<th>$10^6$</th>
<th>$10^7$</th>
<th>$10^8$</th>
<th>$10^9$</th>
<th>$10^{10}$</th>
<th>$10^{11}$</th>
<th>$10^{12}$</th>
<th>$10^{13}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of earthquakes</td>
<td>17</td>
<td>159</td>
<td>182</td>
<td>81</td>
<td>25</td>
<td>6</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Two epicenter maps are shown, one for earthquakes with $E \geq 10^9$ j (Figure 1) and the other for $E < 10^9$ j (Figure 2). Earthquake epicenters are concentrated within three areas which are indicated in Figure 1 by 1, 2, and 3. Temporal variation of seismic activity for the three epicentral areas is shown in Figure 3. Focal mechanism solutions are given for 2 earthquakes with
Fig. 1. Epicenter Map of Earthquakes with Energy $E \geq 10^9$ j Originating in the Altay-Sayan Zone during 1967.

Earthquake energy (in joules): $1 \cdot 10^3 < 2 \cdot 10^3 < 3 \cdot 10^3 < 4 \cdot 10^3$. 
Fig. 2. Epicenter Map of Earthquakes with $E < 10^3$ J in the Altay-Sayan Zone during 1957.
Earthquake energy (in joules): $1 \times 10^8$, $2 \times 10^7$, $3 \times 10^6$. 

-72-
Fig. 3. Variation of seismic activity with time for each of the epicentral areas marked in Figure 1:

1- between 51°5 - 52°0 N and 95°7 - 96°3 E; 2- 48°7 - 50°0 N and 96°0 - 98°7 E; 3- 50°5 - 51°6 N and 97°1 - 98°7 E.
$E = 10^{12} j$ and $E = 10^{13} j$, originating in areas 1 and 2, respectively. The stress state in the two areas is as follows: In area 1, a slightly inclined compressive stress axis and a more inclined tensile stress axis lie in a north-south direction, transverse to the surface tectonic structures; a nearly horizontal intermediate stress axis is parallel to the tectonic structure. In area 2, the slightly inclined compressive and intermediate stress axes lie in the north-south direction and transverse to the surface tectonic structures, while a nearly horizontal tensile stress axis lies parallel to the tectonic structures.


Observations of earthquakes in the Baykal seismic zone during 1967 were conducted at twenty-three permanent and temporary seismographic stations which were equipped as follows:
<table>
<thead>
<tr>
<th>Station</th>
<th>Seismograph</th>
<th>Station</th>
<th>Seismograph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irkutsk SK, SG</td>
<td></td>
<td>Bodaybo SKM-3</td>
<td></td>
</tr>
<tr>
<td>Kyakhto SK</td>
<td></td>
<td>Chara VEGIK</td>
<td></td>
</tr>
<tr>
<td>Kabanski SK</td>
<td></td>
<td>Nelyaty VEGIK</td>
<td></td>
</tr>
<tr>
<td>Barguzin SKM</td>
<td></td>
<td>Sredniy Kalar VEGIK</td>
<td></td>
</tr>
<tr>
<td>Alla VEGIK, SKM-3</td>
<td></td>
<td>Uakit USF</td>
<td></td>
</tr>
<tr>
<td>Nizhneangarski SKM</td>
<td></td>
<td>Arshan SKM-3</td>
<td></td>
</tr>
<tr>
<td>Orlik SKM-3</td>
<td></td>
<td>Udokan VEGIK</td>
<td></td>
</tr>
<tr>
<td>Kumora SKM-3</td>
<td></td>
<td>Naminga SKM-3</td>
<td></td>
</tr>
<tr>
<td>Mondy SKM-3</td>
<td></td>
<td>Zapadnyy VEGIK</td>
<td></td>
</tr>
<tr>
<td>Turan SKM-3</td>
<td></td>
<td>Lurbun VEGIK</td>
<td></td>
</tr>
<tr>
<td>Tupik USF, SKM-3</td>
<td></td>
<td>Tyrgan VEGIK</td>
<td></td>
</tr>
<tr>
<td>Zakamensk SKM-3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The response curves for the seismographic systems of the Baykal region stations are shown in Figure 1. The following data are given:

Fig. 1. Response Curves for the Baykal Seismographic Stations. (Curve numbers correspond to above list).
for 297 earthquakes with $E \geq 10^9$ j originating in the Baykal seismic zone in 1967: date, origin time (GMT), epicenter coordinates, accuracy class, magnitude, energy class $K = \log E (j)$, and the name of the region where the earthquake originated. The distribution of 1809 earthquakes in the Baykal region with respect to energy is as follows:

<table>
<thead>
<tr>
<th>Earthquake energy (in joules)</th>
<th>10$^{13}$</th>
<th>10$^{12}$</th>
<th>10$^{11}$</th>
<th>10$^{10}$</th>
<th>10$^{9}$</th>
<th>10$^{8}$</th>
<th>10$^{7}$</th>
<th>10$^{6}$</th>
<th>10$^{5}$</th>
<th>10$^{4}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of earthquakes</td>
<td>2</td>
<td>2</td>
<td>14</td>
<td>30</td>
<td>146</td>
<td>449</td>
<td>763</td>
<td>379</td>
<td>20</td>
<td>1</td>
</tr>
</tbody>
</table>

The epicenter maps are given, one for earthquakes with $E \geq 10^9$ j (Figure 2) and the other for all earthquakes (Figure 3). Most of the earthquakes in Baykal in 1967 occurred at a depth of about 5 - 10 km (Figure 4). Most of the earthquakes in the Baykal seismic zone in 1967, as in previous years, were confined to the Baykal rift zone. Their epicenters fall in a strip, wide in the southwestern part of the Baykal rift zone and narrow in the South and Central Lake Baykal areas, divides into three branches: 1) the northern branch extending along the east coast of the North Lake Baykal and the Upper Angara basin; 2) the central branch extending along the Barguzin ridge, the northern part of the Barguzin basin, and the Severo-Muyskij ridge; and 3) the southern branch intersecting the Ikatskiy ridge and reaching the Muyskaya basin. Two concentrations of epicenters in the Baykal rift zone are observed: one between the Upper Angara and Muyskaya basins and another between the Muysko-Kudinskaya and Chara basins. The temporal distribution of earthquakes with $E \geq 10^8$ j along the Baykal rift zone (shown in Figure 5) was uniform during 1967. The cumulative strain energy release graph for the Baykal rift zone is given in the article. The slope of the recurrence graph for the rift zone is $\gamma \sim 0.5$ (the same as for the entire Baykal seismic zone). Seismic activity in the southwestern part of the rift zone was less than in the northeast (the average value of $\ldots$

* three strong earthquakes originating outside the Baykal zone are also listed

$\ldots$ $\log N = f(k)$ where $k = \log E(j)$

-76-
Fig. 3. Epicenter Map of All Earthquakes in Baykal in 1967

Earthquake magnitude: 1- $6 \leq M \leq 7$; 2- $5 \leq M < 6$; 3- $4 \leq M < 5$; 4- $M < 4$. Accuracy class: 5- a; 6- b; 7- A; 8- B; 9- seismograph station; 10- fault; 11- Revived fault; 12- area of epicenters concentration, numeral denotes the number of earthquakes with $E \leq 10^8$. 
Fig. 2. Epicenter Map of Earthquakes with $E \geq 10^9$ J in Baykal in 1967

Earthquake energy (in joules): 1 - $E = 10^{16}$; 2 - $E = 10^5$; 3 - $10^{13} \leq E < 10^{14}$; 4 - $10^{12} \leq E < 10^{13}$; 5 - $10^{11} \leq E < 10^{12}$; 6 - $10^{10} \leq E < 10^{11}$; 7 - $10^{9} \leq E < 10^{10}$.

Accuracy class: 8 - a; 9 - b; 10 - A; 11 - B; 12 - seismograph stations; 13 - faults; 14 - revived faults; 15 - area of epicenter concentration, numeral denotes the number of earthquakes with $E = 10^9$ J.
Fig. 4. Distribution of Baykal Earthquakes with Respect to Focal Depth.

h - focal depth; n - number of events

The number for the rift zone is about 0.08. A seismic activity map for the Baykal seismic zone is shown in Figure 6. Seismic activity was highest in the central part of the eastern shore of northern Lake Baykal and in the northeastern part of the Barguzin ridge ($A_{10} = 2.0$).

$A_{10}$

Number of earthquakes with $E = 10^{10}$ per year over 1000 km$^2$

Calculated from the formula: $A = \frac{N \cdot 10^{10} (1 - 10^{-\gamma})}{S^{\alpha + 1} \cdot (K_0)}$,

where $N$ - number of earthquakes with $E \geq 10^6$; averaging area $S = 1700$ km$^2$; observation period $T = 1$ year; energy class of earthquakes for whose seismic activity level is calculated as $K_0 = 10$; energy class of earthquakes recorded without lapse $K = 8$. 

-81-
Fig. 5. Variation of Seismic Activity with Time in the Baykal Rift Zone During 1967.

Earthquake energy (in joules): 1 - $E=10^{13}$; 2 - $E=10^{12}$; 3 - $E=10^{11}$; 4 - $E=10^{10}$; 5 - $E=10^9$; 6 - $E=10^8$. Numbers denote the number of earthquakes.
Fig. 6. Seismic Activity Map for Baykal in 1967.

1 - Boundary of the region for which seismic activity is calculated; 2 - contours of seismic activity;
3 - epicenters of the strongest earthquakes.
Two new regional seismographic stations were added in 1967 to the existing network for the Far East seismic zone, one on the island of Urup in October and another on the island of Iturup in December. The newly set up stations facilitated lowering the recording threshold to $E \geq 10^9 - 10^{8.5} \text{j}$ for earthquakes originating in the Simushir-Urup, northern Iturup, and Kunashir regions. However, the existing network does not provide data for the determination of epicenter for all earthquakes with $E < 10^9 \text{j}$ in the southern and central parts of the Kurile Islands region, and with $E < 10^{10.5} \text{j}$ in the northern part. Two catalogs of earthquakes in the Far East (excluding Kamchatka north of 52° N and the Commander Islands) are given: 1) a catalog listing the following data on 660 earthquakes with $E \geq 10^9 \text{j}$ originating in the Kurile Islands and Kamchatka south of 52° N in 1967: date, origin time (GMT), epicenter coordinates, focal depth, accuracy class, magnitude, energy class $k = \lg E(j)$, and the region where the earthquake originated, with macroseismic data for 89 shocks; 2) a catalog listing the following data on 114 located earthquakes originating in Sakhalin in 1967: date, origin time (GMT), epicenter coordinates, seismographic recording stations, energy class, and the name of the region where the earthquake originated. The seismicity of the Kurile Islands and the Sakhalin region in 1967 are considered separately.
Kurile Islands. The distribution of earthquakes in the Kurile Islands with respect to energy and magnitude is as follows:

<table>
<thead>
<tr>
<th>Earthquake energy (in joules)</th>
<th>7</th>
<th>7.5</th>
<th>8</th>
<th>8.5</th>
<th>9</th>
<th>9.5</th>
<th>10</th>
<th>10.5</th>
<th>11</th>
<th>11.5</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of earthquakes</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>62</td>
<td>144</td>
<td>182</td>
<td>218</td>
<td>147</td>
<td>131</td>
<td>64</td>
<td>47</td>
<td>34</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>54</td>
<td>6</td>
<td>64</td>
<td>47</td>
<td>34</td>
<td>12</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

The location of the epicenters of earthquakes with $E \geq 10^9$ j is shown in Figure 1 and $E < 10^9$ j in Figure 2.

The location of the hypocenters of earthquakes originating between the volcanic arc and the Kurile-Kamchatka Trench is shown in Figures 3 and 4. Figure 3 represents a projection of hypocenters onto a vertical plane parallel to the axis of the Kurile-Kamchatka Island arc at a distance of 130 km from the coast. Figure 4 shows projections of hypocenters onto a vertical plane perpendicular to the axis of the island arc for five separate sectors of the Kurile Islands region (indicated by A, B, C, D, E in Figure 1).

A map of epicenter density is shown in Figure 5, while the variation of epicenter density along the Kurile Islands arc is shown in Figure 6. The distribution of the earthquakes with respect to focal depth is shown in Figure 7. The variation of seismic activity with time for each of the sectors is shown in Figure 8. The expression for the recurrence graph obtained for earthquakes with $H = 0-80$ km is $\lg n = 6.4 - 0.44 K$.

Seismic activity in the Kurile Islands region in 1967 was higher than in 1964-1966 (1 shock with $M = 7$ followed by aftershocks occurred in the epicentral area of the disastrous 1963 Urup earthquake). Maximum activity, migrating toward Simushir Island during 1963-67, occurred on the island of Urup in 1967. In 1967, some redistribution of the epicenter density
Fig. 1. Epicenter Map of Far East Earthquakes with $E \geq 10^9$ j ($M \geq 4$)

Earthquake magnitude and energy (in joules): 1- $M \geq 6$; 2- $10^{13} > E > 10^{12}$; 3- $10^{12} > E > 10^{11}$; 4- $10^{11} > E > 10^9$.

Focal depth (in km): 5- $0 < H \leq 30$; 6- $30 < H < 60$; 7- $60 < H \leq 90$; 8- $90 < H \leq 300$; 9- $300 < H$; 10- focal depth assumed to be $0 < H \leq 70$; 11- bottom of the Kurile Trench; 12- sectors of the Kurile Islands region; 13- location of sections shown in Figures 3 and 4; 14- seismographic stations.

Fig. 2. Epicenter Map of Far East Earthquakes with $E < 10^9$ j

Earthquake energy (in joules): 1- $10^9 > E = 10^8$; 2- $E < 10^8$. Focal depth (in km): 3- $0 < H \leq 30$; 4- $30 < H \leq 60$; 5- $60 < H < 90$; 6- $90 < H \leq 300$; 7- focal depth assumed to be $0 < H \leq 70$; 8- bottom of the Kurile Trench; 9- seismographic stations.
Fig. 3. Projection of Hypocenters of Kurile Earthquakes in 1967 Originating between the Kurile Volcanic Chain and the Kurile Trench onto a Vertical Plane along the Kurile-Kamchatka Arc at a Distance of 130 km from the Coast

1-4 - the same as in Fig. 1; 5 - \( E < 10^{-9} \); 6 - water; 7 - sedimentary layer \( (V_p < 3.5 \text{ km/sec}) \); 8 - "granitic" layer \( (V_p = 5.2-6.4 \text{ km/sec}) \); 9 - "basaltic" layer \( (V_p = 6.4-7.0 \text{ km/sec}) \).

Fig. 4. Transverse Vertical Projection of Hypocenters of Kurile Earthquakes in 1967 Originating within Each Sector in Figure 1. Designations are the same as in Figures 1 and 2.
Fig. 5. Epicenter Density (P) Map for the Kurile Epicentral Region, Reduced to $M = 4$ Using the Recurrence Graph.

1 - $P_M = 4 \leq 1$; 2 - $1.1 \leq P_M = 4 \leq 3$; 3 - $3.1 \leq P_M = 4 \leq 9$;

4 - $9.1 \leq P_M = 4 \leq 27$; 5 - $27.1 \leq P_M = 4 \leq 81$; 6 - $81.1 \leq P_M = 4 \leq 243$

7 - bottom of the Kurile Trench.

Fig. 6. Variation of Epicenter Density along the Kurile-Kamchatka Arc.
Fig. 7. Distribution of Earthquakes Relative to Focal Depth.
Fig. 8. Variation of Ses:sm. c Activity with Time for Each of the Sectors:

A - Paramushir; B - Onekotan-Matua; C - Simushir-Urup; D - northern Iturup; D - Kunashir.
Fig. 9. Epicenter Map of Earthquakes Originating in Sakhalin in 1967.

Magnitude and energy (in joules):
1. $M = 5 1/2$; $2. 10^{11} \geq E > 10^{10}$;
3. $10^{10} > E > 10^{8.5}$; $4. 10^{8.5} > E > 7$;
5. $E < 7$; 6. epicenter determined from records of a group of stations;
7. from records of one station;
8. seismographic stations;
9. boundary of the insular shelf.
occurred. The number of shallow events east of the deep-sea trench increased significantly. The distribution of earthquakes with respect to depth is similar to that for 1960-67, but the number of earthquakes in the 11-70 and 50-60 km depth ranges decreased by a factor of 2. Seismic activity in each sector of the Kurile Islands arc is described.

**Sakhalin.** An epicenter map of earthquakes in Sakhalin during 1967 is shown in Figure 9. In addition to southern Sakhalin, Lesogorsk-Uglegorsk and Nogliki regions (active in 1964-67), and two additional regions, central Sakhalin and the northeastern part of the island, exhibited seismic activity. A strong earthquake with $M = 5 1/2$ occurred in the aseismic region of northern Sakhalin (aseismic based on data from 1909-1966). The rest of the article contains descriptions of the seismic activity in individual regions of the island.


The Soviet network of basic seismographic stations provides reliable data on global earthquakes with $M \geq 6$. This article contains a catalog compiled from data available in the Seismological Bulletin of the Network of Seismological Stations of the USSR, listing the following data on strong earthquakes: date, origin time (GMT), epicenter coordinate, focal depth (when determined), magnitude $M_L$ and $M_p$, and the name of the region where the earthquake originated. An epicenter map of earthquakes
with $M \geq 6$ occurring throughout the world in 1967 is shown, as are a table giving the energy of earthquakes within individual global seismic belts and a table giving the earthquake energy released throughout the world (listed separately for the Circum-Pacific seismic belt) in 1963-67. Brief descriptions of the seismic activity in each seismic belt are included.
Recent Selections


A. Abstracts

Mkheidze, G. P., M. D. Rayzer, M. S. Rabinovich, and A. A. Rukhadze.


The authors briefly review the limitations on present high current pulsed accelerators and suggest a compromise design for an improved charging circuit. With a single switching point, the problem is to avoid increased bulkiness as energy storage is increased; this can be reduced by going to parallel storage with multiple switching, which however requires synchronization of switch times to the order of a nanosecond.

The charging network proposed by the authors is a voltage multiplier scheme consisting of active and passive pulse-forming lines charged to intermediate levels, which are coupled as disk sections, forming a cylinder 8 m long by 7 m diameter. Schematics of the design are given but unfortunately are illegible; however the network is referred to a design of Mesyats et al (Formirovaniye nanosekundnykh impul'sov vysokogo napryazheniya. Moskva, Energiya, 1970).

The circuit described would provide 100 nsec pulses of 60 ka at 30 Mev, using an intermediate voltage of 2 Mev. Forty sections of line are used, spaced 10 cm apart and 170 cm long; maximum field is not over 300 kv/cm and coupling capacity is 0.17 μf. The line charging unit should be of the Arkad’yev-Marx type which can charge the pulse shaper in 1 microsecond or less; the suggested example would be 5 m long by 5 m in diameter.

The authors include a table of linac characteristics, comparing several U. S. and Soviet designs of 1967-1970.
Rayzer, M. D. Transient effects during heavy-current electron beam generation. ZhTF, no. 8, 1972, 1639-1642.

Factors governing the transient development period of a heavy current pulse are analyzed. The study takes account of the fact that the current load cannot be considered purely resistive, but must include an inductance \(L_{ak}\) associated with generation of the current's own magnetic field. Hence the voltage \(U\) actually available for electron acceleration is diminished, i.e. \(U = U_k - L_{ak} \frac{di}{dt}\) where \(U_k\) is voltage delivered to cathode. The author examines \(U\) and pulse current \(I\) as functions of time and pulse shape for the vacuum diode and drift tube cases, where the relationships are essentially identical, as well as for injection into plasma. Since the ideal square pulse is not realizable, the analysis is also extended to more realistic pulse shapes, namely triangular and sinusoidal. The study shows that the nonstationary interval in question may be a limiting factor on peak attainable current, and can strongly affect the energy spectrum of the electron beam in long drift tubes.

Rukhadze, A. A. Heavy-current electron beams. VAN, no. 1, 1972, 19-23.

This is an informative review on the state of the art in high current generation. It discusses the inherent limits to current flow in terms of electron density and relativistic factor \(\gamma\), and the fact that the product of electron density and velocity holds constant owing to the integral space charge of the beam.

Past and present research into powerful beam generation in the U. S. and U. S. S. R. is reviewed. Soviet activities cited as presently involved in beam applications include the group under Ya. B. Faynberg in

-97-
Kharkov; Ye. K. Zavoyskiy's group at the Kurchatov Institute for Atomic Energy, where CTR research on the "elektronnyy termoyad" (electron thermonuc) is proceeding, and R. Z. Sagdeyev's laboratory in the Institute of Nuclear Physics of the Academy's Siberian Branch, where promising CTR results are similarly being obtained with e-beam heating of a plasma. Several other potential applications for high-current beams are suggested, such as ultrahigh pressure generation, new x-ray sources, atmospheric probing, etc. (See JPRS Translation 55568, 20 March 1972).


Charged particle emission spectra in undulators are analyzed. The spectral emission distribution is found for undulators of varying lengths. It is shown that particle emission spectra halfwidths can be made much smaller than synchrotron emission spectra halfwidths. The application of undulator emission in vacuum ultraviolet and x-ray spectroscopy simplifies the problem of pre-emission monochromatization. A numerical example is described which shows that the spectral emission intensity impinging on a unit of a shield surface changes only negligibly with an increase in the undulator field, but the spectrum widens significantly. Conclusions are: 1) Particle emission in undulators is linearly polarized and directed in a narrow angular interval \( \sim 1/\gamma \) where \( \gamma = E/mc^2 \). \( E \), \( m \) = energy and mass of charged particle, and \( c \) = light velocity. 2) The particle emission intensities impinging on a unit frequency interval close to \( \omega_m' \) (where \( \omega_m' = 2\gamma^2 \omega_o \), \( \omega_o \) = particle oscillation frequency), are in the ratio of 18:15:1 for, respectively, an ideal undulator, an undulator with a piecewise uniform magnetic field without indefinite length gaps and a magnet with a uniform field, when the total emission intensities are equal. 3) A selection of magnets \( N > 16 \) is required to lower the maximum spectral distribution of emission intensity in a finite length undulator no more than 30% in relation to an infinitely long undulator. 4) A total of 80% of the particle emission intensity in an undulator with a piecewise uniform magnetic field without gaps and \( N \to \infty \) occurs at the fundamental frequency. This supports the assumption, in most practically important cases, that undulators with a large number of periodic elements and sign reversals over the magnetic length are ideal. 5. The particle
emission spectra fall steeply at frequencies \( \omega > \omega_m' \), which in principle makes feasible threshold particle detection using an undulator with low fields.

6) An optimum value of magnetic field intensity exists in an undulator with a piecewise uniform magnetic field, which corresponds to \( \gamma_m' = 1 \) (\( \gamma' = 2 \gamma_m' \), \( \gamma' \) - particle velocity deflection angle in a magnetic field), at which the spectral emission intensity impinges on a unit of the detector surface and the characteristic frequency \( \omega_m' \) is maximum. 7) The relative energy dispersion of particle emission in a low field undulator is much less than in a high field undulator.


The results are presented of an investigation of light flash intensity and its changes with time in comparison to electrical indicators of discharge development in aqueous electrolytes of various composition. Electrolytes used were aqueous solutions of ammonium chloride and sodium thiosulfate in various concentrations, as well as with the addition of 5-methyl resorcinol, which is prone to active oxidation. A description of the experimental installation is presented, together with a block diagram.

Tabulated results show that a difference in the electrical and optical discharge indicators for solutions with like electrical conductivity is caused by a change in the chemical composition and the presence of an organic additive.
The curves of Fig. 1 show that a decrease of luminescence intensity is accompanied by the capability of mineral and organic electrolytes to participate in oxidation reactions in water. The changes of luminescence intensity (quenching) shown in Fig. 2 for solutions of sodium thiosulfate, and

![Fig. 1. Typical oscillograms of discharge current and voltage (a) and luminescence intensity in the center of the plasma channel in various electrolytes. (b) NH₄Cl (0.3%); (c) NH₄Cl (0.3%) + orcinol (0.2%); (d) Na₂S₂O₃ (0.9%); (e) Na₂S₂O₃ (0.9%) + orcinol; U = 22 kv, C = 0.32 μf, l = 15 mm, γ = 6.8x10⁻³ ohm⁻¹ cm⁻¹.](image)

![Fig. 2. Luminescence intensity distribution along the plasma channel in various electrolytes: (a) NH₄Cl; (b) Na₂S₂O₃; 1 - γ = 6.8x10⁻³ ohm⁻¹ cm⁻¹; 2 - same with orcinol additive (0.2%); 3 - γ = 2.2x10⁻² ohm⁻¹ cm⁻¹; 4 - same with orcinol additive (0.2%); U = 22 kv, C = 0.32 μf, l = 1.5 mm.](image)

with the addition of orcinol, are an indication of acceptor phenomena in the system which become more complex in the anode and cathode regions. Further studies are planned on the mechanism of the electrophysical phenomena and the chemical mechanism of these processes.
Kolyada, V. D. Shapiro, and V. I. Shevchenko.

Excitation of low-frequency oscillations by
electron beam in a hot plasma, confined by a

The interaction of an electron beam with hot plasma in an
open magnetic trap was investigated, along with plasma heating by ion-
acoustic oscillations excited by the beam. The magnetic trap was filled with
cold hydrogen plasma (density $10^{13}$ el/cm$^3$) using a titanium pulse source.
The electron beam (30 kev, 20 a, and $\tau$ - 300 $\mu$sec) was then injected, as a
result of which 1-10% of the electrons were heated to a temperature on the
order of tens of kv from the plasma-beam interaction. After the plasma and
electron beam sources were switched off the plasma was allowed to decay for
5-10 ms at $10^{-6}$ torr. The cold plasma component ($T_e \sim 0.1$ to 0.5 kw) disappear from
the trap in 1-5 msec, leaving only plasma with a high electron temperature
($T_e \sim 50$ kev, $n \sim 210^{11}$ el/cm$^3$) in the system. The electron beam was re-
jected into the high temperature plasma at a lower velocity than the electron
thermal velocity (2-15 kev), a current of 1-10 a and a duration $\tau \sim 200 \mu$sec.
The excited oscillation spectra in this plasma, the ion temperature, the beam
ergy loss, and the plasma potential were studied. Trap parameters were:
$H_{\text{max}}/H_{\text{min}} = 2$, stress in the trap center = 1.5 kg (force), spacing between
plugs = 0.8 m, and vacuum chamber diameter = 20 cm. Figs 1 and 2 show
oscillation spectra from an harmonic analysis of oscillograms. The

![Fig. 1. Oscillation spectra in electron beam region.](image1)

![Fig. 2. Oscillation spectra on plasma periphery.](image2)
oscillation spectra are in the plasma ion frequency zone with absolute values between 30 and 120 MHz. Instability occurred at currents above critical, and a limiting beam velocity was identified which when increased had no effect on instability. The limiting velocity results from the conditions of Cerenkov resonance between beam velocity and ion-acoustic waves; its experimental value equalled 30 Cs (Cs - sound velocity), which is close to the theoretical value (10-20 Cs). Electron beam scattering at ion-acoustic oscillations and capture by the magnetic trap led to a high radial electrostatic potential formation and the excitation of centrifugal instabilities. Oscillation excitation in the trap was followed by significant ion heating. The plasma consisted of two ion-component groups with temperatures of 400 ev and 1.3 kev.


Electron-optical investigations are reported of discharge development in the prebreakdown phase and during rapid and gradual increases of discharge current under a variable initial electron density and field (E). In the prebreakdown phase, the ionization front traveled from the cathode to the anode at \( V = (1.5-6) \times 10^8 \) cm/sec with \( E = 55-100 \) kv/cm. At \( E = 55 \) kv/cm, a second front was observed moving from the anode. The discharge gap was filled with low-conductance plasma immediately before the voltage drop, at which point a diffused discharge occurred when the initial electron density was sufficiently high. The plasma from this discharge occupied a large volume,
but had a low ionization velocity \((10^{-4} - 10^{-5})\) and the current increased due to impact ionization. A high conductivity channel was formed in the second intermediate phase.

An extended discussion of this experiment has subsequently been published by the authors (ZhTF, no. 8, 1972, 1674).


The instability is investigated of an electron current, interacting with a cold homogeneous electron plasma confined between a cathode and an anode. The electron current, with a given density and velocity \(V_0\), is generated on the cathode plane perpendicular to its direction, and is absorbed on the anode plane at a distance \(L\) from the cathode. A linear differential equation is derived for the wave potential, and it is shown that when:

\[ \nu^4 + 16\xi_p^2 > \nu^2\xi_b^2 \]

and (when \(\nu = (2n + 1)\pi\), \(\xi_p = \omega_p L/V_0\), \(\xi_b = \omega_b L/V_0\), \(\omega_p\), \(\omega_b\) = electron Langmuir frequencies in plasma and current, respectively), the increment of frequency oscillations is positive, wave energy is dissipated, plasma energy increases and system oscillations attenuate with time. When \(\nu^4 + 16\xi_p^2 < \nu^2\xi_b^2\), the system instability increment is negative, excitations increase with time, the system transmits energy to the wave, and oscillation swinging occurs.
Approximate dispersion equations are derived for two conditions: 1) in the high frequency region, \( \omega > \omega_p \), when the electron beam density is well below the plasma electron density, and 2) for low plasma frequencies. At \( \xi_0 = 2n\pi \) and a high frequency where \( n = 1, 2, 3 \ldots \) (\( \xi_0 = \text{Re}\xi \) is a positive real root of the equation \( \text{Re}\xi \eta = 0 \)), the system instability increment \( \gamma \omega < 0 \), and oscillations increase with time; and at \( \xi_0 = (2n + 1)\pi \), \( \gamma \omega > 0 \) and system HF oscillations attenuate with time. For low plasma frequencies, when \( \xi = 2n\pi \) (\( n = 1, 2, 3 \ldots \)), spatial acceleration exists and excitations increase in space; but when \( \xi = (2n + 1)\pi \), the excitations attenuate in space.


A method is suggested for calculating the emission characteristics of a cathode during a heavy-current discharge in plasma, taking into account the mutual effect of adsorption on the cathode surface and processes in the precathode region of the discharge. The characteristics of the electrode film, made from a plasma material, determine the work function, and thereby the discharge current density and precathode potential drop \( \varphi_s \). The level of the absorbed particle film on the cathode however depends significantly on \( \varphi_s \). Equations are derived for precathode region processes based on relationships reported earlier by two of the authors, Minyatov and Pankratov (ZhTF, v. 41, no. 4, 1971). The simultaneous solution of the equations made it possible to determine the precathode region characteristics of the cathode surface adsorption processes. Calculations were based on a tungsten cathode with
const. = 70 a cm⁻² deg² and a lithium adsorbate. The plasma electron temperature was assumed to be $T_e = 10^4$K, and the plasma ions and neutral atoms temperature was $T_i = T_a = 4 \times 10^3$K. Fig. 1 shows typical volt-ampere characteristics in the pre-cathode region and Fig. 2 shows cathode
surface temperature versus current density. The analysis reveals that an increase in plasma ion concentration results in a higher cathode temperature and a reduced voltage drop in the precathode layer. The increased ion concentration also leads to a decrease in the effect of adsorption on precathode processes. The relationship $T_\omega = f(j)$ ($T_\omega$ - cathode surface temperature) reflects the significant effect of precathode processes on the cathode film level. The study shows that precathode region calculations which ignore adsorption processes yield incorrect results.

*Linear accelerator of charged particles.*  
Author's certificate USSR, no. 334931, published March 18, 1970. (Otkr izobr, 30/72)

The proposed accelerator design is in the form of a cavity resonator with drift tubes and spatial tuning devices. To stabilize accelerating field amplitude and phase characteristics, electrically conducting movable stubs are mounted on the end wall parallel to the resonator axis.

Kapel'yan, S. N., and Z. M. Yudovin.  
*Vaporization of metal during a heavy-current pulsed discharge.* DAN RSSR.  
v. 16, no. 11, 1972, 991-994.

The effect of metals of powerful thermal pulses from a heavy-current pulsed discharge is examined. Expressions are derived for thermal processes, the phase transition front temperature, and the front
propagation distance. Data on the kinetic process of metal destruction by electric pulses were obtained experimentally using the device shown in Fig. 1.

Discharge current oscillograms and time relationships were obtained for the destructive deepening front of Pb, Cd, Sn, Zn and Al metals (Fig. 1 is a plot for Zn). The destructive deepening processes differed significantly for the anode and the cathode. Deepening in the anode began immediately with the pulse; but in the cathode, a preliminary "warm-up" occurred and noticeable deepening of the vaporization front started after 20-25 μsec. With the exception of Al, the vaporization front velocity for all metals in a steady-state regime \( C_0 \) was higher on the anode than on the cathode (Table I). The \( C_0 \) was identical on the aluminum anode and cathode, equalling 1.1 m/sec. The warm-up time and transient process duration for Al were 80-90 μsec and 120-150 μsec, respectively, which exceeded the corresponding values for the other metals. Thermal flux densities were calculated for various time intervals: at the initial pulse stage \( q_1 \), during the transition process, \( q_2 \), and
Experimental data on vaporization kinetics.

for a steady-state regime, $q_3$ (Table 1). Integral current densities at the anodes and cathodes, estimated for all the metals tested, were between $1 \times 10^5$ and $4 \times 10^5$ a/cm$^2$.

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Results are described from a study of power instability of heavy-current pinched discharges in a dense optically opaque plasma, formed by electric explosion of metal wires in a vacuum. Experiments were conducted in a capacitive storage device consisting of 24 condensers, charged to 20 kv.
Discharge current duration was 25 μsec at a 160 ka amplitude. The discharge chamber was in the form of two flat electrodes spaced 25 cm apart inside a 10 cm diameter quartz vessel. Al, Cu, Ag, and W wires of 0.09 - 0.14 mm diameters were stretched between the electrodes and exploded at a chamber pressure of 10⁻⁵ torr. The average discharge radius and brightness temperature were determined from streak camera photos and spectrograms as a function of time. Results agreed well with earlier findings of two of the authors (KSPF, no. 6, 1970, 58). A clearly evident stage of magnetic confinement of the plasma was noted close to the time of the initial current maximum; the average discharge radius was about 1.2 cm. The character of discharge emission corresponded to black-body radiation at this moment, and the temperature, which varied slightly, was about 2 ev. Unstable radiation developed in the plasma at this discharge stage. Fig. 1 is a typical photograph of the discharge channel with highly developed instability, taken during an Al-wire explosion. The authors classify instabilities into helical and constricted types. Harmonic expansion coefficients, \( A_n \) (for helical) and \( B_n \) (for constricted) in Fourier series were determined and graphs are given (e.g., Fig. 2) for \( A_n/A_{n\text{max}} \) and \( B_n/B_{n\text{max}} \) with respect to the dimensionless parameter \( \alpha = \frac{k_z r p}{p} \), where \( k_z \) is the wave number of the corresponding harmonic and \( r_p \) is the uniform radius of the
plasma column at a given moment. The constricted instability amplitude was maximum at harmonics corresponding to \( k \cdot r_p \approx (0.7-0.9) \leq 1 \), while the helical maximum occurred at \( k \cdot r_p \approx 0.15 \), which corresponds to \( k_z = \pi / l \), i.e. an excitation wave length equal to twice the discharge gap length. Growth increments \( \gamma \) corresponding to various instability modes were calculated for specific moments of time, and were found to decrease approximately in proportion to \( \sqrt{\gamma} \), i.e. \( \sqrt{M} \) (M is the ion mass). Experimental and theoretical results are in good agreement.
Collisionless plasma expansion is calculated in a vacuum containing impurities of ion mass $M_2$ and charge $Z_2$, in addition to the basic ion mass $M_1$ and charge $Z_1$. Assuming that the characteristic inhomogeneity level is larger than the Debye radius $R_D$ and ion velocities are low in comparison with the thermal velocities of electrons, results show that the plasma dispersion process is self-similar and may be described by a nonlinear equation for the ion distribution function. A computer-aided solution is obtained for the equation and two problem formulations are analyzed.

The first problem is for the value $N_2 << N_1$ of a plasma containing a small amount of impurities of the second type. The solution reveals that the impurity ions are accelerated at a much higher rate than the basic gas ions and their concentration decreases slowly with dispersion. Many of the impurity ions are consequently captured in the field generated by the noncompensated space charge, owing to electrons overtaking the ions. At an ion energy of $\sim 500 T_e Z_1$, for example, ion flow decreases by one-half. The thermal scattering of velocities in a developing dispersion process is negligible but the ion directional velocity is substantial; therefore, a hydrodynamic equation is used to determine the energy distribution of accelerated impurity ions, $\nu$, passing through a unit surface at a point $X_0$. The energy distribution is independent of the observation point $X_0$ and falls relatively slowly with increased particle energy. When the similarity parameter $\rho = M_1 Z_2^2 / 2 M_2 Z_1 > 1$, the impurity ions accelerate more energetically than the basic ions and the distribution pattern becomes similar for ions with varying masses and charges. In a singly-ionized plasma the lighter impurity ions are accelerated fastest, and $0.1\%$ of the total number of impurity ions acquire an energy of $\sim 500 \rho T_e$. 

Analysis of the problem solution indicates that impurity ion acceleration is controlled by the plasma electron temperature $T_e$. When the electrons are rapidly heated in a freely expanding plasma, using electron beams or radiation, the multicharged impurity ions may be substantially increased (to $\epsilon \sim 10^2 - 10^3 \, T_e$). The acceleration is a function of the plasma basic ion mass $M_1$; acceleration, for example, is higher in deuterium and tritium than in hydrogen.

The maximum ion energy in the acceleration mechanism is restricted by the condition $\epsilon \ll M T_e / m$, and is dependent solely on the impurity ion mass, not the charge. The theoretical results agree with laboratory experimental data (accelerating multicharged ions in an expanded rarefied plasma). The mechanism described is applicable to studies of solar and stellar bursts.

The second problem examined is on ion-containing plasma expansion in a vacuum, when $N_2$ has a finite value. For an undisturbed plasma the authors use the relationship: $N_{20} Z_2^2 / N_{10} Z_1 = 0.1$. The most characteristic feature is that at a given moment of plasma dispersion the concentration of basic ions $N_1$ decreases slowly and tends to disappear. The impurity ion concentration drops very slowly and the $N_2$ begins to occupy a considerable plateau area. Concurrent with this dispersion moment, the impurity ions also display plateau characteristics. The plateau distribution function changes only slightly with the dispersion.

The plateau region was also formed under other conditions of plasma expansion in a vacuum containing an ion mixture. Solutions obtained in this study of plasma expansion are applicable in analyzing the structure of the disturbed zone surrounding rockets and space vehicles in the ionosphere.
The authors also investigated self-similar waves and ion-acoustic instability. The self-similar waves are kinetic waves related to particle velocity distribution and therefore do not occur in hydrodynamics. Their excitation begins with the dispersion process when heavy ions are accelerated and the additional force disturbs the distribution of light ions. The disturbance propagates in the form of self-similar waves travelling in the expanding plasma. Using the dispersion equation, oscillatory solutions are suggested. The dispersion equation for arbitrary ion-acoustic waves indicates the existence of a non-attenuating branch of the ionic sound, having a large wave vector \( K_0 D > 10^4 \). Following the onset of dispersion, unstable rising ion-acoustic waves appear at \( K < K_0 \); and by a specific dispersion moment, all waves with the vector \( K_0 > K > 0 \) become unstable. This instability probably limits the investigated acceleration mechanism potential for large concentrations of impurity ions.


The space-time distribution of optical plasma density of heavy-current pulsed discharges in Li and In vapors was investigated using a gas laser beam absorption method. A 10 mw Ho-Ne laser was used operating at \( \lambda = 6328 \text{ Å} \). Plasma was generated by explosion of Li (diam = 0.1 and 0.17 mm) and In (diam = 0.17 mm) wires. The discharge chamber was glass with a 10 cm i.d. and 14.5 cm spacing between electrodes. Current pulses consisted of two half-cycles; 14 kj were delivered in the chamber during the first half-cycle (70 μsec) and 3 kj during the second half-cycle. Optical plasma density \( \chi \) was determined from the relation \( J = J_0 \exp (-\chi l) \) where \( J_0 \) and \( J \) are the quantum flows impacting on and passing through the plasma, respectively; \( \chi \) is the absorption coefficient; and \( l \) is the absorption layer thickness. Relationships were
obtained for $x(t)$ with respect to time ($t$) and radius ($r$) (Figs. 2 and 3). The plasma absorption coefficient was plotted as a function of radius for $t = 35 \mu\text{sec}$, corresponding to the steady-state. The optical density of the plasma column was radially nonuniform; the maximum occurred at a small distance $r_o$ from the discharge axis. A sharp drop was noted at the discharge center and boundary (Fig. 4). Discharges in which the plasma temperature is maximum at the discharge center are discussed.

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Fig. 1. Experimental sketch.

- $k$ - discharge chamber;
- $L_1, 2, 3$ - lenses;
- $D_1, 2, 3$ - diaphragms;
- $G$ - Glan prism;
- $IF$ - interference filter;
- $M$ - monochromator;
- $SZ$ - discharge triggering system.

Fig. 2. Relationship $x(t)$ for Li plasma.

1 - 10 $\mu\text{sec}$; 2 - 35 $\mu\text{sec}$.

Fig. 3. Relationship $x(r)$ for Li plasma.

1 - 10 $\mu\text{sec}$; 2 - 35 $\mu\text{sec}$.

Fig. 4. Relationship $x(r)$ for 1 - Li and 2 - In. Plasma current = 200 ka.
Current shell acceleration was investigated in a coaxial accelerator, consisting of two copper electrodes: an external one with a diameter of 10 and a 40 cm length, and an internal one with a diameter of 3.2 and a 56 cm length. A hydrogen supply inlet was placed on the internal electrode 37 cm from the accelerator end. During a selected time delay, $\sim 1.5 \times 10^{19}$ hydrogen atoms were injected into the accelerator gap through a pulse thermal valve. A condenser battery (5.4 μF), charged to 25 kV, was connected to the electrode. Discharge current reached 114 kA with a half-cycle of 3.4 μsec. The hydrogen pressure in the gap before discharge was $\sim 1.0$ torr. Relationships were plotted for magnetic and electric fields in the accelerator gap as functions of time. Current shell dimensions and the line current shape were determined along with the time and location of closed current and forebunch generation. The transition time from a combustion regime with an anode voltage drop to a cathode drop regime was examined. Results indicate that a comparatively narrow current bridge was formed during the initial discharge stage. The observed plasma acceleration is accompanied by current distribution along the electrodes and increased longitudinal dimensions of the bridge. Plasma acceleration ceased with the appearance of closed currents in the system.

Interferometric and spectroscopic measurements were used to plot time relationships of charged particle density distribution in the current shell of the accelerator gap, and also to estimate plasma temperature and localization of impurities. Experimental conclusions are:

1. In electrodynamic accelerators with pulsed hydrogen supply, current shell formation occurs with the generation of the ionization front, and not in agreement with "snow plough" and "hard current bridge" models.

2. The existence of the ionization front is explained by the type of spatial density distribution and the current shell width.

3. Ion currents play a significant role in plasma acceleration.

4. The linear electric field, where it exists, is due to the Hall effect.


Results are described of investigations of the integral energy characteristics of an $F_2 + H_2$ laser, pumped by a relativistic electron beam. The experimental arrangement is shown in Fig. 1. Relativistic

Fig. 1. Experimental sketch
1 - laser cavity, 2 - external chamber, 3, 3' - mirrors; 4 - calorimeter, 5 - gas injection evacuation system, 6 - Ge-Au detector, 7 - titanium foil (50 μ); 8 - accelerator magnetic lens; 9 - quartz splitter; 10 - alignment laser, 11 - CaF$_2$ windows.
electron beams from the accelerator (electron energy $E = 2$ Mev, beam current $I = 4$ ka, and pulse duration $\tau = 5 \times 10^{-8}$ sec) were transversely injected into the laser cavity through two titanium foils. The active part of the copper cavity was 5 cm long and its cross-section was 1.5 \times 1.5 cm; this volume was cooled to 100 to 1500 K by liquid nitrogen. The gas injection velocity into the active region did not exceed 10 torr/sec. A portion of the radiation was registered by the Ge-Au detector, which was shielded against spurious gamma rays by a small lead shell. The time constant of the measuring device was $10^{-6}$ sec. Laser positioning of the optical system was done by a He-Ne laser at $\lambda_1 = 0.63 \mu$ and $\lambda_2 = 3.39 \mu$. The duration of pulse generation was $\sim 20 \times 10^{-6}$ sec, and the threshold was reached at mixture pressures of 150 to 200 torr. Near the threshold, pulse generation parameters were unstable and sensitive to electron beam parameter fluctuations. Pulse consistency was good when the mixture pressure exceeded the threshold value. A relationship is plotted in Fig. 2 for laser radiation energy as a function of initial mixture pressure. The linear characteristics of the relationship indicated the direct proportionality of the laser radiation energy to the beam energy absorbed in the mixture. The energy absorption was calculated, based on known mixture density and electron energy values. The ratio of laser output energy ($Q_1$) to the beam energy absorbed in the medium ($Q_{abs}$) was 1.5 to 1.8. In the pressure range investigated...
(200 to 600 torr), the energy efficiency $Q_L/Q_{abs}$ was found to be constant. The authors note that the absolute value of efficiency obtained is not the maximum value, since no attempt was made to optimize the resonator. The experimental results support the feasibility of using electron beams to initiate chemical reactions in laser media.


The feasibility of using a vacuum undulator to measure relativistic particle energy $W$ has been discussed by Motz (J. Appl. Phys. 22, 527, 1957) and Korkhmazyan (IAN Arm, 5, 418, 1970, 7). The present work examines the sharp increases in the presence of radiation intensity obtainable by use of a transparent medium in the undulator. Expressions are given for the dipole moment amplitude and energy of charged particles. In transparent media at $\beta n > 1$, the radiation energy is concentrated near the Cerenkov angle $\Theta_0$, $\Theta_0 = \arccos(1/\beta n(\omega))$ $n(\omega)$ - refractive index at a frequency $\omega$. The undulator radiation power in the media exceeds that of undulator radiation in a vacuum to the value $W/Me^2 \sim 10^6$. Radiation in the medium usually propagates at the angle $\Theta_0 \sim 1$ and is visible. The undulator radiation energy $S_g$ and Cerenkov radiation energy $S_0$ were compared and the undulator radiation was found to be weaker at $W > W_c \approx 3\times10^{10}$ ev. The number of photons radiated in the undulator in the medium however would be adequate for recording even at $W >> W_c$, possibly an energy of $W \approx 3\times10^{12}$. The principal disadvantage of an undulator counter in the medium is that the radiated energy $S_g$ drops with increased particle energy $W$. The author points out that combining a Cerenkov counter with an undulator should prove to be an effective measurement method.
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(RZhElektr, 1/73, no. 1A255)

A. Abstracts


The atomic structure of tungsten wire surface defects generated by 10-20 kbar hydrostatic pressures was analyzed using an auto-ionization microscope. The defects were studied in relationship to the pressure-induced changes in the physico-mechanical characteristics of metals and alloys. Two non-annealed W wire specimens and two annealed at 1500°C in a protective container were subjected to a hydrostatic pressure for 20 sec, 1, and 2 hr. periods at 2-3 kbar/min loading and unloading rates. Micrographs of one non-annealed surface after 1 h. of testing under 10 kbar pressure showed a decrease in atom clusters in the decorated band, linear atomic chains formed in the (121) plane, and small pockets in the (111) plane. A second non-annealed surface, similarly treated, revealed a shift of the decorated band with kink formation along the decoration boundary. Since the defects disappeared after vaporization of several tens of atomic layers, the observed effects are limited to a thin subsurface layer.

The presence of linear atomic chains, which may be attributed to the formation of interstitial atom clusters, led to the conclusion that a partial relaxation of internal microstrains occurs under a high hydrostatic pressure in the pre-deformed W. The pockets are probably the sites of dislocations emerging on the surface under pressure. Micrographs of annealed specimens subjected to 15 kbar pressure for 20 sec. reveal intercrystalline boundary migration, vacancy clusters, and screw dislocations in the (100) plane. The first two defects disappeared after vaporization of a few atomic layers. After one hour treatment under 15 and 20 kbar pressures, respectively, a strong distortion of the surface crystal structure and dislocations in the (121) and (010) planes were observed. Crystal structure remained distorted after removal of several tens of atomic layers. The surface high dislocation density is apparently...
caused by the high pressure application. Pre-existing dislocations also emerge at the surface under a high pressure. The described high pressure effects depend on both pressure magnitude and pressurization time.


Experimental data are given on fatigue resistance of two carbon steels and two machine chrome steels heat-treated by different methods. The objective was to select the optimum heat-treatment ensuring high operational reliability of engineering structures. In both static and shock loading experiments the resistance $\gamma$ to ring crack propagation increased with increased C content in carbon steels tempered at 100-600° C. Accelerated heat-treatment at an $8^\circ$ C/sec. rate for all four steels increased the static $\gamma$, but only at tempering temperatures between 100-300° C. Micrographic analysis revealed that a change in martensite structure caused steel strengthening after accelerated heat-treatment, water or oil quenching, and tempering at 100-300° C. The advantage of accelerated heat-treatment was confirmed by data on the resistance of the steels to crack formation by ring bending. Results confirm that quenching after differing heat-treatment, the C content of steel, and the tempering temperature substantially affect the material $\gamma$. 

-126-
Thermal conductivity $\lambda$ and resistivity $\rho$ of type PG-50, GMZ, and PROG-2400 graphites before and after impregnation with liquid silicon were measured in the 80-2,500$^\circ$ K range, to evaluate the thermal state of the siliconized graphite products. Conductivity was measured by the method of stationary axial heat flux, using external heaters in the 80-320$^\circ$ K range or internal heaters in the 400-1300$^\circ$ K and 1300-2500$^\circ$ K ranges. Temperature in the first two ranges was recorded with thermocouples and in the third range pyrometrically. The axial heat flow was determined from current and voltage drop measurements. Accuracy of the $\lambda$ measurements was $\pm$ 5, $\pm$ 8-10, and $\pm$ 13-15% in the 80-320, 400-1300, and 1300-2,500$^\circ$ K ranges, respectively. For the highly porous PG-50 graphite with a high free Si content, $\lambda$ was determined at $T < 1,300^\circ$ K only because of optical pyrometer limitations. The $\lambda$ versus $T$ plots show 40 and 65% maximum increases in $\lambda$ of GMZ and PROG-2400 graphites after siliconizing and a four-fold increase in $\lambda$ in siliconized PG-50 graphite. The latter exhibits nearly the same $\lambda$ as silicon carbide. It is concluded that heat transfer below 1,500$^\circ$ K in siliconized graphite occurs not only from graphite, but also from silicon carbide and silicon. At $T \geq 1500^\circ$ K, the $\lambda$ of the siliconized GMZ and PROG-2400 graphites decreased to its value in the original materials. Similarly to $\lambda$, the $\rho$ of the GMZ and PROG-2400 graphites increased by 50-60% after impregnation. The increase in $\rho$ of PG-50 was only 13% presumably due to formation of C of higher electroconductivity in the Si solution in addition to SiC of a low conductivity. The increase in both $\lambda$ and $\rho$ of siliconized graphites is due to the combined $\lambda$ and electroconductivity of the graphite skeleton, silicon, and silicon carbide.

Enthalpy $i_{273}$ and heat capacity $C_T$ of eight domestically manufactured graphites were determined experimentally by a combination method reported by the authors (TVT, v. 8, no. 3, 1970). The method consists of an experimental $i_{273}$ determination and true $C_T$ calculation by differentiation of an approximate equation based on the experimental data. All but one of the graphites were very dense (1.8 - 1.9 g/cm$^3$) and finely-structured.

The experimental data in the 273-1000° K range are described with a ± 1.5% accuracy by the empirical equations

$$i_{273} = 0.322 \cdot T + 5.2 \cdot 10^{-5} \cdot T^2 - 1.7 \cdot 10^3 \cdot T^{-1} - 154.2, \text{ kcal/kg}, \quad (1)$$

$$C_T = 0.322 + 10.4 \cdot 10^{-5} \cdot T - 1.7 \cdot 10^3 \cdot T^{-1}, \text{ kcal/kg \cdot deg.} \quad (2)$$

The data in the 600-3600° K range are described by equations containing an additional exponential term to account for an accelerated increase in calorific properties above 3,000° K. The experimental true $C_T$ data (Table 1) are compared with the Soviet and American data from the literature. Although the authors' data agree well with most of the Soviet and American data, the findings are 10-15% higher than certain American data. This discrepancy is explained by the fact that the authors' $i$ and $C_T$ data at high $T$ for different graphite brands vary within the experimental error (±2.3% at 3600° K), while the corresponding American data for four graphite brands vary up to 12%. The $C_T$ variations between different American-made graphites are attributed to impurities and differences in preparation procedures. It is concluded that it is normally not necessary to determine high temperature calorific properties.
Table 1. Experimental enthalpy and heat capacity of domestic graphite brands

<table>
<thead>
<tr>
<th>Graphite</th>
<th>T°K</th>
<th>Experimental $i_{273}$, kcal/kg</th>
<th>$i_{273}$ data calculated from (2), kcal/kg</th>
<th>Difference $i_{exp - i_{emp}}$, %</th>
<th>Experimental $C_{273}$ data, kcal/kgxdeg</th>
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</thead>
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<td>19.4</td>
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<tr>
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<td>0</td>
<td>0.227</td>
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<tr>
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<td>56.3</td>
<td>53.2</td>
<td>+2.0</td>
<td>0.212</td>
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<td>819</td>
<td>105</td>
<td>110</td>
<td>-0.9</td>
<td>0.322</td>
</tr>
<tr>
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<td>211</td>
<td>211</td>
<td>0.0</td>
<td>0.321</td>
</tr>
<tr>
<td>AIP</td>
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<td>222</td>
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<td>0.319</td>
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<tr>
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<td>0.343</td>
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<tr>
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</tr>
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<tr>
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<td>2718</td>
<td>1059</td>
<td>1052</td>
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<td>0.416</td>
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<td>1111</td>
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<td>1419</td>
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<td>0.147</td>
</tr>
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</tr>
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<td>1514</td>
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<td>0.182</td>
</tr>
<tr>
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<td>5029</td>
<td>1650</td>
<td>1694</td>
<td>+2.6</td>
<td>0.192</td>
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</tbody>
</table>

for each graphite when the composition and preparation techniques are similar to those of the brands studied. More accurate experimental $i_T$ and $C_T$ data were obtained at higher temperatures than in previous studies.

The effect of injected metals on the structure of metal-carbon fiber materials was investigated using electron-microscopic and x-ray analysis. The elementary composition of carbon and metal-carbon fibers, made from oxidized cellulose (monocarboxyl cellulose -- MCC) and its salts (Al, Fe), was determined within the heat-treatment temperature (HTT) range of 400-1600° C. Electron-microscope photos show no essential morphological changes in carbon specimens made from MCC. The particles have a lamellar structure and are nearly equiaxial in shape. Specimens prepared at low pyrolysis temperatures were more difficult to grind in an ultrasonic disperser under the selected conditions than were high-temperature specimens. Radiogram of the tested fibers are shown in Fig. 1.

![Fig. 1. Radiograms of iron-carbon fibers (a) at heat treatment temperature of: 1 - 600, 2 - 800, 3, 4 - 1200, 5, 6 - 1400, and 7 - 1600° C; and (b) carbon fibers at 1 - 600, 2 - 800, 3 - 1000 and 4 - 1600° C.](image-url)
Elementary analysis data (Table 1) show considerable variations in the composition of carbon fiber material as a function of HTT.

Table 1. Elementary composition of carbon and iron-carbon specimens

<table>
<thead>
<tr>
<th>Specimen</th>
<th>C</th>
<th>H</th>
<th>O</th>
<th>Fe</th>
<th>Weight, %</th>
</tr>
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<tbody>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>81.89</td>
<td>1.85</td>
<td>11.26</td>
<td></td>
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<tr>
<td>400</td>
<td>80.97</td>
<td>1.90</td>
<td>6.96</td>
<td></td>
<td></td>
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<tr>
<td>500</td>
<td>82.07</td>
<td>2.00</td>
<td>4.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>600</td>
<td>97.15</td>
<td>0.66</td>
<td>2.19</td>
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<tr>
<td>700</td>
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<tr>
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<td>0.59</td>
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</tr>
<tr>
<td>900</td>
<td>99.07</td>
<td>0.31</td>
<td>0.59</td>
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<tr>
<td>1000</td>
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<td>0.31</td>
<td>0.59</td>
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Iron-carbon:

<table>
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<tbody>
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<tr>
<td>400</td>
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<td>3.07</td>
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<tr>
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<td>1.14</td>
<td>0.35</td>
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<tr>
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<td>0.39</td>
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<tr>
<td>700</td>
<td>95.07</td>
<td>0.35</td>
<td>3.58</td>
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<tr>
<td>800</td>
<td>98.93</td>
<td>0.22</td>
<td>0.85</td>
<td>4.34</td>
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<tr>
<td>900</td>
<td>91.22</td>
<td>0.14</td>
<td>0.65</td>
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<td></td>
</tr>
</tbody>
</table>

* The carbon residue with no iron content is assumed to be 100%.

The radiograms of aluminum-carbon and carbon specimens were analogous. Liner of crystalline aluminum or its compounds were absent. With increasing HTT, the carbon content in the elementary composition of aluminum-carbon specimens increased, and the hydrogen and oxygen content decreased. Essential changes occurred in the carbon fiber structure when iron was added to its composition. The external appearance of the grinding products of iron-carbon specimens differs essentially from that of the carbon and aluminum specimens. It is concluded that iron is reduced to the metallic state within the 700-800°C HTT range and, in this form, effects the formation of a more ordered carbon structure.
Okonishnikov, G. B., and V. P. Skripov.

Effect of a high-pressure gas environment on mechanical properties of PMMA. FKhMM, no. 5, 1972, 72-75.

Experiments are described to determine the effect of $\text{CO}_2$ and $\text{Ar}$ saturation pressure $P_S$ on the mean ultimate tensile stress $<\sigma>$, dynamic Young's modulus $E$, and viscosity of unplasticized PMMA specimens. The specimens were saturated for three days in a steel chamber under 10-50 atm $\text{CO}_2$ or $\text{Ar}$ pressure at 19°C. Increased mass and coefficient of linear expansion (except in $\text{Ar}$) indicate that internal tensile strains are generated by absorbed gases, which may contribute to polymer fracture under applied loads. Determination of $<\sigma>$ for the gas-saturated specimens was made in the same gaseous medium without removal after saturations. The experimental $<\sigma>$ data (Fig. 1) suggest that, in the presence of 1-2 wt % of dissolved $\text{CO}_2$

![Fig. 1. Mean ultimate tensile stress for PMMA in a gaseous medium at 19 ± 1°C. 1 - CO$_2$, 2 - Ar.](image)

gas, interpack plasticizing and a decrease in strain concentration at the surface crack edges occur. In agreement with data in the literature, polymer strength is found to increase. At low $P_S$, the fracture pattern is typical of brittle material.
At higher $P_S$ of CO$_2$, strength decreases continuously owing to CO$_2$ molecular penetration into structural formations and subsequent increased chain mobility. At increased temperature, the $\langle \sigma \rangle$ strength of CO$_2$-saturated specimens at $P_S = 30$ and 40 atm peaks (Fig. 2) as a result of two competing processes: the initial decrease in the dissolved gas concentration, and a trivial decrease in strength. Similar to the $\langle \sigma \rangle$ isobars, the $E$ isobars determined by a resonance method exhibit a maximum at $P_S$ of CO$_2 > 30$ atm. The maximum shifts toward higher temperatures when $P_S$ is increased.

Viscosity under static load, determined from the experimental creep curves at $20 \pm 1^0$, decreased by an order of magnitude when the $P_S$ of CO$_2$ was increased by about 2 atm. It is concluded that a gaseous medium (especially CO$_2$) under elevated pressure can significantly affect the viscoelastic and strength characteristics of a polymer.

A method is introduced for the simultaneous measurements of temperature and pressures above 17 kbar using a single sensor. The method is based on the fact that the temperature \( T_{\alpha \rightarrow \gamma} \) of the \( \alpha \rightarrow \gamma \) phase transition in iron decreases noticeably with increased pressure, and consequently acts as an indicator of chamber pressures above 17 kbar. The pressure-temperature sensor consists of an Armco iron foil strip, 100 \( \mu \) thick, and a chromel-alumel thermocouple with leads spot welded at the strip ends. Chamber pressure is determined from the HF resistance jump of the sensor at the \( \alpha \rightarrow \gamma \) transition. The jump and temperature are recorded in potentiometer fashion by the same thermocouple, minimizing the number of chamber lead-ins. Pressures to 60 kbar were measured by this method to approximately 1 kbar accuracy. The pressure measurement data were compared to calibrated data using BiII - BiII, BiII - BiIII, and T\( \epsilon \) II - T\( \epsilon \) III standard phase transitions (Fig. 1).

![Diagram showing pressure calibration curve for one chamber](image)

Fig. 1. Pressure calibration curve for one chamber. 1 - Experimental data from the \( \alpha \rightarrow \gamma \) transition (1), and from transitions in Bi and T\( \epsilon \) (2).
Prolonged heating to 1,200°C negligibly affected thermal emf of the thermocouple, which illustrates the high stability of the sensor. The method thus permits the measurement of given pressures within the indicated pressure and temperature ranges in the same high-pressure chamber while using a minimum number of lead-ins.


Strain hardening by impact loading was studied in technical grade annealed Armco iron, Ti, Cu, Ni, and ferrite-perlitic carbon steels at 200 to 1150 kbar pressures behind the shock wave front. The experimental impact loading diagram (Fig. 1) is based on shock wave initiation by high-speed

Fig. 1. Impact loading diagram:
1 - detonator, 2 - shock wave initiation system, 3 - explosive charge, 4 - striker, 5 - lead specimen holder, 6 - specimen(-angle of taper, H - charge height, x - throwing distance).
impact of the striker on the specimen. Plane waves were generated at $\gamma = 120$ degrees and selected detonation velocities. Shock wave pressure $p$ was dependent on impact velocity for a given specimen-striker combination. Armco-iron loaded at 450 kbar and $\gamma = 90-140$ deg. more than doubled in hardness.

At $p = 850$ kbar iron was hardened significantly only at $\gamma > 120$ deg. Since the results of iron dynamic hardening at $\gamma = 120$ deg were inconclusive, all metals were loaded at $\gamma > 120$ and $\gamma < 120$ deg. using slightly divergent or convergent shock waves and concurrent specimen deformation. The experimental data illustrated by Vickers hardness $HV$ versus $p$ plots for iron (Fig. 2) indicate that all the metals studied exhibited the same strain hardening pattern at systematically increased shock wave pressures. The region of increased hardening ceased for all metals at 200-300 kbar, followed by a region of constant hardening, then an abrupt decrease in metal strength to the initial value for the annealed specimen. Micrographs of the compressed samples reveal that the poor hardening capability of metals at very high $p$, near the elastic modulus value, is a consequence of crystal lattice instability. In contrast to Te and Ni, phase transitions in polymorphic Fe and Te occurred during the shock compression process. The transitions lead to complete recrystallization and weakening of the crystal structure.

High-temperature erosion of channel internal walls by an incandescent gas flow is analyzed as a particular case of ablation in the absence of chemical reactions. Using an energy balance equation and introducing the heat of erosion concept $\Delta H_e$, the ratios of the mass losses due to mechanical wear ($m_w$) and sublimation ($m_s$) to the total mass loss $m_e$ were calculated to be

$$k_1 = \frac{m_w}{m_e} = \frac{\Delta H_e - \Delta H_v}{\Delta H_{inc} - \frac{1}{2} C_p \Delta T}$$

$$k_2 = \frac{m_s}{m_e} = \frac{\Delta H_v - \frac{1}{2} C_p \Delta T}{\Delta H_{inc} - \frac{1}{2} C_p \Delta T}$$

$$k_{12} = \frac{m_w}{m_s} = k_1$$

It follows from (1) and (2) that high-temperature erosion studies require the determination of $\Delta H_v$, the heat of vaporization, $C_p$, the heat capacity, and $\Delta H_e$. The latter is determined from the equation

$$A = \Delta H_e/4.575$$

where $A$ is given by the logarithmic temperature dependence of the erosion vapor pressure $p_e$. The cited theoretical deductions were verified by an experimental study of the erosion resistance of two MgO-base refractory concretes heated at a 40-50 deg/min rate by high-temperature (1900 - 2400 deg K) gas flow. The experimental $m_e$ versus $T$ data were used to calculate the $p_e$ and $\Delta H_e$ of the two concretes. The theoretical $\Delta H_v$ of pure MgO was higher than the $\Delta H_e$ of both materials. The difference $\Delta H_v - \Delta H_e$ was explained as the effect of the experimental conditions, the medium, and the materials composition. It is concluded that the theoretical sublimation rate can be used to evaluate the erosion resistance of materials.
The article presents a survey of domestic and foreign literature on methods of preparing heat-resistant polymer fibers. Coverage includes the initial materials, materials processing, and fibers processing to obtain the desired mechanical characteristics and an optimal degree of heat resistance. A bibliography of 33 items cites 4 articles from Western sources, and 8 foreign patents (one French, one US, and six British).

The literature survey focuses on processing methods based on the following characteristics of high heat-resistant polymers:

1) poor solubility requiring the application of such aggressive solvents as fuming sulphuric, hydrofluoric and polyphosphoric acids;
2) the extremely high viscosity of spinning solutions, previously not used in preparing artificial and synthetic fibers; and
3) the self-ordering capacity of polymers both in solution and in the solid state.

The author concludes that to produce heat-resistant fibers with optimal functional properties, in addition to maximal fiber cyclization it is also necessary to provide for suitable parameters over the entire technological process.
Obmoin, B. I., and N. K. Moroz.

Thermostat for NMR studies at high pressures and temperatures from 8 to 400° K. PTE, no. 5, 1972, 208-210.

A thermostat (Fig. 1) is described for NMR studies of substances at high pressures and over an expanded range of temperatures. The temperature in the bomb is coarsely controlled by adjusting the blowing rate of liquid N\textsubscript{2} or He through the Dewar flask. Fine temperature control and stabilization is effected by means of the heater which is connected in the power amplifier circuit. The amplifier responds to an error signal from a thermocouple connected to a potentiometer; temperature in the bomb is thus maintained constant to ± 0.05° K for long periods over the entire working range of 8° to 400° K. A specially designed lead-in makes it possible to study angular distribution of NMR spectra. The cylinder protrudes 30 mm on each side from the electromagnet interpolar gap.
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Tishchenko, V. V. Computer analysis of vibration analyzer models. Problemy bioniki, no. 9, 1972, 116-119.


An experiment is described in which a spontaneous glow discharge was obtained in a high speed flow of distilled water thru a nozzle. The discharge, which the author compares to known ball lightning characteristics in the atmosphere, is generated as follows. Distilled water at a high flow rate expands abruptly at a nozzle exit into a section of tubing having a suitable dielectric liner. Severe pulsating cavitation occurs owing to the pressure drop in the exit area, resulting in extremely rapid development and collapse of bubbles each carrying a surface charge. Bombardment of the dielectric wall by the charged particles causes a strong secondary emission, including some electrons from inner atomic shells. A net charge gradient is thus developed which is positive at the wall surface and in the exit region, with an electron cloud between; under proper conditions this plasma is maintained by the dielectric property of the water.

Recombination of electrons in the wall dielectric then yields optical emission typical of the material, appearing as a continuous glow discharge. An asbestos cement liner gives a rose color, plexiglass and ebonite give yellow and blue respectively. A sketch of the apparatus is given but no other quantitative data are mentioned.
the antennas move relative to each other at a constant velocity along the baseline during an observation interval, which permits a shorter interval to be used. During this time the signals from both antennas are continuously and synchronously recorded and summed.


Calculations are discussed relating to measurements of the effective coefficient of sound reflection from the ocean bottom under normal incidence, assuming that the bottom acts as an uneven boundary surface between two media. For simplicity, sound absorption in water during propagation is ignored and the bottom is assumed to return all the propagating sound energy to the upper half-space.

A formula for the effective coefficient of ocean bottom sound reflection under normal incidence is given as:

\[ V_{\text{eq}} = 4H \frac{J_{\text{pr}}}{J_o} R \]  

where \( J_{\text{pr}} \) is the signal strength at the point of reception, \( J_o \) is the radiating sign strength at a distance \( r_o \) from the transmitter, and \( R \) is the distance between the transmitter-receiver point and the bottom.

The coefficient of bottom sound scattering \( m_o \) is defined as:

\[ m_o = m / J S \]  

-177-
where \( w_s \) is the power per unit spatial angle, scattering over a bottom area \( S \), from which the scattering signal simultaneously approaches the point of reception; and \( J_1 \) is the intensity of sound wave propagation on the ocean bottom. The scattering indicatrix is approximated for surface scattering according to the Lambert law.

Calculations indicate that the sound reflection formula (1) is not always applicable for regions with strongly dissected topography. In these regions, the sound scattering indicatrix approaches the limits of the Lambert law at frequencies higher than a few kHz for which: (1) the effective coefficient of reflection is derived solely from scattering properties, and (2) the sound attenuation in water is pronounced and not uniform in all directions of the bottom effective scattering surface. This conclusion is also valid for regions in which sound bottom backscattering is primarily a function of soil heterogeneity and obeys the Lommel-Seeliger law.

The reflected signal strength at the point of reception in such regions under normal incidence should be determined experimentally for all transducer types and transducer locations relative to the ocean bottom. However, when the angular dependence of the scattering coefficients is known, the bottom signal at the point of reception in such regions may be precomputed for any given event.


The contribution of nonlinear shifts in the plasma oscillation frequency to the appearance of a stationary turbulence level in a parametrically
non-stable plasma is calculated. It is presently feasible to compute parametrically non-stable plasma turbulence levels using approximation methods by taking into account the nonlinear interactions of developing plasma disturbances owing to induced wave scattering on particles.

The authors illustrate the stabilizing effect of a nonlinear frequency shift on the basis of aperiodic disturbances. In the parametrically-excited plasma, these disturbances arise along with plasma oscillations at the pumping wave frequency. A nonlinear dispersion equation for the high frequency plasma oscillations is examined. The real part of this equation yields a nonlinear frequency shift value $\delta \omega(k)$, which is assumed to be small; the imaginary part yields a normal expression for the linear damping decrement $\gamma(k)$ of the high frequency plasma waves and a nonlinear addition $\delta \gamma(k)$ to the damping factor, which can be compared to $\gamma$. With the $\delta \omega(k)$ and $\delta \gamma(k)$ values added to the plasma oscillation frequency and the damping increment, the equality condition of a parametric non-stability zero increment provides a relationship describing the stationary turbulence level. This relationship indicates that when the pumping electric field intensity exceeds the threshold value $E_{\text{thresh}}$ (determined by linear theory of parametric resonance), the nonlinear stabilization of aperiodic parametric instability is possible even at $\gamma \gg \delta \gamma$. The stabilization results from the nonlinear frequency shift $\delta \omega$ of high frequency plasma oscillations. The negative value $\delta \omega < 0$ increases the negative frequency difference.

An effective intensity value of the plasma oscillation electric field is given describing the stationary turbulence level and the nonlinear frequency shift of plasma oscillations in the near-threshold area. This permits determination of the effective intensity value of the electric field $E_a$ (the aperiodic turbulence in plasma).
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</table>

-189-
<table>
<thead>
<tr>
<th>ЖРЭФ</th>
<th>Zhurnal eksperimental'noy i teoreticheskoy fiziki</th>
</tr>
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<td>Zhurnal tekhnicheskoy fiziki</td>
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<td>Zavodskaya laboratoriya</td>
</tr>
</tbody>
</table>
9. AUTHOR INDEX

<table>
<thead>
<tr>
<th>A</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aleksandrov, A. F.</td>
<td>108</td>
</tr>
<tr>
<td>Alferov, D. F.</td>
<td>98</td>
</tr>
<tr>
<td>Anan’in, O. B. 1</td>
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</tr>
<tr>
<td>Apanasevich, P. A.</td>
<td>10</td>
</tr>
<tr>
<td>Azizov, T. S.</td>
<td>66</td>
</tr>
<tr>
<td>B</td>
<td></td>
</tr>
<tr>
<td>Batanov, V. A. 9</td>
<td></td>
</tr>
<tr>
<td>Bomko, V. A. 106</td>
<td></td>
</tr>
<tr>
<td>Brazhnev, V. V. 135</td>
<td></td>
</tr>
<tr>
<td>Brodskaya, B. 99</td>
<td></td>
</tr>
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<td>Bronshten, V A. 25</td>
<td></td>
</tr>
<tr>
<td>Bychenkov, V. A. 15</td>
<td></td>
</tr>
<tr>
<td>Bychkov, Yu. I. 102</td>
<td></td>
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<tr>
<td>C</td>
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<tr>
<td>Chernyshov, A. D.</td>
<td>17</td>
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<td>D</td>
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</tr>
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<td>Deribas, A. A. 13</td>
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<tr>
<td>Dmitriyev, V. N. 125</td>
<td></td>
</tr>
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<td>Dubinskyy, I. B. 59</td>
<td></td>
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<td>Dzhanuzakov, K. 50</td>
<td></td>
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<td></td>
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<tr>
<td>Elizbarashvili, T. Sh. 27</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Gerasimov, B. P. 8</td>
<td></td>
</tr>
<tr>
<td>Ginzburg, V. L. 118</td>
<td></td>
</tr>
<tr>
<td>Golendantskiy, S. I. 74</td>
<td></td>
</tr>
<tr>
<td>Golodenko, N. N. 4</td>
<td></td>
</tr>
<tr>
<td>Grebinskiy, A. S. 176</td>
<td></td>
</tr>
<tr>
<td>Gurevich, A. V. 111</td>
<td></td>
</tr>
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</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>Karasev, V. N. 104</td>
<td></td>
</tr>
<tr>
<td>Kazhdan, Ya. M. 24</td>
<td></td>
</tr>
<tr>
<td>Khrometskaya, Ye. A. 55</td>
<td></td>
</tr>
<tr>
<td>Klebanov, Yu. D. 134</td>
<td></td>
</tr>
<tr>
<td>Klevtsov, I. V. 22</td>
<td></td>
</tr>
<tr>
<td>Klochkov, V. F. 18</td>
<td></td>
</tr>
<tr>
<td>Kogan, A. I. 51</td>
<td></td>
</tr>
<tr>
<td>Koldamasov, A. 176</td>
<td></td>
</tr>
<tr>
<td>Kondrat’yev, V. N. 6</td>
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<tr>
<td>Kostyuk, O. P. 57</td>
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<tr>
<td>Kovchik, S. Ye. 126</td>
<td></td>
</tr>
<tr>
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<td></td>
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<td>Kudryavtsev, G. I. 138</td>
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<tr>
<td>Kurochkina, R. I. 58</td>
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<tr>
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<td>Kuznetsov, V. M. 16</td>
<td></td>
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</tr>
<tr>
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<tr>
<td>Luk’yanyov, G. A. 23</td>
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<td>Lukov, A. I. 127</td>
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<td></td>
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<td>Mirkin, L. I. 2</td>
<td></td>
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<tr>
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</tr>
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<tr>
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<td></td>
</tr>
<tr>
<td>Okonishnikov, G. B. 132</td>
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</tr>
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<td>21</td>
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<tr>
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<td>20</td>
</tr>
<tr>
<td>Poplavskaya, L. N.</td>
<td>84</td>
</tr>
<tr>
<td>Prozorov, A. G.</td>
<td>41</td>
</tr>
<tr>
<td>Pustovalov, V. V.</td>
<td>178</td>
</tr>
<tr>
<td>Rakhuba, V. K.</td>
<td>13</td>
</tr>
<tr>
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<td>7</td>
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<td>Rayzer, M. D.</td>
<td>97</td>
</tr>
<tr>
<td>Rukhadze, A. A.</td>
<td>97</td>
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<tr>
<td>Sheyndlin, A. Ye.</td>
<td>128</td>
</tr>
<tr>
<td>Shuirnova, M. N.</td>
<td>48</td>
</tr>
<tr>
<td>Solodilov, T. A.</td>
<td>22</td>
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<td>115</td>
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<td>113</td>
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</tr>
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<td>18</td>
</tr>
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<td>130</td>
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<td>17</td>
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<tr>
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<td>116</td>
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<td>177</td>
</tr>
</tbody>
</table>