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13. ABSTRACT

This report includes abstracts and bibliographic lists on major contractual subjects that were completed in April, 1972. The major topics are: laser technology, effects of strong explosions, geosciences, and particle beams. A section on material sciences is included as the optional fifth topic. The abstracted material includes some selections prior to 1972 that have not otherwise been reported.

To avoid duplication in reporting, only laser entries concerning high-power effects have been included, since all current laser material will appear routinely in the quarterly bibliographies.

An index identifying source abbreviations and an author index to the abstracts are appended.

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INTRODUCTION

This report includes abstracts and bibliographic lists on major contractual subjects that were completed in April, 1972. The major topics are: laser technology, effects of strong explosions, geosciences, and particle beams. A section on material sciences is included as the optional fifth topic. The abstracted material includes some selections prior to 1972 that have not otherwise been reported.

To avoid duplication in reporting, only laser entries concerning high-power effects have been included, since all current laser material will appear routinely in the quarterly bibliographies.

An index identifying source abbreviations and an author index to the abstracts are appended.

TABLE OF CONTENTS

1. Laser Technology

A. Abstracts

Avotin, S. S., E. P. Krivchi ova, I. I. Papirov, P. I. Stoyev, and V. I. Tereshin. Change in electrical resistance of beryllium from laser radiation. ZhETF, v. 62, no. 1, 1972, 288-293.

Transient and long-term effects of laser irradiation on resistivity of beryllium are described. Tests were run on 0.2 mm thick Be foil strips, exposed to pulsed radiation from a GOR-100M laser (not identified) generating 1 millisecond pulses at 40 j, focused to a 2.5 mm dia. spot on the foil surface. Resistivity ρ was measured during and after exposure with a constant 1 a current passed through the specimen. Variation of ρ during exposure is illustrated in Fig. 1, with calculated values of local

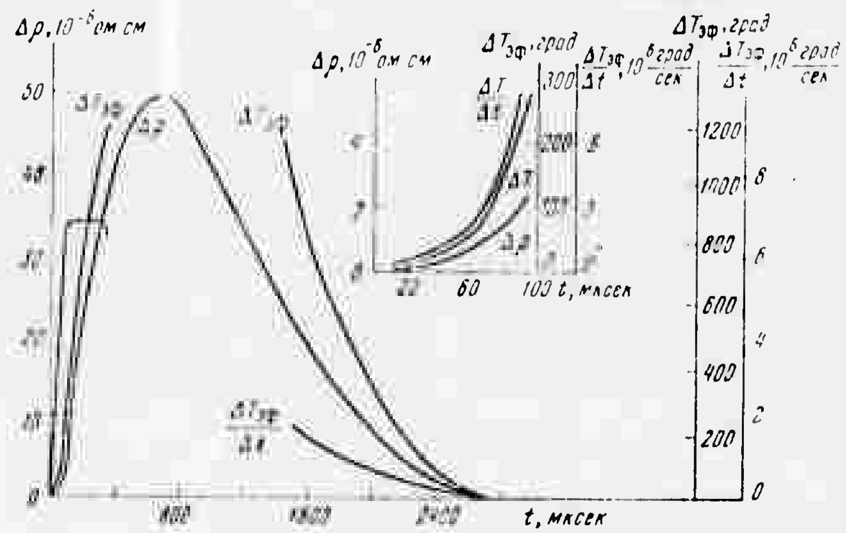


Fig. 1. Resistivity variation in laser-irradiated beryllium.

temperature rise ΔT_{eff} also included. A detailed examination shows three distinguishable stages in $\Delta\rho$ (t) up to the 700 μsec point, as indicated by the curve form. In the initial stage ($<100 \mu s$) a local heating rate of about 10^6 deg/sec was calculated to exist in the impact region. It is noteworthy that a full anneal back to pre-exposure values of ρ occurs when the test is done in a 300°K ambient, whereas at 77°K, ρ continues to increase for an interval following irradiation, and after several hundred microseconds levels off at a value some 9% above the original value. The latter effect is ascribed to an increase in structural defect density during the high temperature anneal.

Belozerov, S. A., G. M. Zverev, V. S. Naumov, and V. S. Pashkov. Destruction of transparent dielectrics by radiation from a mode-locked laser. ZhETF, v. 62, no. 1, 1972, 294-299.

A comparative test was made on damage thresholds in various dielectrics from pulsed laser radiation. The main purpose was to illustrate the difference in effect of single pulse (10 ns) and a train of short pulses (30 x 4 ns) from a mode-locked Nd laser on dielectric breakdown. The test materials included type K-8 glass, fused and crystal quartz, leucosapphire, and ruby with and without color centers. The test conditions and findings generally duplicate those of Orlov et al (Effects of High Power Lasers, Dec. 1971, p. 49), who also advised on the present experiment. A typical filamentary breakdown in the short-pulse regime indicated self-focusing, evidently not thermal, which was not apparent in the monopulse regime. The tests verify that while energy densities for threshold are of the same order of magnitude for all dielectrics tested, the power density threshold for the short-pulse mode is typically several orders higher than for the 10 ns monopulse, and was found to go as high as 10^{14} w/cm^2. This suggests a thermal relief mechanism operating between pulses in the pulse train case. Photos are also included comparing filament appearance of the ruby with color centers to that in the remaining specimens.

Zverev, G. M., Ye. A. Levchuk, V. A. Pashkov, and Yu. D. Poryadin. Optical destruction of the surface of lithium niobate. ZhETF, v. 62, no. 1, 1972, 307-312.

Anomalous breakdown thresholds of laser-irradiated $LiNbO_3$ are examined and the types of destruction mechanisms taking place are suggested. In contrast to most dielectrics, $LiNbO_3$ has both a markedly lower breakdown threshold at room temperature, as well as a distinctly irregular change in breakdown level with increase in ambient temperature. This was observed in radiation tests with a focused Q-switched Nd glass laser at 1.06μ on polished $LiNbO_3$ specimens, in which 20 ns, 0.1 j pulses were applied at f = 15 cm. Threshold at room temperature (120 Mw/cm^2) increases with ambient temperature as seen in Fig. 1, exhibiting step jumps at the Curie points. In contrast, the threshold characteristic of $LiTaO_3$

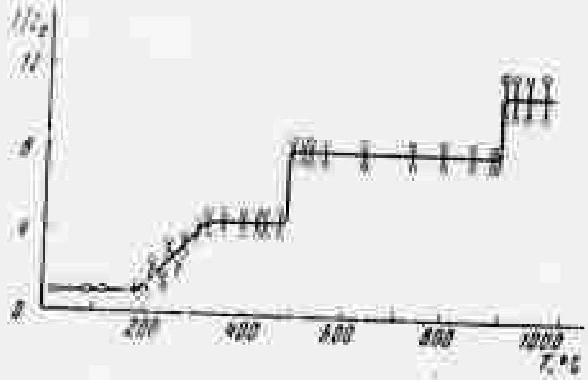


Fig. 1. Relative threshold intensity vs. temperature, $LiNbO_3$.

and $BaTiO_3$ were found to have no temperature dependence until the Curie point was reached, while for ruby and glass, no temperature dependence of threshold could be found between 20--700°C. At lower temperatures a cumulative effect of laser pulses on threshold is also noted in $LiNbO_3$ which is shown in Fig. 2. An analysis of these findings

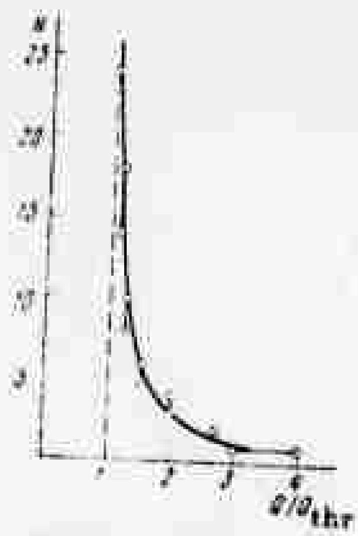


Fig. 2. Relative threshold vs. total laser pulses, N.

indicates that for temperatures below 330°C, surface damage is a function of light absorption in small trapping centers, whereas at higher temperatures the predominant mechanism is absorption by free carriers in the surface layer.

Uglov, A. A. Work presented in the seminar on the physics and chemistry of materials processing by concentrated energy beams. FIKhOM, no. 5, 1971, 158-159.

Highlights are given of selected papers in the 27th Seminar on the title subject, held in Moscow during February, 1971. The seminar was chaired by Academician N. N. Rykalin, and attended by over 80 leading researchers in the field from Soviet institutes. The bulk of the articles deal with high-power laser interaction with metal and dielectric targets, CO_2 lasers being most often mentioned. To a lesser degree, particle-beam interactions are also discussed.

A paper by V. P. Veyko et al discussed the growth kinetics of thin oxide films on metals from pulsed heating, and methods for optimizing film control. Experiments with a c-w CO_2 laser have yielded a 40-50 Å oxide film on chrome at 1 millisec exposure, which is consistent with calculated values. A number of test results by the same authors on polymer targets was also discussed.

A. E. Kuznetsov et al presented their findings on vaporization of dielectrics by 10.6 micron laser radiation, using quartz and other optical glass under c-w CO_2 exposure. From their results the authors have developed an approximate mathematical model based on the law of mass conservation. Commenting on this, Yu. N. Lokhov noted the similarity in characteristics between CO_2 destruction of dielectrics and the self-consistent damage mode of metals under giant pulse exposure.

A paper by I. G. Stolyanova et al discussed aspects of laser milling techniques in microelectronics; the authors have developed a technique for producing laser-cut thin film resistors.

An interesting report by M. S. Baranov et al described computer and experimental studies on the effect of laser pulse envelope in beam-target tests. Results with rectangular, triangular and approximately sinusoidal waveforms showed maximum metal vaporization for the triangular waveform and minimum for the half-wave sinusoid. A criticism offered here by A. A. Uglov, which applied generally to the laser beam-target tests, was that attention tends to focus only on the strictly thermal effects occurring, whereas chemico-thermal mechanisms also play a part and warrant more detailed examination.

Techniques for electron beam processing of materials are mentioned by A. N. Kabanov, D. B. Zvorykin et al, and Yu. D. Belotovskiy et al. These concerned nonthermal beam processing, electron lithography, and beam deposition techniques for metal films.

In summary, Dr. Rykalin observed that advances in laser tunability are needed to expand laser processing techniques, and that more detailed study of chemico-thermal processes is needed for both laser and particle beam techniques.

Liberman, M. A., and A. T. Rakhimov. Penetration of e-m waves into a plasma with allowance for nonlinearity. ZhETF, v. 61, no. 3, 1971, 1047-1056.

The authors examine the structure of an alternating electromagnetic field interacting with a weakly ionized plasma, for the case of thermal nonequilibrium in the plasma. It is noted that nonlinear effects begin to appear in such a case at relatively weak fields in comparison to the characteristic plasma field. The discussion is limited also to the case where the incident e-m field frequency is well above the electron-atom collision frequency, but below plasma frequency. Using this model the authors show that the effect of the e-m field on the local ion-recombination balance in the plasma causes an appreciable change in the penetration depth of the field into the plasma, according to the relation c/ω_p where ω_p is electron frequency in the interaction region. Expressions are derived illustrating the nonlinear decrement in e-m intensity with penetration, and some sample calculations are given for the effect, using typical plasma and beam parameters.

Norinskiy, L. V. Initiation of a controlled breakdown in gas by third-harmonic emission from a neodymium laser. IN: Kvantovaya elektronika. Sbornik. Moskva, Izd-vo Sovetskoye radio, no. 5, 1971, 108-109.

An experiment is described which was an extension of work by Akmanov et al (ZhETF P, v. 8, no. 8, 1968, 417), in which a directional breakdown in gas was triggered by u-v laser radiation at 4.7 ev photon energy and 300 Mw/cm^2 density. The present author has duplicated the effect in atmospheric air, obtaining a controlled breakdown from the third harmonic of an Nd glass laser at 3.5 ev. A collimated 3rd harmonic beam was passed through slotted high-voltage electrodes which were 1 cm apart, to obtain the controlled breakdown effect. Power density in the gap was about 3Gw/cm^2, or two orders less than natural optical breakdown. Attempts to repeat the effect at the fundamental and second harmonic were unsuccessful, since breakdown threshold was first exceeded in both cases. The results confirm the inability of the fundamental (1.17 ev) and second harmonic (2.34 ev) to generate the controlled breakdown condition owing to their insufficient photoionization levels. Norinskiy emphasizes that his results were obtained with a multimode laser, and should be repeated with a single-mode regime for better clarification of this phenomenon.

Alekseyev, E. I. A description of the interaction of noncoherent radiation with matter. ZhPS, v. 15, no. 6, 1971, 1090-1093.

A general probability expression is presented from which the interaction of radiation with matter can be approximately described. The model assumes most types of noncoherent radiation sources of macroscopic nature, and includes certain types of laser radiation as well; random noise sources are however excluded. A general expression defining radiation interaction with a density matrix of material elements is given, which can be treated as a system of ordinary stochastic differential equations with stipulated or random initial conditions. A rigorous solution for the assumed model could be obtained by a form of the Fokker-Planck-Kolmogorov equation; however for practical considerations a satisfactory solution may be had by using only the mean value of density matrix elements. The author illustrates the approach by examples of approximate equations describing differences of population levels in a two-level system, under the effect of radiation taken to be a normal stationary process with zero mean. The method is tedious, requiring computer solution, and is limited to systems with a few levels only, but in theory applies to radiative interaction of arbitrary intensity and spectral characteristic with matter, as long as the radiation may be considered as a normal stationary process.

Kaytmazov, S. D., A. A. Medvedev, and A. M. Prokhorov. Effect of a 400 koe magnetic field on the plasma of a laser spark. ZhETF P, v. 14, 1971, 314-316.

An experiment is briefly described in which the controlling effect is studied of an external magnetic field on the geometry of a laser spark plasma. Two conditions must evidently be met for field control of spark geometry, namely (1) field pressure must exceed gas kinetic pressure in the plasma, and (2) the skin layer should not exceed spark radius, r. This means that the external field must be sufficiently great that on lowering of plasma pressure to the magnetic pressure level, plasma temperature still remains high enough to preclude diffusion in the external field. The corresponding threshold for field control in the present case was calculated to be on the order of 300 koe. Tests to corroborate this were run at levels up to 500 koe, using a transformer-fed one-turn coil of 0.8 cm dia. instead of the usual capacitor bank. A 100μsec field pulse was thus generated, which simplified the requirement of exact synchronization of laser spark and field pulse. Tests were run in ambient air, using a neodymium glass laser at 2--3 j in both giant pulse and spike regimes to produce breakdown. The comparative effect of the field is seen in Fig. 1, where the spark is confined to a cylindrical form with

a

b

c

Fig. 1. Field effect on laser spark. a, c - no applied field; b - field applied

a smooth boundary. In both laser regimes the field increased spark axial length by about 1.5 times; it follows that this formation should retard plasma cooling. Nominal spark parameters of r = 0.1 cm and time constant τ = 3 x 10^{-7} sec led to the conclusion that the plasma temperature attained was at least 6 x 10^5 deg. K.

Afanas'yev, Yu. V., and V. B. Rozanov. Spectrum of multiply-charged ions in a laser plasma. ZhETF, v. 62, no. 1, 1972, 247-252.

A physical model is proposed for the energy spectral form of multiply ionized atoms in a laser plasma. Based on certain assumptions regarding plasma diffusion, the model permits the development of an analytical expression which describes the desired ion energy distribution. The analysis demonstrates that a principal factor governing the energy spectrum for a range of Z-charged ions is the recombination process during the diffusion period following termination of the laser pulse. It is furthermore shown that the set of Z present at the end of the pulse does not necessarily contain all Z values present following this time. For simplicity a spherically symmetrical plasma flare is assumed to exist at pulse termination, expanding into a vacuum according to a self-similar law. The energy spectrum is then derived as a function of initial flare density N_0 and time. Assuming values of $N_o = 10^{20}/cm^3$, temperature $T = 100$ ev and $Z \cong 20$, the authors find a characteristic photorecombination time $\tau_{pr} \cong 3 \times 10^{-10}$ sec, which is less than plasma diffusion time, hence the recombination effect can be appreciable. Analogous experimental work of Bykovskiy et al is cited (ZhTF, 1970, 2578, and ZhETF, v. 60, 1971, 1306), but lack of complete data from the latter preclude a useful comparison of theory with experiment. A more recent similar work of Mattioli is also cited (Plasma Physics, v. 13, 1971, 19) in which decay of an LiH plasma was calculated from ionization and recombination processes.

Golant, V. Ye. Wave penetration in plasma at frequencies near the lower hybrid. ZhTF, no. 12, 1971, 2492-2503.

Theoretical considerations are presented for optimizing the introduction of e-m radiation into a magnetized plasma. It has been shown that injection near the lower hybrid frequencies may be advantageous since plasma opacity to the incident wave will be minimal here, to a wave with correctly applied longitudinal delay. The author therefore investigates the transformation region for frequencies near the lower hybrid, and derives expressions for optimum energy transfer under these conditions. It is assumed that the applied frequency lies well below electron cyclotron resonance and well above ion cyclotron resonance. For the case of a uniform applied magnetic field, expressions for optimal delay structure parameters are obtained, assuming the idealized delay configuration of Fig. 1. In some cases in a uniform field the requirements on delay

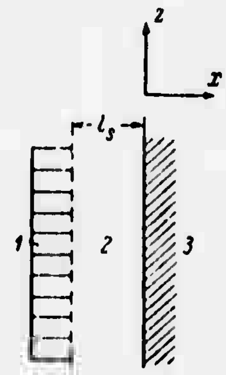


Figure 1. Delay geometry.
1 - delay element; 2 - vacuum;
3 - plasma.

parameters may become excessive; in that event a nonuniform external field may be applied, resulting in two transformation regions and simplifying the delay line operation.

Askar'yan, G. A., and T. G. Rakhmanina.
<u>Scattering, refraction and reflection of sound under the action of intense light on a medium.</u>
ZhETF, v. 61, no. 3, 1971, 1199-1202.

An analytical discussion is given describing the effect of powerful optical absorption in a medium on acoustic parameters of that medium. Coherent or noncoherent radiation of sufficient intensity can cause substantial local changes in acoustical scattering, refraction and reflection owing to gas evolution, bubble formation, etc. The case of a liquid medium is treated here, with bubbles assumed to be formed by beam absorption, as this produces drastic changes in the cited acoustical parameters. An expression for mean bubble size is derived as a function of breakdown threshold and other parameters of the liquid medium. A comparison of theoretical scatter in bubbles with scatter in locally heated regions, at the same per unit energy absorption, shows that the bubble scattering cross-section will exceed that of the heated regions by as much as 10^{13}, which indicates the predominant scattering effect of bubble formations. A brief treatment on sound refraction and reflection from optically disturbed regions is also given. The discussion in general is concerned with acoustic velocities ranging from supersonic to hypersonic.

Yevtushenko, T. P., V. Kh. Mkrtchyan, and G. V. Ostrovskaya. Spectroscopic studies of a laser spark. IV. Absorption spectrum of a spark in hydrogen. ZhTF, no. 12, 1971, 2581-2589.

This is the fourth report in a series by the authors on laser spark spectroscopy; the previous article was reported in Effects of High Power Lasers, Dec. 1971, p. 7, on spark spectra in air, He and Ar. In the present tests the absorption spectrum of hydrogen at 6 atm was measured and compared to the continuous spectrum of an air breakdown. The same method was used as in the earlier tests, as shown in Fig. 1, using two Nd glass lasers to generate the sparks. The lasers were identical

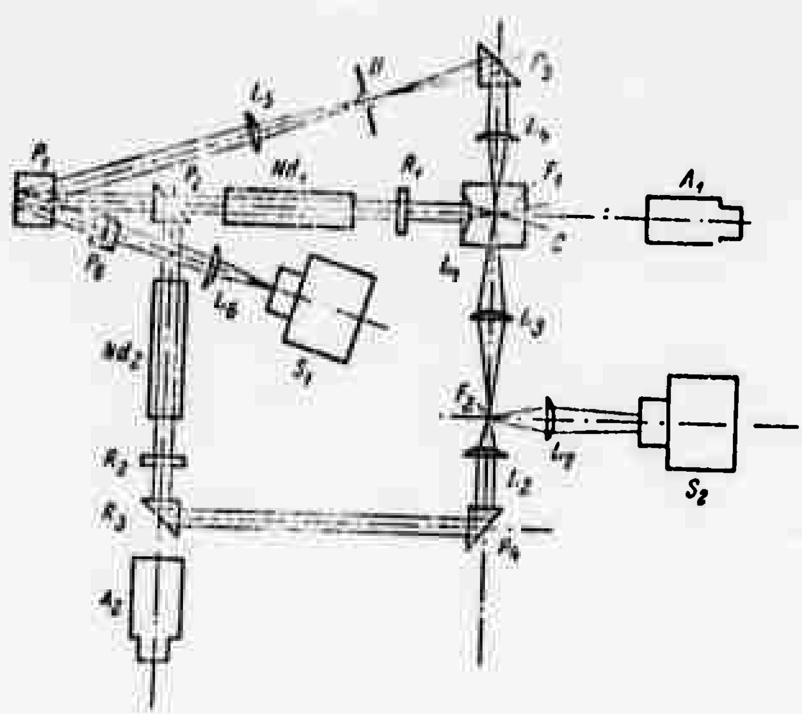


Fig. 1. Schematic for spectral study of a laser spark in hydrogen. A_1, A_2 - monitor tubes; C - hydrogen vessel at 6 atm; F_1, F_2 - sparks; S_1, S_2 - spectrographs.

and developed giant pulses of 0.5 j using a driven prism Q-switch rotating at 27,000 rpm. A large amount of graphical data on spark parameters, deduced from the spectral response, is presented and analyzed including the time characteristics of absorption, N_e, and plasma temperature. An example is given in Fig. 2, showing temperature, pressure and density variation in the center of the spark. In conclusion

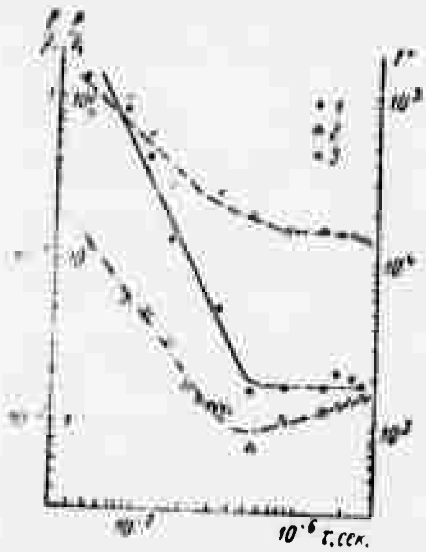


Fig. 2. T, p, ρ(t) in the center of a laser spark in hydrogen. 1 - pressure; 2 - density; 3 - temperature.

the authors discuss the accuracy of the spectral method for deducing the cited spark parameters.

Anisimov, S. I., and V. I. Fisher. Ionization relaxation and light absorption behind a strong shock wave in hydrogen. ZhTF, no. 12, 1971, 2571-2576.

A simplified analysis is presented which describes the effect of ionization kinetics behind a shock wave on e-m radiation absorption in this region. The model assumes a plane stationary shock wave, and limits the consideration to hydrogen, since this avoids the complications of multiple ionization. The ionization relaxation zone in the shock wave wake is divided for analytical purposes into two regions with differing mechanisms of free electron formation: (1) a region of "seed electron" formation from atom-atom collisions; and (2) an electron avalanche region, with electrons freed predominantly by electron-atom collisions. Most of the optical absorption, as well as the significant change in gas state, occurs in region (2), which is therefore the region mainly treated in the paper. Equations for incident flux density and degree of ionization are numerically integrated, together with equations for one-dimensional stationary flow of the gas. The calculated results of density and temperature profile, together with ionization characteristics, are shown to have a definite correlation with incident flux density. The authors emphasize that the characteristics of hydrodynamic variables in such a shock wave, i.e. one absorbing an intense optical flux, will differ from the corresponding parameters in the usual detonation wave, owing to the ionization relaxation region which will exist in the former case. Some graphical solutions of the results are included.

B. Recent Selections

i. Beam-Target Effects

Apollonov, V. V., A. I. Barchukov, V. K. Konyukhov, and A. M. Prokhorov. Thermoelastic surface deformation of a solid by a laser beam. ZhETF P, v. 15, no. 5, 1972, 248-250.

Cherkun, Yu. P., and I. N. Konotel'ko. Current status of experimental and theoretical studies in the field of combined heat exchange. I-FZh, v. 22, no. 4, 1972, 757-758.

Frolov, V. V. Temperature fields in multilayer semitransparent coatings under conditions of pulsed radiation heating. I-FZh, v. 22, no. 4, 1972, 755-756.

Gurevich, V. I. Pulse forms of a periodic point source of heat on the surface of a large body. FiKhOM, no. 2, 1972, 19-22.

Kapel'yan, S. N., and Z. M. Yudovin. Duration of vaporization after termination of a powerful thermal flux. DAN BSSR, no. 3, 1972, 214-216.

Kurchatov, Yu. A., and I. A. Malinov. Reflection of a multimode laser beam from a dielectric interface. OiS, v. 31, no. 2, 1971, 283-287.

Mirkin, L. I. Dynamic deformation of low-carbon steel from the effect of a laser beam. IN: Sbornik. Vysokoskorostnaya deformatsiya. Moskva, Izd-vo nauka, 1971, 109-112. (RZhMekh, 3/72, #3V1469)

Novikov, N. P., and A. A. Kholodilov. Destruction of thermoplastics by the combined action of gas and powerful thermal flux. I-FZh, v. 22, no. 4, 1972, 618-626.

Poltavtsev, Yu. G., V. P. Zakharov, and V. N. Chugayev. Structural studies of graphitization of carbon films induced by powerful light pulses. Kristall, v. 16, no. 2, 1971, 415-419.

Sayfiyev, R. Z. Calculating temperature fields in an infinite plate from the surface action of a circular heat source. FiKhOM, no. 2, 1971, 138-141.

Strunskiy, M. G. A thermal conductivity problem with shifted boundary conditions for the case of a point heat source. I-FZh, v. 22, no. 4, 1972, 746-749.

Uglov, A. Subjects of the seminar on physics and chemistry of material processing by concentrated energy fluxes. (Moscow, July 1971). FiKhOM, no. 2, 1972, 158-159.

Zakharov, V. P., and I. M. Protas. Mass spectrometer study of vaporization of type $A^{III}B^{V}$ semiconductor compounds by laser radiation. ZhTF, no. 3, 1972, 670-672.

ii. Beam-Plasma Interaction

Afanas'yev, Yu. V., E. M. Belenov, and I. A. Poluektov. Optical breakdown in molecular gases. ZhETF P, v. 15, no. 1, 1972, 60-63.

Bliokh, Yu. P. Stability of a monochromatic wave as a function of stimulated scattering. ZhTF, no. 3, 1972, 490-492.

Bykovskiy, Yu. A., V. G. Degtyarev, N. N. Degtyarenko, V. F. Yelesin, I. D. Laptev, and V. N. Nevolin. Kinetic energy of ions in a laser plasma. ZhTF, no. 3, 1972, 658-661.

Bykovskiy, Yu. A., N. M. Vasil'yev, N. N. Degtyarenko, V. F. Yelesin, I. D. Laptev, and V. N. Nevolin. Form of the ion energy spectrum in a laser plasma. ZhETF P, v. 15, no. 6, 1972, 308-311.

Kaliski, S. Averaged equations for laser heating of a two-temperature plasma, taking into consideration the heat of nuclear fusion. Bull. de l'Acad. Pol. des Sci., Ser. sci. techn., v. 20, no. 2, 1972, 23-28.

Kaytmazov, S. D., A. A. Medvedev, and A. M. Prokhorov. Effect of a 400 koe magnetic field on the plasma of a laser spark. ZhETF P, v. 14, no. 5, 1971, 314-316.

Krasyuk, I. K., and P. P. Pashinin. Breakdown in argon and nitrogen from a picosecond laser pulse at the 0.35 micron wavelength. ZhETF P, v. 15, no. 8, 1972, 471-473.

Nikashin, V. A., G. I. Rukman, and V. K. Sakharov. A method for obtaining a motion picture hologram of a dynamic process. OiS, v. 32, no. 3, 1972, 626-627.

Stepanov, N. S., and Yu. M. Sorokin. Kinetic theory of e-m waves reflected from a moving inhomogeneous plasma layer. ZhTF, no. 3, 1972, 578-583.

2. Effects of Strong Explosions

A. Abstracts

Godunov, S. K., A. A. Deribas, I. D. Zakharenko, and V. I. Mali. Investigation of viscosity of metals during high velocity shock. FGiV, no. 1, 1971, 135-141.

This article describes a study of metal viscosity during shock from explosive welding. An experiment is described in which steel plates were welded as shown in Fig. 1. On detonation of explosive (5), the upper plate (3) is driven onto the lower plate (1), as a result of which the two plates are welded as shown in Fig. 1b. The welded specimen was then cut along the direction of

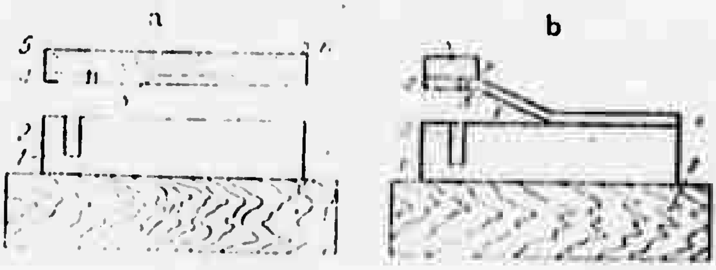


Fig. 1. Explosive weld.
1, 3 - steel plates; 2 - slot; 4 - hole (0.3~0.5 mm); 5 - explosive; 6 - detonator; 7 - wooden base.

movement of the contact point and the cross-section was microphotographed (Fig. 2). Horizontal displacement z with relation to the distance y from the interface was measured on the photograph. At $y > \delta_1$ (δ_1 - thickness of upper plate, δ_2 - thickness of lower plate), the relationship between z and y follows a parabolic curve, $z = a(y - \delta_2)^2$; while at $y < \delta_1$, $z = be^{-ky}$ - an exponential curve (a, b = constants). Displacement of impact points of the plates with relation to metal viscosity was investigated and was found to be inversely proportional to viscosity. Mathematical expressions are derived for determining stored impulses and the diffusion of horizontal velocities in both upper and lower plates. Using experimental data and derived formulas, viscosity coefficients were determined for Al, Cu and steel (Table 1). Viscosity coefficients for Al, Cu and steel are seen to have an increasing order of $(0.3{\sim}0.8)10^5$p, $(2{\sim}2.7)10^5$p and $(3{\sim}5)10^5$p respectively.

Fig. 2. Microphotograph of weld section.
1 - lower plate; 2 - compressed plate;
3 - upper plate; 4 - compressed wire.
Arrow indicates the direction of detonation.

The authors compare these values with those of Popov (Inzhenernyy sbornik, 1941, 1, 1) and Il'yushin (Inzhenernyy sbornik, 1941, 1, 1), and the value of viscosity coefficient for steel is found to be the same in both cases. Similarly, the obtained value for Al is found to be in good agreement with the results of Sakharov, Zaydel', et al (DAN SSSR, 1964, 159) and Mineyev and Savinov (ZhETF, 1967, 57, 3). However, according to the results of Il'yushin (Uchenyye zap. MGU, Mekh, 1940, 39, 11 and Inzhenernyy sbornik, 1941, 1, 1), aluminum and steel have approximately the same coefficient of viscosity (about 10^5p), which lies far below the results of Table 1. Similarly, works of Sakharov, Zaydel', etc, as well as Mineyev and Savinov, disagree with the present results in the fact that in their results Al, Cu and steel all have the same viscosity value. The authors discuss these discrepancies, and express doubts as to the accuracy of the cited other experiments.

Materials	δ_0, см	δ_0, см	$V \cdot 10^{-5}$, см/сек	[illegible]	$\mu \cdot 10^{-5}$, poise	
					$y = 0,4$	$y = 0,8$
Al (Д 16)	0,4	2,0	2,5	10°30′	0,31	0,32
	0,4	3,0	3,1	14°	0,81	0,86
Cu (M 3)	0,4	1,4	1,7	21°	2,1	2,7
	0,4	2,4	4,2	14°20′	2,5	2,0
Steel (Ст. 3)	0,45	2,8	3,1	15°20′	3,9	4,1
	0,[illegible]	3,0	4,0	14°20′	4,8	4,8

Table. 1. Shock viscosity results.

Podurets, M. A., G. V. Sumakov, R. F. Trunin, L. V. Popov and B. N. Moiseyev. Compression of water by strong shock waves. ZhETF, v. 62, no. 2, 1972, 710-712.

Measurement of shock compressibility of water by absolute methods is limited to a maximum pressure of 1~2 Mbar. For higher pressures, compressibility can be found only by relative methods, based on a reliable interpolation of the impact adiabatic curve of a standard analog substance, which in case of water can be aluminum. In this article the authors use the cited method to investigate the relative compressibility of water at pressures ~14 Mbar. The measurements were obtained by successive recording of a shock wave propagating through an aluminum block of thickness $\Delta = 160$ mm and a water layer of thickness $\Delta = 80$ mm; wave velocity (D) was determined with an error < 1%. Parameters of compressibility, according to this known wave velocity, were determined by P-U diagrams (pressure - body velocity of the substance behind shock wave front). Damping of the shock wave at the interface between aluminum and water surfaces is taken into account by a small correction in the calculations. Initial parameters in aluminum are found to be $D_{Al} = 36.40$ km/sec; $U_{Al} = 25.55$ km/sec; $P_{Al} = 25.20$ Mbar, and for water they are $D = 43.95$ km/sec, $U = 32.42$ km/sec, $P = 14.25$ Mbar, and $\rho = 2.815$ g/cm^3. Errors in determining the water density are connected with the experimental inaccuracy in measuring the wave velocity in both media, and also with the uncertainty in the standard adiabatic curve for aluminum; they amount to about $\Delta\rho/\rho \approx 0.03$. Results are plotted in Fig. 1. The figure includes a curve calculated according to the quantum-statistical Thomas-Fermi model. A comparison of calculated and extrapolated experimental dynamic adiabatic curves

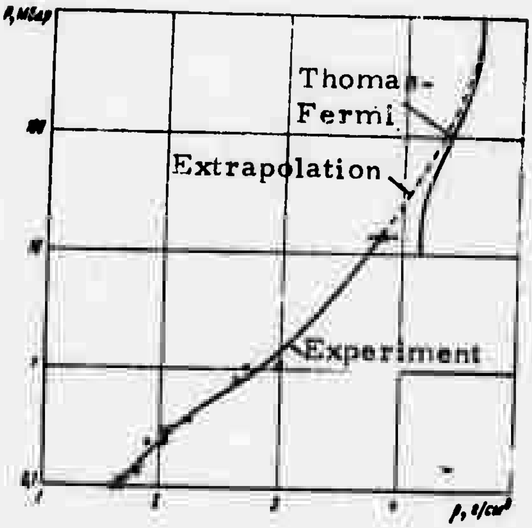


Fig. 1. Shock adiabats of water.
▲ - authors' results
o } - experimental adiabats, other authors.
•

of water shows the applicability of the Thomas-Fermi model for determining the parameters of compressibility for relatively light substances such as water in the region of very high pressures, $P \geq 400$ Mbar.

Brudnyy, V. N., V. P. Voronkov, M. A. Krivov, and S. V. Malyanov. Effect of electron radiation on gallium arsenide photodiodes. IVUZ Fiz, no. 1, 1972, 106-107.

Results are reported of an investigation on characteristics of gallium arsenide photodiodes after radiation by electrons with 1.5 MeV at 300°K. Experiments were done with diodes having a base thickness of 120, 130 and 520 microns at radiating flux densities of 0; $1.1 \times 10^{15} cm^{-2}$, $2.2 \times 10^{15} cm^{-2}$ and $3.3 \times 10^{15} cm^{-2}$. In all cases the volt-ampere, spectral, and luminescence characteristics were graphed for conditions before and after irradiation (four characteristic curves are given). Comparison of the curves shows a significant change in the characteristics of photodiodes after radiation, particularly in the forward v-a characteristic. The authors recommend taking these effects into account during operation of such devices in a radiation field.

I. A. Bogashchenko, A. V. Gurevich, R. A. Salimov, Yu. I. Eydelman. Flow of a rarefied plasma around a body. ZhETF, v. 59, no. 5, 1970, 1540-1555.

The structure of the disturbed wake behind a disc around which a rarefied plasma is flowing is studied in detail by the Langmuir probe technique. The plasma was produced in a Q-machine as shown in Fig. 1. Properties of the plasma flow are discussed. A characteristic radial distribution of quasi-neutral plasma is shown to exist, with maximal density around the system's axis. The distribution of ions in the plasma is given by

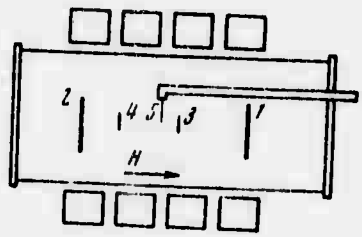


Fig. 1. Plasma generator.
1 - ionizer; 2 - anode; 3 - disc #1;
4 - disc # 2; 5 - test probe.

Maxwell's function; the anode potential is chosen so that the electron distribution in the plasma can also be given by the Maxwell function. The density, velocity and temperature in the plasma flow, surface potential and position of the disc were varied. Test measurements and their comparison with theory indicate the presence of ion acceleration in a selfconsistent electric field produced in the plasma. In the immediate vicinity behind the disc the effect of the electric field on ion motion is quite pronounced, causing a noticeable ion concentration near the axis. The plasma wake has a damped oscillatory profile; it is shown that the decrease of ionizer temperature and the increase of plasma density will increase the damping, and for $T \cong 1800^{\circ}K$ the distribution of plasma behind the body assumes an almost monotonic character. At large distances from the disc, plasma disturbance is shown to be a function of the radius only. An important role in oscillation damping is played by the deformation of the ion distribution function. The effect of ionic collisions on the ion distribution function is discussed in detail. An investigation of oscillation damping shows that the longitudinal and transverse ion temperatures gradually level out as a result of collisions. It is shown that the change of sign of the body potential relative to that of th plasma does not appreciably affect the structure of the disturbed wake behind the disc. However, a change of sign in the potential of another body located in the disturbed zone of the first body strongly affects the structure of the zone in the region between the bodies. Theoretical and experimental data are compared for the axial and radial plasma distribution in perturbed regions, and the results of the measurements are found in accordance with theory.

Shurshalov, L. V. Calculation of powerful underwater explosions. MZhiG, no. 5, 1971, 36-40.

A problem on powerful underwater explosions is solved by finite -difference equations, with the introduction of an artificial viscosity $Q = Q_1 + Q_2$, where Q_1 and Q_2 are linear and quadratic components of Q. In contrast to relatively weak explosions, a full thermodynamic description of the properties of water over a broad range of pressures, temperatures and densities is required in the present problem. A numerical solution is developed using an equation of state derived earlier by the author (MZhiG, no. 4, 1967, 184) to describe the properties of water at pressures over 1,000 atm. At a pressure below 1,000 atm, the Tait equation of state was used.

A spherical envelope ($v = 3$) containing a strongly heated compressed gas and located in an infinite space filled with water, with specific volume V_2 at a pressure p_1, served as a mathematical model of an underwater explosive charge. Motion of water and gas was calculated from the time $t = 0$, when the envelope disappears instantaneously. A set of Lagrangian equations of motion, which included the term Q, and equations of state of detonation products and water were solved by the finite-difference method. A numerical calculation using the finite-difference equations was performed for explosion of a spherical TNT charge of $\rho_0 = 1.5$ g/cm^3 at about 60 m depth. Characteristic values selected were: $p_* = 10^4$ kg/m^2, $V_* = 10^{-2}$ m^4/kg x sec^2, and $l_* = r_0$, where r_0 is the initial radius of the charge. The coefficients C_1 and C_2 in the expressions $Q_1 = C_1 a \, \Delta U/V$ and $Q_2 = C_2^2 \, \Delta U^2/V$ (where $\Delta U = U(R + \Delta R) - UR$, U, V, and R are dimensionless velocity, specific volume, and Euler coordinate respectively, and a is the local sound velocity) were assumed to be $C_1 = 0.5$ for extremely powerful or ≈ 0 for weak waves and $C_2 = 2$. The calculated hydrodynamic parameters are plotted in Fig. 1-3, where $\tau = t/t_*$, dashed lines describe variations of the shock wave parameters, and $R_1 = 1$ corresponds to the boundary of a gas bubble. The dots and circles represent the data calculated with a time step twice (dots) and one half (circles) that used in calculation of data represented by the curves. Comparative analysis shows that the calculations are satisfactorily accurate. The flow parameters were also calculated for dispersion in water of a spherical ($v = 3$), cylindrical ($v = 2$), or a plane-parallel ($v = 1$) volume of a compressed gas whose initial parameters were $P_g = 5 \times 10^5$, $V_g = 0.49$, and $U_g = 0$.

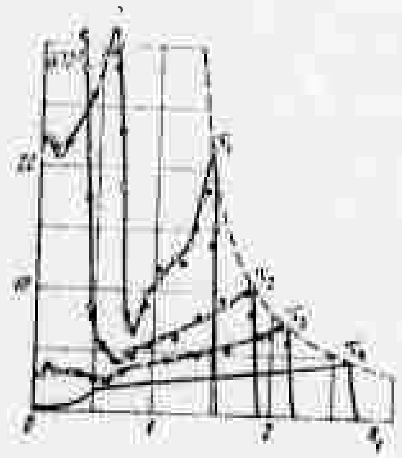


Fig. 1. Pressure versus Lagrangian coordinate R_1.

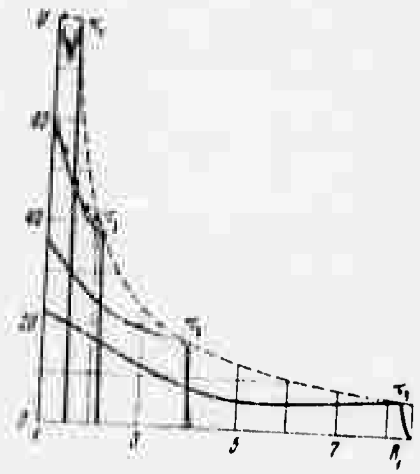


Fig. 2. Velocity versus R_1.

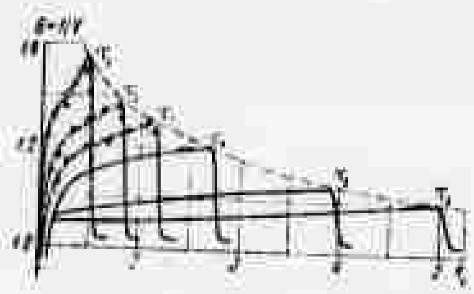


Fig. 3. Density versus R_1.

In Fig. 4, calculated pressure, velocity, and density drop at the shock wave front are plotted as continuous, dashed, and dot-dash lines.

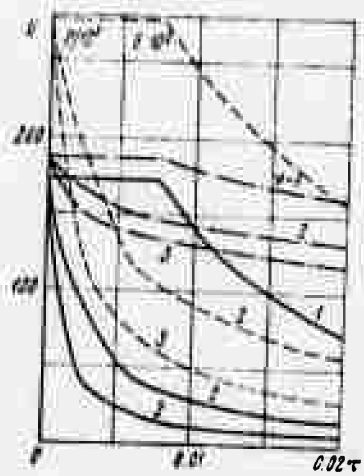


Fig. 4. Shock wave parameters in water versus time τ for v = 1, 2, and 3.

Abramova, K. B., V. P. Valitskiy, N. A. Zlatin, B. P. Peregud, and I. Ya. Pukhonto. Radiation generated by rapid deformation and rupture of metals. DAN SSSR, v. 201, no. 6, 1971, 1322-1325.

Experiments are described which were designed to test hypotheses on the magnetohydrodynamic origin of radiation emitted by rapid mechanical deformation and rupture of metals. The particular case considered was for an impact velocity $V \approx 1,000$ m/sec and in the absence of an electric field. Radiation in the 3,000 - 8,200 Å range was not reliably detected in preliminary measurements of rupture of Cu, Al, Mo, and Bi samples using an impact testing machine at V = 7 m/sec. Other tests at V up to 1,200 m/sec were done by the technique of "contactless" rupture of a sample (1) separating two cylindrical chambers (2) and (3) as shown in Fig. 1a. Pressure was maintained at 1 torr in chamber (2) and at 10^{-3} - 10^{-2} torr in chamber (3). Deformation or rupture of the rear side surface (1) which closes chamber (3) was initiated by a 15 mm dia copper impactor (4). Radiation in the 3,000 - 8,200 Å range was recorded by a photomultiplier (6) through window (7). A copper deformation rate of about 100 m/sec was determined from x-ray shadow photographs taken at regular intervals.

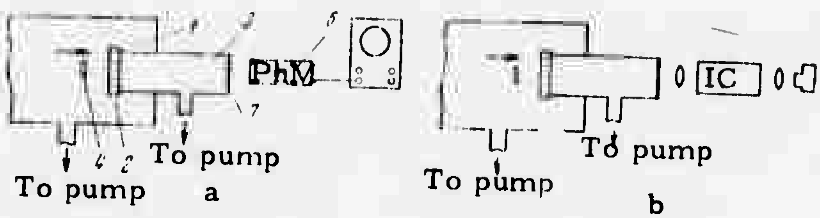


Fig. 1. Experimental configurations.

Rupture of the rear surface was accomplished in 112μsec. At a 1200 m/sec impact velocity, oscilloscope signal traces from the photomultiplier show 2-2.5 msec pulses with several characteristic peaks. Pulse intensity from a ruptured copper surface was 3-8 times that from a deformed surface without any visible rupture. The radiation pulses were recorded with 27 and 33 mm thick samples. In one control experiment, a 50 mm thick sample was not deformed and no radiation was detected. A special control experiment was set up involving exclusion of triboluminescence of the oxide film. In this experiment, a supposedly oxide-free copper surface formed on the rear face of a 27 mm thick sample by a previous impact was reimpacted 2-3 min after the first impact. A light pulse of the same intensity, but shorter than the first one, was recorded in this experiment. In both experiments, radiation from collision or friction of the sample with the small chamber walls did not interfere with the recordings, because the colliding and friction parts were shielded from the photomultiplier. Residual gas interference in the shock wave front was also excluded, since a shock wave could not develop at subsonic deformation velocities. No trace of crack edge melting was detected on the photographs, indicating that thermal radiation was recorded. Analogous results were obtained in experiments with duralumin. Final proof of radiation emission from the part of the sample in the process of deformation and rupture was obtained by photographing the self-radiation of a luminescent crack in copper using an image converter (Fig. 1b). The radiation contour in the photograph coincides closely with the crack contour.

It is concluded that the experimentally observed radiation is emitted by deformation and rupture of the metal. This radiation exhibits the principal characteristics of luminescence, i.e. it exceeds thermal radiation at a given temperature, and its lifetime exceeds significantly the period of a light wave.

Vakatov, V. P., A. B. Karasev, V. P. Malyavin, and B. K. Tkachenko. Studies on an electrical discharge shock tube. ZhPS, v. 15, no. 6, 1971, 989-992.

A diaphragm type electrically discharged shock tube is described and various data on its operation are discussed. The configuration (Fig. 1)

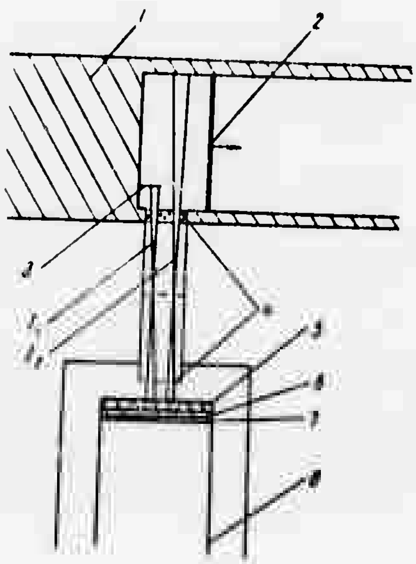


Fig. 1. Discharge tube.
1 - main tube; 2 - reflected shock wave; 3 - knife edge; 4 - diaphragms; 5,6 - optical filters; 7,8 - phototube.

was a 4m x 50 mm dia main tube and a 30 x 200 mm discharge chamber, lined with a variety of isolating materials. Temperatures in the discharge chamber following diaphragm rupture were registered in the 10--20,000°K range, and gas pressure (He) up to 600 bar from an initial 5--20 bar level. Data include the loss rate of the insulating liner as a function of discharge parameters; rates for vinyl and textolite liners were found to vary monotonically with discharge intensity, for example. Graphical results are also given for shock wave velocity and liner loss rate for tests in which water and teflon were the insulators; spectral analyses of the plasma emission were also made. The technique is concluded to be a useful one for shock excitation of gases in the 10--20,000°K range.

Simonov, V. A. On processes originating during the falling of an impact wave on a tapered cavity. FGiV, no. 2, 1971, 280-284.

Results are described of experimental investigations on processes arising from an impact wave of subsonic velocity on the tip of a tapered cavity in metals, and a study is made of the stability of the flat cumulation jet which is produced. Experiments were conducted with aluminum, copper and steel, the arrangement for which is shown in Fig. 1. The cylindrical explosive charge of diameter 40 cm and height 10-15 mm consisted of type TG 50/50 compound. Detonation of the charge was synchronized with photographic instruments to obtain a true picture of the detonation processes; the range of angle γ(Fig. 1) was varied from 0.5° to 32°.

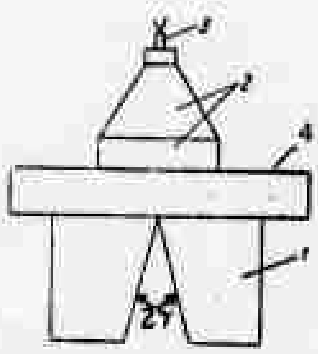


Fig. 1. Experimental sketch.
1 - metallic specimen; 2 - explosive charge with flat wave regenerator; 3 - detonator;
4 - metallic plate of given thickness.

Experiments with aluminum specimens showed that a flat cumulation metallic jet was formed during the normal interaction of the impact wave on a tapered cavity with an angle $2\gamma = 30°$. With decrease of γ, jet formation disappears, that is, a regime of collapsing without jet formation occurs, characterized by a periodic deformation very similar to wave formation during explosion welding. The length of this wave was found to vary with change in angle γ. At $\gamma = 1.5°$, wavelength λ was 1.5 mm; at $\gamma = 6.5°$, $\lambda = 5.5$ mm. In the range $\gamma \approx 6° \sim 8°$, both wave and jet regimes were found to exist simultaneously. At $\gamma \geq 8°$, only the jet regime existed, and at $\gamma = 15°$, this jet was capable of piercing through a duralumin plate of 10 mm thickness.

A series of experiments with copper samples showed a very similar process to that with Al, and the transition of wave regime to jet regime was noted between the same interval of angles $\gamma = 6^{o} \sim 8^{o}$. The wavelength of a Cu sample with respect to γ is given below. Increasing γ from 2^{o} to 5^{o} increases

γ°	2	4	5	5.5	6	7
λ, мм	1	2	2.5	3	3.5	3.5

wavelength from 1 to 3.5 mm; however a further increase in angle does not increase the wavelength. It is noted that geometrical dissymmetry does not affect the angle of transition from wave to jet formation, and that the jet formed is always directed along the bisector of angle 2γ (Fig. 1).

Similar experiments with steel samples showed that transition of wave to jet regime takes place at an interval between angles $\gamma = 4^{o} \sim 5^{o}$.

Experiments were also conducted with samples of different materials, but having a like geometry. The angle of transition from wave to jet regime was noted to increase very significantly. When one cube was titanium and the other copper, the jet regime was noted only at angles $\gamma > 20^{o}$; and the jet was inclined from the symmetrical axis towards the metal having a heavier density, in this case copper.

The author makes a comparison of his results with those of Walsh et al, (Mekhanika. Sbornik perevodov, vyp. 2(24), 1954), but they do not seem to be in good agreement. In Walsh et al, angles of transition from wave to jet formation for steel and Al were found to be $2\gamma = 30^{o}$ and $2\gamma = 34^{o}$, respectively, taking into consideration the effects of incoming flow U_o. In the present article, U_o is neglected, as it depends very little on angle γ. ($U_o = \frac{D - U}{\cos \gamma}$, where D - velocity of impact wave in sample, U - body velocity of particles). According to Walsh et al, impact of solid bodies without jet formation has been proven possible, and it was established that jet formation cannot take place in presence of two impact waves at the point of contact. In the present article, the author points out that a stationary impact wave cannot exist at the point of contact at any angle γ, as the falling impact wave is at subsonic speed, so that the jet formation automatically occurs. However, in spite of the above discrepancies, the author still agrees with the possibility of the process occurring without jet formation, but with generation of deformations in the form of waves on the collapsing surface. He points out that in such a case, for explaining the phenomenon of transition from jet to wave regime, it is necessary to take into account other criteria related to the model of an ideal fluid.

Kozlov, V. I., and Yu. G. Shafer. On a possible mechanism for the localization of fission products from a high-altitude nuclear explosion. Kosmicheskiye issledovaniya, no. 4, 1971, 630-631.

Recorded particle data on the Cosmos 3, 5 and 6 satellites following the U. S. Starfish high-altitude detonation in July, 1962 showed a concentration of fission products at the conjugate point to Johnson Island. This concentration was detected at high altitudes and persisted for an appreciable length of time. In the present paper the authors use the Starfish results for a model with which they analyze the type of trapped particles, their transport characteristics, and the geometry of the trap region at the conjugate point.

A magnetic-gravitational trap is postulated in the conjugate point region which will act as a potential well for the heavier charged particles. At some radial distance r_0 from earth center the combination of gravity and repulsion potentials will have a minimum, which determines the depth of the potential well; in the proposed model this is shown to be $E_{\perp} = m g r/3$, where m = ion mass. Assuming particles with atomic weight of 100 and an altitude of 400 km, we find that $E_{\perp} \cong 30$ ev, i.e., the portion of the dispersing cloud of fission products having energies on the order of 30 ev will be trapped at the 400 km level. This level is consistent with the values obtained by Neff et al [1] and Golgate [2] at the conjugate point.

The arrival time of the major portion of charged particles is generally a function of plasma dispersion in the geomagnetic disruption at the detonation point; Askar'yan [3] gives the velocity as on the order of 10^7 cm/sec for the Starfish test, which for a force line length of about 4×10^8 cm yields an arrival time of 40 seconds.

The authors next examine the factors determining the duration of the trap region. As the analysis shows, the size of the well is a direct function of particle charge, hence the well assumes a "funnel" configuration according to trapped charge level. The confinement time is given approximately by

$$\tau_c = 0.785 \times \bar{\tau}_i \ln \frac{B_{max}}{B} ,$$

where $\bar{\tau}_i$ is mean ion relaxation time and B is magnetic inductance, on the assumption that the main loss mechanism is coulomb scattering in the funnel region.

If a Maxwellian temperature distribution of atmospheric ions is assumed, then a numerical solution for τ_c under the assumed atomic weight and ionization level falls in the range of 10^2--10^5 sec in the 250--1000 km altitude range. This suggests that the cone region is sustained by continuous replenishment of particles from the upper energy regions.

Finally, it is concluded that dissipation of the funnel region owing to drift of trapped particles is negligible (0.2 - 0.5 deg/day), which was corroborated by experimental evidence that the trap region acted as a compact β and γ radiation source for a substantial period.

References

1) Nef, C. G. et al. Operatsiya "Morskaya zvezda". Atomizdat, 1964, 109.
2) Golgate, S. A. J. Geophys. Res., v. 70, no. 13, 1965, 3161.
3) Askar'yan, G. A., and M. S. Rabinovich. ZhETF, v. 48, no. 1, 1965.

Shafer, Yu. G., V. I. Kozlov, I. S. Kiriyenko, A. D. Bolyunova, R. B. Salimzibarov, and S. M. Oshchepkov. Measurements of radiation effects of the thermonuclear explosion in China, December 27, 1968, by the Cosmos-259 and Cosmos-262 artificial satellites. Kosmicheskiye issledovaniya, no. 4, 1971, 558-564.

This paper is the first extensive analysis to appear of Soviet recordings of explosion products from the Chinese nuclear explosion in December, 1968. At the time of the explosion two Cosmos satellites were in orbit and carrying several types of radiation monitoring equipment: Cosmos-259 (apogee 1353, perigee 219 km), and Cosmos-262 (apogee 818, perigee 263 km). The orbital planes of both were inclined at 49° to the equatorial plane. The Cosmos-259 recording equipment included triple-coincidence panoramic telescopes featuring type STS-5 gas discharge counters (identified as the STS channel), and an unshielded STS-5 counter, identified as the SSVS channel, mounted on the end of a 2 meter boom. The panoramic system recorded only charged particles, protons with $E > 190$ MeV and electrons > 12.5 MeV; the single SSVS counter was intended for protons ≥ 10 MeV and electrons ≥ 50 KeV; it could also register photons, but at an efficiency not above 1%. The 262 carried an intensity array consisting of four STS-5 gas discharge counters connected in parallel and shielded by 3m Al and 3 mm Pb screens.

This equipment was used to transmit real-time data on radiation intensity levels from orbital regions over the USSR, Mongolia and China, around the time of the detonation. For the purpose of illustration the authors have chosen the intensity data from orbits lying below the regions of stable capture of near-earth radiation. This data is presented graphically according to satellite trajectory as shown in Figs. 1-3, giving increase in count rate N over that of a "quiet" day, i.e., December 18 and 19, 1968.

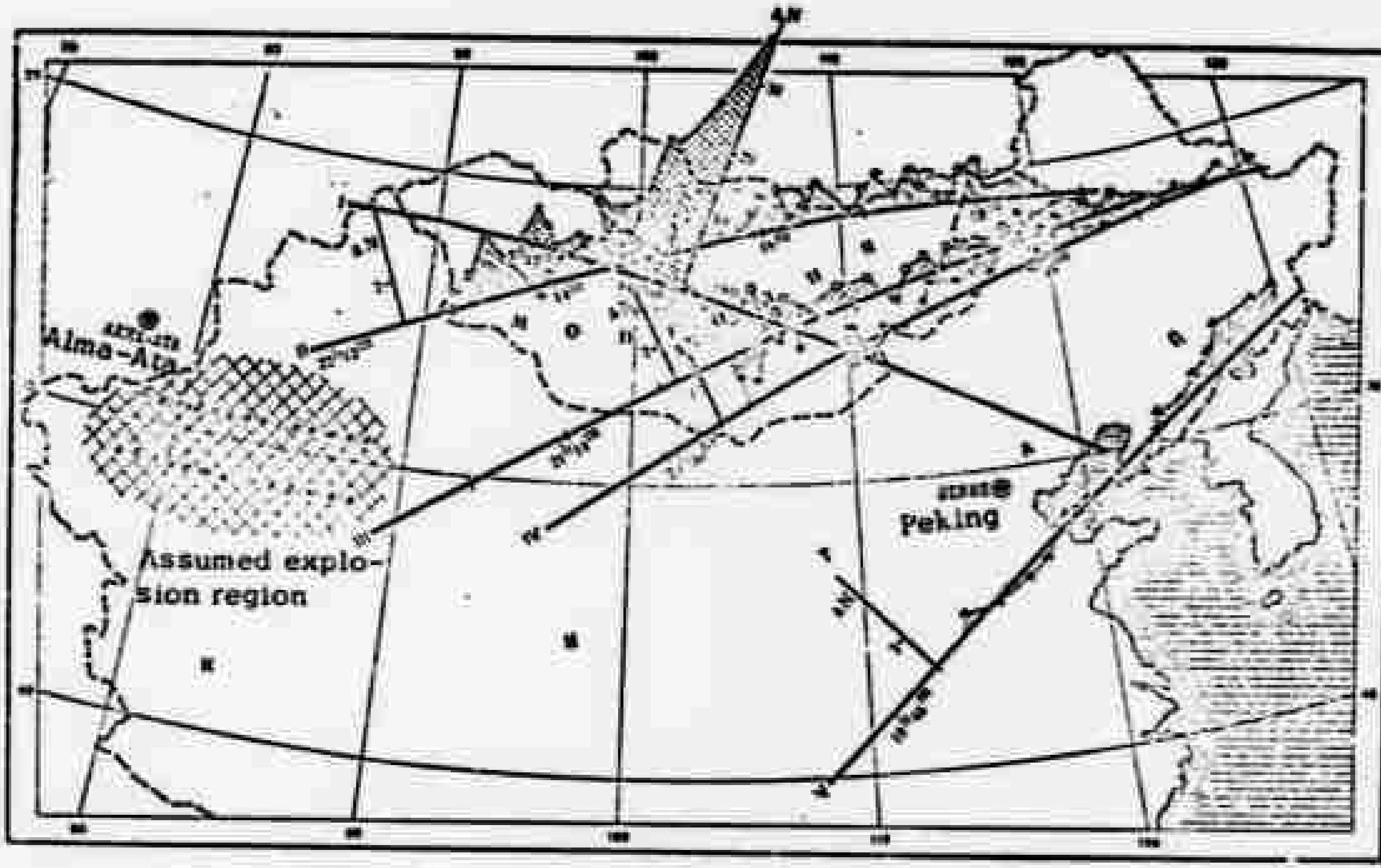
The data show that the shielded single counter (SSC) in the Cosmos-259 recorded during two minutes an ~80% increased intensity in its 196th orbit, i.e., about 10 hours after the explosion; this recording was made at an altitude of about 700 km over the Mongolian Peoples Republic in an area whose coordinates were 43-45°N. Lat. (geographic) and 100-110°E. Long. The counting rate of the triple-coincidence telescope increased at the same time. Twenty-four hours after the explosion, over approximately the same territory in the 209th and 210th orbits above the eastern territory of China, the satellites noted an increase of intensity $(\Delta N/N)_{SSC}$ = 20 and 60%, $(\Delta N/N)_{STS}$ = 50 and 40%, respectively. In the 211th orbit, the counting rate increments of the single shielded counter reached 1.5-2 pulses per second, which amounts to 30-40% over background.

On December 27 in the 196th orbit, beginning with 2113-2117 hours, the external SSVS counter rates increased by a factor of 2-8; a maximal increase by a factor of 10 was noted at 2115 hours 30 seconds. Subsequently the count rate began to fall off and at 2118 hours only background oscillation was recorded. In the 197th orbit, the count rate increased by a factor of 2-2.5. On December 28 in the 209th orbit, the satellite recorded only the cosmic ray background while in the 210th orbit, whose trajectory is near the 196th orbit, in a real-time transmission regime, the count rate increased by a factor of 1.5-2. The maximum "excess" of the count rate in the 211th orbit, whose trajectory almost coincided with the 197th orbit, reached 100%.

Analogous results are reported for the Cosmos-262 count rate, e.g., 262's counters registered a doubled intensity 23 hours after the explosion; the recording was also made over the Mongolian Peoples Republic in an area whose coordinates were 48-47°N. Lat. and 95-105°E. Long., at an altitude of 270 km.

It is noteworthy that no increase in radiation intensity was recorded when the Cosmos-259 satellite passed in its 209th orbit over the magnetic conjugate of the Chinese explosion point, which is to be expected in low altitude explosions. Consequently, there was no direct ejection of explosion products into the force tube. A further theoretical analysis is given to define the absorption mechanism taking place in the vicinity of the detonation point; the fact that neither Cosmos satellite intercepted fission fragments is taken as evidence of strong atmospheric absorption, and on this basis it is concluded that detonation occurred at not over 20 km altitude.

The level of protons above 190 MeV registered by the STS counters suggests that there may have been some release of them from the radiation belts owing to the disturbing effect of the Chinese detonation. Using calculations from the U. S. Starfish test, the authors verify this mechanism as a possible additional result of the test.



<u>Fig. 1</u>. **Variation of radiation intensity from the Chinese thermonuclear explosion according to data of the single shielded counter (SSC).** I -- 29th orbit, 12-28-1968, Kosmos-262; II -- 211th orbit, 12-18-1968, Kosmos-259; III -- 196th orbit, 12-27-1968, Kosmos-259; IV -- 210th orbit, 12-28-1968, Kosmos-259; V -- 209th orbit, 12-28-1968, Kosmos-259.

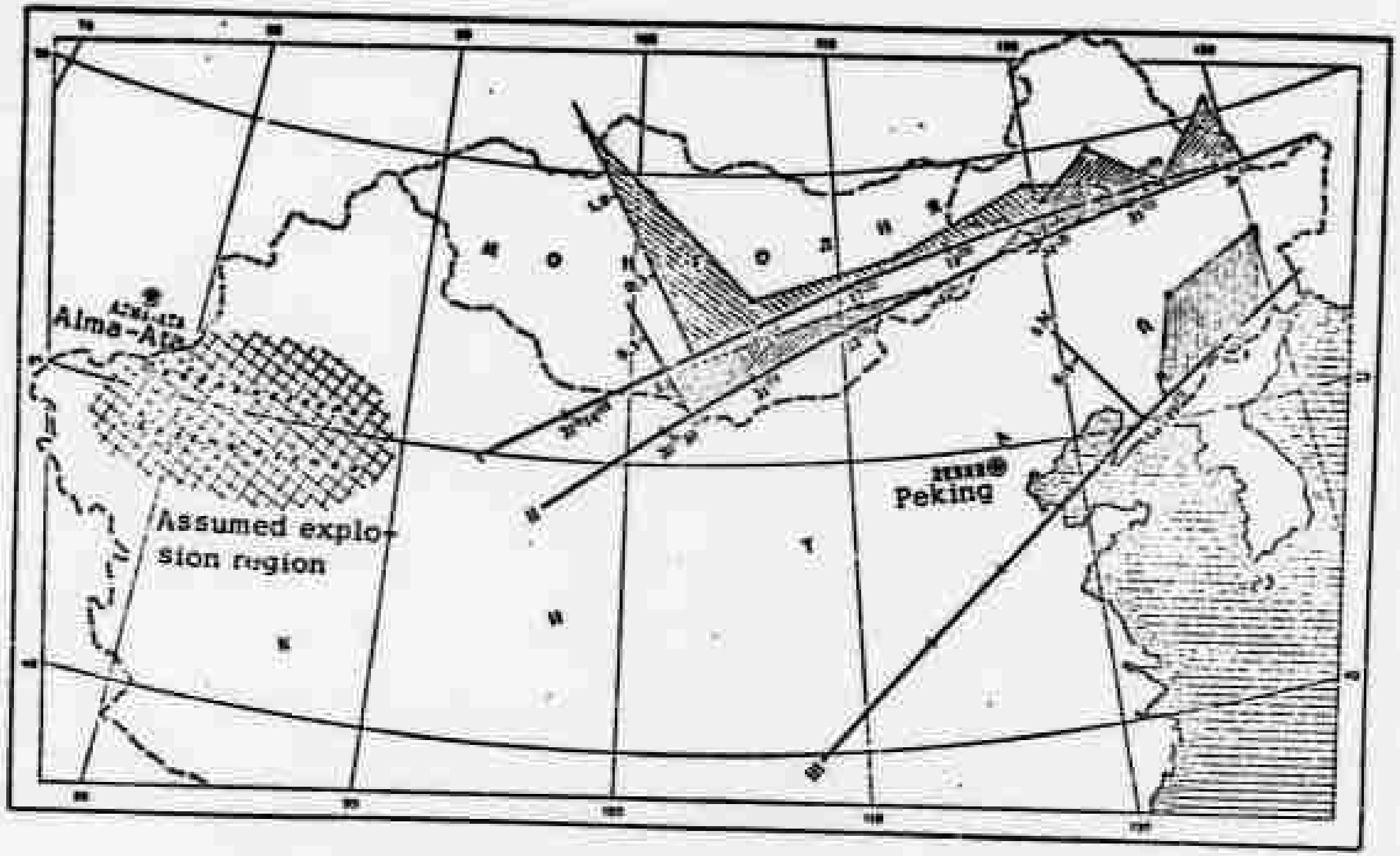


Fig. 2. Variation of radiation intensity from the Chinese thermonuclear explosion according to data from the panoramic triple-coincidence telescopes (STS) on board Kosmos-259. I -- 196th orbit, 12-27-1968; II -- 210th orbit, 12-28-1968; III - 209th orbit, 12-28-1968.

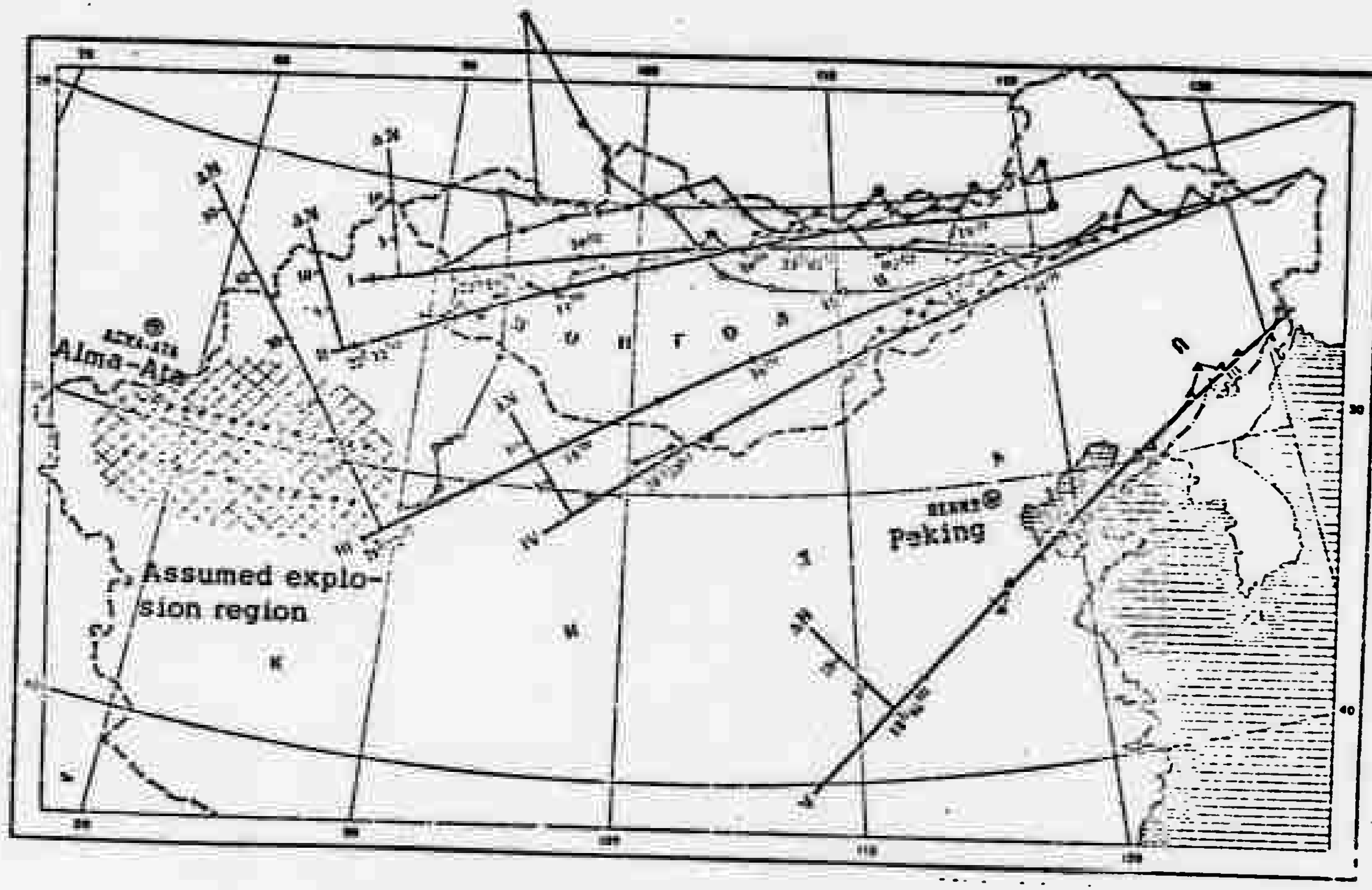


Fig. 3. Variation of radiation intensity from the Chinese thermonuclear explosion according to data from the SSVS external counter on board Kosmos-259. I -- 197th orbit, 12-27-1968; II -- 211th orbit, 12-28-1968; III -- 196th orbit, 12-27-1968; IV -- 210th orbit, 12-28-1968; V -- 209th orbit, 12-18-1968.

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The author proposes possible mechanisms for increasing (or decreasing) electron density in a localized region of the ionosphere by means of a powerful r-f beam, and shows the considerable effect that such a beam may have on the nonuniform composition of the affected region. The analysis gives examples of the effects obtainable in terms of the D, E and F layers.

As is known, raising the electron temperature in a plasma may result in a drop in electron density N owing to ejection of plasma from the heated region, or alternatively N may increase owing to an upset of the ion recombination balance. In the first case N is established over a time $t_D \sim r_0^2/D_i$, where r_o is the distance over which the excitation wave amplitude changes significantly [sic], and D_i is the ion diffusion coefficient. In the second case, N is determined by the lifetime of a free electron, $t_e \sim (\alpha' N_0)^{-1}$, where α' is the effective coefficient of electron recombination and N_o = original unexcited density.

Therefore, for $t_D < t_e$ the plasma ejection process is dominant, e.g. for the upper portion of the F-layer, where

$$N \approx N[1 + (E(r)/E_p)]^{-1}, \qquad (1)$$

in which E = amplitude of the excitation wave and E_p = plasma field, as defined by Gurevich [1]. Conversely, when $t_e < t_D$ the recombination process dominates, as in the lower ionosphere where

$$N \approx N[1 + (E(r)/E_p)^2]^{3/4}. \qquad (2)$$

Using standard parameters for the F-layer and assuming $r_o < 300$ km, Alimov shows that Eq. (1) applies; for the E-layer at $r_o > 0.1$--1 km, Eq. (2) would apply. In the latter case it must be emphasized that (2) is valid only for a concrete relation of α' to electron temperature T_e. This applies in the E-layer, but at present it is not possible to assert a definite α' (T_e) for the D-layer.

A brief consideration of the effect of ionospheric drift on excitation lifetime shows that drift effect is negligible on the steady-state component of the excited region, providing the excitation rate is sufficiently larger than normal decay. This is the case, for example, in the E- and F-layers for $r_o > 7$ km.

Besides changing the gross level of N in the foregoing manner, the r-f excitation also affects the fluctuating component. Thus in the E-layer the mean square fluctuation in electron density will increase by

$$\overline{(\Delta N)^2} = \overline{(\Delta N_0)^2}[1 + (E(r)/E_p)^2]^2 , \qquad (3)$$

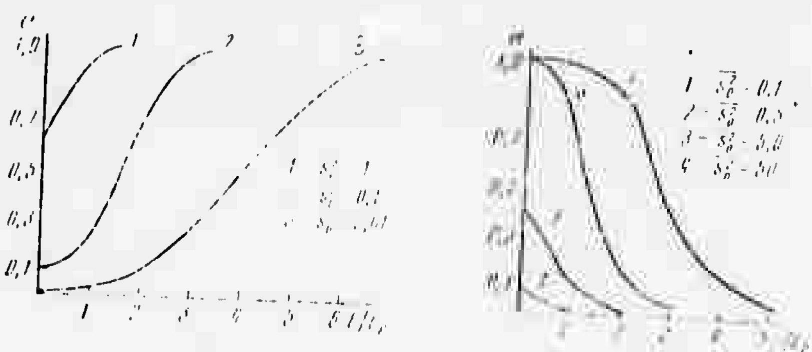
and in the F-layer will decrease by

$$\overline{(\Delta N)^2} = \overline{(\Delta N_0)^2}[1 + (E(r)/E_p)^2]^{-2}. \qquad (4)$$

The turbidity of the excited region is then shown to be a function of r-f field, where turbidity factor α is given by

$$\alpha = \frac{P_s}{P_0} = 1 - \exp(-\overline{S}^2). \qquad (5)$$

in which P_0 is incident energy, P_s is scattered energy, and $\overline{S}^2$ is mean square phase fluctuation in the layer. Using an earlier notation[2] for transmission of r-f through the layer, namely $\overline{S}^2 = \overline{S}_0^2 \; \overline{(\Delta N)^2}/\overline{(\Delta N)_0^2}$, the author obtains graphical solutions from (3), (4) and (5), showing the effect of applied field on turbidity. These are given in Fig. 1 for the E- and F-layers respectively, and show the considerable effect of incident r-f field. This appears particularly



(a) (b)

Fig. 1. Turbidity factor variation with applied field for E-layer (a) and F-layer (b).

significant for the F-layer, since there the turbidity effect is sharply reduced at sufficient transmitted power, tending to nullify the disturbance effect.

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3. Geosciences

A. Abstracts

Lukk, A. A. Seismic-wave attenuation in the focal region of deep-seated Pamir-Hindu Kush earthquakes. IN: AN SSSR. Institut fiziki Zemli. Eksperimental'naya seysmologiya (Experimental seismology). Moskva, Izd-vo Nauka, 1971, 87-97.

It is hypothesized that the elastic properties of the medium within the hypocentral region of Hindu Kush earthquakes differ from those within the surrounding region.

The attenuation of the maximum amplitude of compressional and shear waves for both regions has been studied.

Observational data on 200 deep focus Hindu Kush earthquakes (energy class K = 10-15, recorded in 1965-1966 by 25 seismograph stations) were analyzed. Six of the 25 stations were located in the epicentral region, and recordings were made with a standard system consisting of an SKM-3 seismograph having a natural oscillation period of 1.5 - 2.0 sec and a GB-IV galvanometer with a natural frequency of 5 - 7 Hz. The pass band of the system corresponds to the period range 0.05 - 1 and 5 - 20 sec, with average magnification of 40-50000.

Amplitude distance curves (maximum amplitude and epicentral distance) for seven groups of earthquakes with focal depths H = 50, 70 - 90, 100 - 120, 130 - 160, 170 - 180, 200 - 220, 230 - 270 km were derived. A large dispersion of amplitudes (0.7 - 0.8) in the epicentral distance ranges was found. The amplitude distance curves consist of two branches (one lower and steeper for short distances and another for long epicentral distances) which correspond to hypocentral and surrounding regions. This characteristic was explained as being due to considerably stronger attenuation of seismic waves in the hypocentral rather than in the surrounding regions. In order to verify this conclusion, the amplitude distance curves for seismic waves recorded by three seismograph stations located in the epicentral region were constructed. The average curves obtained are very similar to the first branch of the original amplitude distance curves.

Variation of the spectra of elastic oscillations with epicentral distance and depth of source have been considered in order to study the effect of high absorption of seismic energy in the hypocentral region. It was found that the high frequency components disappear proportionally with the wave propagation path through the hypocentral region and the deepening of the source.

Another verification of the hypothesis was provided by the analysis of data on 20 distant earthquakes with different epicentral azimuths (the Alaska, Japan, Indonesia, Mediterranean Sea epicentral regions), and all earthquakes were normalized by energy.

It is concluded that the Pamir-Hindu Kush hypocentral region creates a "shadow" effect. If the seismic wave propagation path crosses the hypocentral region, a decrease in its amplitude by a factor of 2.5 occurs.

An evaluation of the magnitude of attenuation of maximum amplitude of elastic oscillations in hypocentral regions has been made. This attenuation is expressed in the form $A = A_0(r_0/r)^{n'}$, where A is the amplitude of dislocation of hypocentral distance r, A_0 is the amplitude of dislocation at the boundary of the focus, n' is the attenuation factor. The dependence of factor n' on focal depth as well as epicentral distance was evaluated. It was found that n' varies with depth, reaching its maximum at 80 - 150 km, where $n'_p = 2.9 \pm 0.1$ and $n'_s = 2.6 \pm 0.2$ and its minimum at depths exceeding 150 km, where $n'_p = 2.2 \pm 0.1$ and $n'_s = 1.7 \pm 0.1$. It is noted that n'_s does not vary with epicentral distances, i.e., $n'_s = 2.9 \pm 0.2$, while $n'_p = 3.2 \pm 0.2$ for a 50-80 km source depth and $n'_p = 3,6 \pm 0.2$ for a 150-250 km source depth across a hypocentral region.

Separate evaluation of attenuation due to absorption of seismic energy has been accomplished from the formula $A = A_0(r_0/r)^n e^{-\alpha r}$, where α is the absorption coefficient. Assuming n = 1, it was found that in the interval 50-250 km, the attenuation coefficients for compressional and shear waves are $\alpha_p \approx 0.010 \pm 0.002\ km^{-1}$ and $\alpha_s \approx 0.0060 \pm 0.0005\ km^{-1}$. It is suggested that the effect of anomalous attenuation of elastic waves in the hypocentral region of deep earthquakes could be characteristic of a region of high seismicity in the Earth's crust and upper mantle, and that this effect could be one of the criteria for correlating the seismicity of different regions.

Vasil'yev, Yu. F. Experimental study of the mechanism of the shear process. IN: AN SSSR. Institut fiziki Zemli. Eksperimental'naya seysmologiya (Experimental seismology). Moskva, Izd-vo Nauka, 1971, 346-359.

A study of forces acting at the focus of earthquakes has been accomplished using a seismic model analogous to a seismic fracture. The mechanism of the faulting (dislocation) process was observed directly at the fracture. The two-dimensional model was made with a 3-mm-thick plexiglass plate 115 x 132 cm. At the midpoint of the longer side of the plate there was a slot 50 mm wide and 37 cm deep which represented one side of seismic fracture. Individual 40 x 3-mm plates of different material (called blocks) representing the other side of the fracture were placed into the slot and exposed to the normal F_n and tangetial F_t forces. In Figure 1 a schematic diagram of the model and the positions of the observation points are shown.

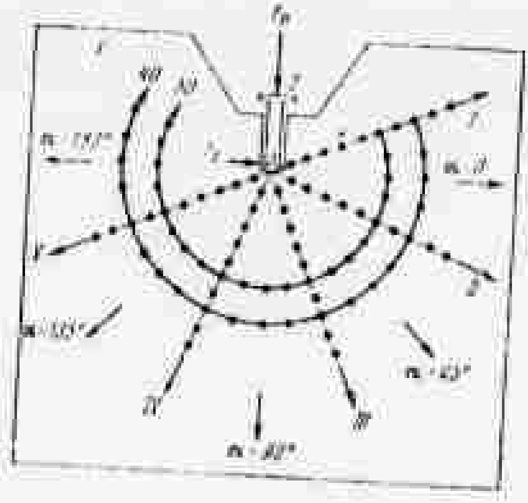

Fig. 1. Schematic of the seismic fracture model. 1 - homogeneous two-dimensional medium; 2 - moving block; 3 - fracture; 4 - observation points; I-V - radial profiles; 30 & 40 - circular profiles; F_n, Ft - normal and tangential forces.

Measurements were performed with a specially designed unit which provided simultaneous observations of wave processes at 5 points in the 2-300 kHz frequency range, as well as the parameter for the force condition at the focus. The experimental technique used to study the radiation pattern and mechanism of faulting are described.

An analysis of the characteristics of the radiation pattern (see Fig. 2) was performed by comparing it with a point source pattern. It is shown that the source yielding the best agreement with model results is a superposition of a double dipole without moment and a concentrated (point) force.

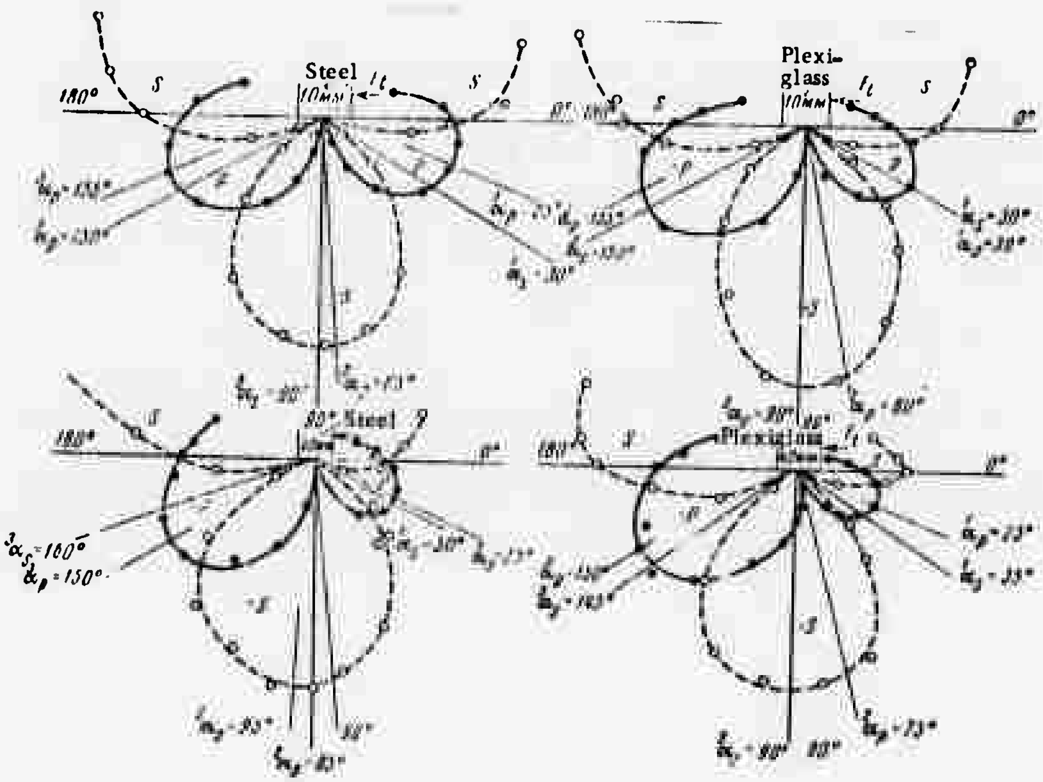

Fig. 2. Radiation patterns for P and S waves in the faulting of steel (a) and plexiglass (b) blocks along contacts 10 and 40 mm long.

The dependence of the radiation of the above-mentioned source on azimuth can be expressed in the form $A_p = \sin 2\alpha + n_p \sin(\alpha + \beta)$ and $A_s = \cos 2\alpha + n_s \cos(\alpha + \beta)$, where n_p and n_s are the ratios of maximum amplitudes of radiation of P and S waves from different simple sources. From the experimental data it was found that $n_p \cong n_s$, with n ranging from 0.05 to 0.53.

The faulting mechanism for blocks along the fracture is analyzed and the propagation velocities of the first motion along the fracture and the magnitude of total dislocation are evaluated.

The ratio of seismic-wave energy and energy released at the focus has been calculated. It was found that the P and S wave energy amounts approximately to 0.12% of the total energy in the focus, released by the rupture and displacement of the block.

Sedova, Ye. N. Study of discontinuities in the crust and upper mantle, based on the dynamic characteristics of distant earthquakes. IN: AN SSSR. Institut fiziki Zemli. Eksperimental'naya seysmologiya (Experimental seismology). Moskva, Izd-vo Nauka, 1971, 97-107.

Discontinuities in the Earth's crust and upper mantle beneath northern Tien Shan have been located using the dynamic characteristics of seismic waves generated by distant earthquakes. These discontinuities are defined as zones of anomalous attenuation of seismic wave energy having a shadow effect on seismic waves arriving from certain azimuthal directions.

Observational data on 89 distant earthquakes ($M \geq 5.75$, epicentral distances $\Delta = 5000 - 10,000$ km, normal focal depths) recorded by northern Tien Shan seismographic stations from 1962 to 1966 have been analyzed. A composite amplitude/epicentral azimuth curve $A(\varphi)$ which is characteristic for the entire region was constructed. Individual amplitude/azimuth curves were constructed for each station from observed maximum amplitudes normalized by average earthquake magnitude $m = 6.7$ and epicentral distance 6500 km and local conditions at the station.

Each individual curve was compared with the average and zones of anomalous attenuation of seismic energy were identified. On the basis of the geometry of seismic rays, discontinuities were identified in the 20--200 km depth range. This was based on the following assumptions: discontinuities no smaller than the central Fresnel zone, located on the path of seismic rays, affect them the most; the velocity of compressional waves in the 50 km thick crust is 6.0 m/sec, in the upper mantle, 8.0 km/sec; angles of emergence are 23° and 28° at the observation station and the M discontinuity, respectively. The discontinuities are determined in terms of minimum cross section at different depths (60, 100, 200 km) for each observation station.

Sections along four profiles with delineated discontinuities are shown in Figure 1.

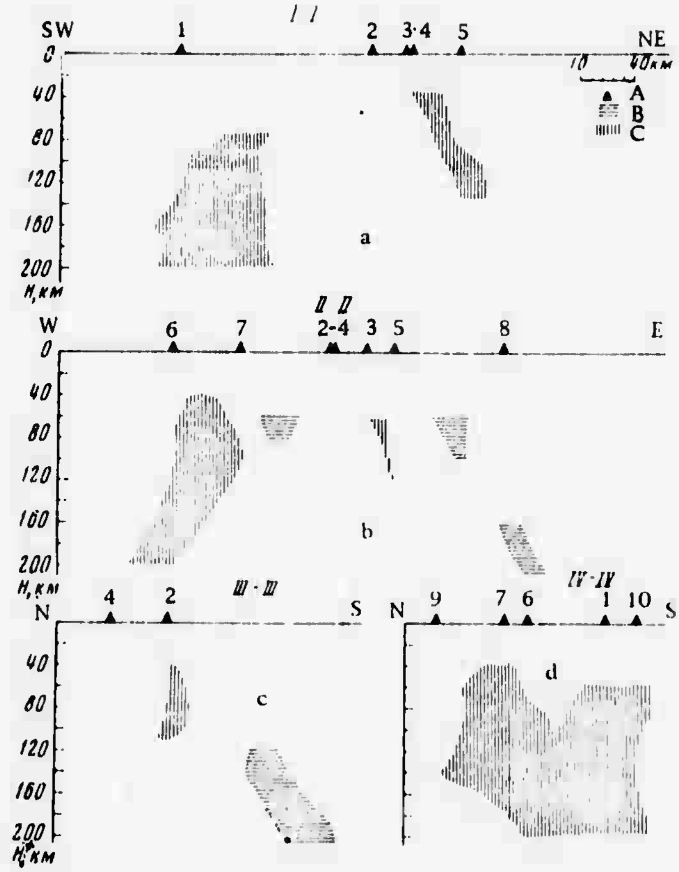

Fig. 1. Vertical sections through regions of anomalous attenuation.

A - Stations; B - high attenuation; C - low attenuation
1 - Boamskoye Pass; 2 - Kurmenty; 3 - Orto-Merke;
4 - Chilik; 5 - Charyn; 6 - Fabrichnaya; 7 - Talgar;
8 - "E" (sic - unspecified station, probably Narynkol);
9 - Ili; 10 - Rybach'ye. Roman numerals indicate individual profiles.

Zones at low and high absorption were compared with macroseismic data on the 1887 Vernen, the 1911 Kemin, and the 1889 Chilik earthquakes. It was found that pleistoseists for the three earthquakes coincide with the deduced zones of low attenuation. It was concluded that regions of anomalous attenuation in the Earth's crust and upper mantle extend up to the diurnal surface.

The above results were compared with the results of the study of nearby earthquakes (Antonova L. V. Study of the field of dynamic characteristics of ground motion. Eksperimental'naya seysmologiya, 1971, 107-112) in the same region. It was found that the results obtained from the distant earthquake study are confirmed by the results of the study of nearby earthquakes. It is concluded that possibilities exist for the detection of zones of anomalous attenuation of seismic waves, based on the amplitude characteristics of distant earthquakes.

Antonova, L. V. Study of the field of the dynamic characteristics of ground motion. IN: AN SSSR. Institut fiziki Zemli. Eksperimental'naya seysmologiya (Experimental seismology), Moskva, Izd-vo Nauka, 1971, 107-112.

It has been assumed that the dynamic characteristics of seismic waves can be a criterion for determining inhomogeneities of the Earth's crust and upper mantle. The dynamic characteristics of compressional P_g and shear L_g waves generated in the Earth's crust and compressional P_n and shear S_n waves generated in the upper mantle have been considered. In the study, 40 seismograms of nearby earthquakes (K = 9.7 - 14, epicentral distances 250 - 1000 km) recorded at 12 seismograph stations located in the northern Tien Shan region are analyzed, and the foci of the earthquakes were in the crust in northern Tien Shan and its adjacent regions.

Amplitude distance curves for individual seismograph stations, previously normalized by energy level (reduced to K = 11), were used for constructing composite curves for P_g, L_g, P_n, S_n waves corresponding to the entire northern Tien Shan region. In the same manner, amplitude distance curves corresponding to the southwestern, southern, northeastern, north-northeastern and northern groups of earthquake foci have been constructed and analyzed. The deviation in amplitude between the individual and average values (1.0 - 1.5, 0.5, 0.2 for P_n, P_g, and S_n waves, respectively), obviously associated with structural features of the Earth's crust and upper mantle, has been noted. It was found that, for the northern Tien Shan region, dynamic characteristics are influenced mainly by the relief of the Mohorovicic discontinuity and upper mantle structure, rather than by crustal structure.

In order to study structural features of the medium near the seismographic station, the field of dynamic characteristics was analyzed. It was found to be inhomogeneous for all seismic waves. It is concluded that the possibilities of using dynamic characteristics for the study of structural inhomogeneities of the Earth's crust and upper mantle is justified.

Artem'yev, M. Ye. The relationship of the disruption of isostatic equilibrium to seismicity. IN: AN SSSR. Institut fiziki Zemli. Eksperimental 'naya seysmologiya (Experimental seismology). Moskva, Izd-vo Nauka, 1971, 322-333.

It has been shown that isostatic equilibrium, after discontinuance of the action of causitive forces, is reestablished almost instantly in a geologic time scale. Thus, the numerous disturbances of isostatic equilibrium observed on the Earth's surface give evidence of the strong forces acting in recent times in the Earth's interior. The relationship of gravitational isostatic anomalies and seismicity is discussed, and it was found that disturbances of isostatic equilibrium are an indicator of tectonic activity. There exist some uniformities in the distribution of isostatic anomalies and the distribution of earthquake foci. It is suggested that data on isostasy can be used as a criterion in the determination of earthquake origin, as well as in seismotectonic zoning.

Pavlov, V. D. Dynamics of ground motion on the slopes of a canyon. IN: AN SSSR. Institut fiziki Zemli. Eksperimental 'naya seysmologiya (Experimental seismology). Moskva, Izd-vo Nauka, 1971, 118-125.

The dynamic characteristics of ground motion from nearby earthquakes and explosions observed in the Naryn river canyon have been analyzed. Three components of motion were measured at points located on the canyon bottom and at various heights on its slopes. It was found that motion amplitudes observed on the slope increase relative to the amplitudes at the bottom by a factor 1.5 - 3, with the amplitude increase becoming more pronounced as the height increases. The magnitude of the amplitude increase varies with the direction of the seismic ray arrival. A frequency resonance occurs at 2.5 Hz for the motion component transverse to the slope and at 1.7 and 5.0 Hz for the component parallel to the slopes. A distortion in the motions of the two slopes, increasing with time, was found. Relative motions of the two slopes exceed the motion in the incident wave by a factor of 2.5.

Zapol'skiy, K. K., Solov'eva, R. P. Spectral characteristics of the strong Alaska earthquake of 28 March 1964 and its aftershocks. IN: AN SSSR. Institut fiziki Zemli. Eksperimental 'naya seysmologiya (Experimental seismology). Moskva, Izd-vo Nauka, 1971, 152-163.

The spectral characteristics of the main shock and aftershocks of the Alaskan earthquake, as well as the (temporal) characteristics of the P wave generation process, have been studied, based on seismograms of the main shock of 28 March 1964 and aftershocks over the period 28 March - 30 April 1964. The seismograms were recorded by a frequency-selective seismic recording system consisting of an SKM accelerometer (T = 12.5) and six channels in the 0.9 - 11 sec frequency range. In the spectral time analysis, the seismic process is considered as a three dimensional function A = A(t, T), where A = A/T or the oscillation velocity, T is the period, and t is the time on the seismogram. Thus, each seismogram is presented in the form of A/T isolines on the time/period plane, with t = const sections representing instantaneous spectra and T = const sections representing envelopes of individual channels.

In order to evaluate the build-up time τ of $(A/T)_{max}$ (maximum oscillation velocity) P-wave envelopes for the main shock and aftershocks are compared, showing that τ increases with magnitude from 1 - 3 sec for M = 5 to 40 - 50 sec for M = 8.6. It was found that the focal-wave spectrum of a strong earthquake varies with time. As far as velocity spectra are concerned, five different types were found; this being explained as a consequence of different focal mechanism and local conditions in the hypocentral zones.

The effect of frequency characteristics of the seismic recording system on the derived earthquake magnitude is discussed. It was found that the stronger the earthquake, the lower the period corresponding to maximum magnitude. For earthquakes with $M_{pv} > 7$, the magnitude does not reach its maximum in the recorded frequency range.

The attenuation decrement δ was determined by comparing curves $e^{-N\delta} = f(t)$, calculated for δ = 0.001, 0.003, 0.005, 0.01 and T from 0.1 to 10 sec, with experimental spectra. Attenuation decrements of 0.002-0.004 were obtained for the majority of earthquakes.

Pavlova, I. N. Dynamic characteristics of the Aleutian earthquake of 4 February 1965 and its aftershocks from seismograms recorded by frequency-selective seismic systems. IN: AN SSSR. Institut fiziki Zemli. Eksperimental 'naya seysmologiya (Experimental seismology). Moskva, Izd-vo Nauka, 1971, 163-179.

Spectral analysis of the 4 February 1965 Aleutian earthquake and its aftershocks has been performed. Data on earthquakes analyzed corresponding to a 650 x 200 km epicentral region are given in tabular form. Seismograms were recorded by three frequency-selective seismic systems -- the Moskva-1 and Sochi stations (in the 0.8 - 15 sec period range) and Moskva-2 (in the 0.25 - 5 sec range). The quality and wave field of seismograms, as well as dependence of duration and amplitudes of P and S waves on earthquake magnitude, are discussed. Amplitude spectra for P and S waves were obtained in two ways: by observing maximum amplitude of a wave group simultaneously on all frequency channels (instantaneous spectra), and by observing amplitudes and periods of a wave group (for different phases of P wave also) through each 5-second interval along the individual seismograms. Amplitude spectra for surface waves were obtained by observing amplitude and periods in the 17 - 50 min interval (relative to onset time).

The following conclusions have been reached:

1. With an increase of earthquake energy, not only the amplitudes and periods of P waves increase, but also the duration of this wave group and the "arrival time" of maximum phase.

2. The total recording duration is considerably smaller for periods less than 0.5 sec than for periods exceeding 1 sec.

3. Spectral composition of compressional waves is basically determined by earthquake magnitude and the location of the hypocenter.

4. Variations of P and S wave amplitudes with magnitude are restricted to within about three orders of magnitude.

5. S wave spectra have more long-period composition as compared to P waves. Periods shorter than 3 sec are not recorded.

6. A_s/A_p spectra are relatively narrow banded with $\Delta \log A_s/A_p = 1.7 \Delta \log T$.

7. The increase of earthquake energy does not significantly affect the spectral composition of the main phase of surface waves.

Tregub, F. S. Analysis of seismic wave field, and a velocity model of the Earth's crust. IN: AN SSSR. Institut fiziki Zemli. Eksperimental 'naya seysmologiya (Experimental seismology). Moskva, Izd-vo Nauka, 1971, 217-239.

In order to study the seismic wave field, a great number of seismograms obtained by deep seismic sounding (DSS) along different profiles, on land as well at sea, have been reconsidered. All DSS profiles, the wave groups identified, their kinematic and dynamic characteristics, and their assumed nature have been tabulated. Wave groups P^{os}, P^o, P^* and P^M connected with the sedimentary layer, granitic layer, basaltic layer, and the Mohorovicic discontinuity were analyzed. The causes of contradictions between the results of the crustal structure study obtained by DSS and seismological methods are discussed. On the basis of the wave field analysis, a hypothetical velocity model of the Earth's crust is proposed. It was found that the only discrepancy between observational data of DSS and seismological method is in the character of the first arrivals. This can be explained by differences in the dynamic range of sources of ground motion. Some contradictory results are, however, due to rather different approaches to the interpretation of observational data. Wave field analysis has yielded the following results and conclusions.

1. Continuously refracted P^o waves decrease sharply in intensity at distances of 80-100 km and are not recorded. This is explained as due to a shadow zone caused by a low-velocity layer within the consolidated crust. If the P^o wave group is divided into individual waves, their apparent velocities slowly increase. The shadow zone shifts at longer distances and a long interval of interference between P^o and P^* group waves occurs.

2. Waves of the P^*_1 and P^*_2 groups are reflected and reflected/continuously refracted. If the existence of a waveguide is assumed, then P^*_1 group waves can be assumed as reflected from the uppermost part of the waveguide and P^*_2 reflected from the axis of the waveguide. Waves of the P^*_2 group change from reflected to reflected/continuously refracted as the distance increases, with the apparent velocity gradually increasing up to 6.8 - 7.0 km/sec. This indicates that the transition from the waveguide to the bottom of the crust is a thin layer, i.e., the velocity gradient is relatively high at that depth interval.

3. The Mohorovicic discontinuity is a transition layer with a thickness comparable to the wave length, thus explaining the attenuation characteristics of the P^M wave group.

4. Average velocity in the crust is 6.0 - 6.2 km/sec, which implies the existence of a thin layer with a sharply increased velocity gradient below the waveguide axis.

A velocity model for the continental Earth's crust as shown in Figure 1 is proposed.

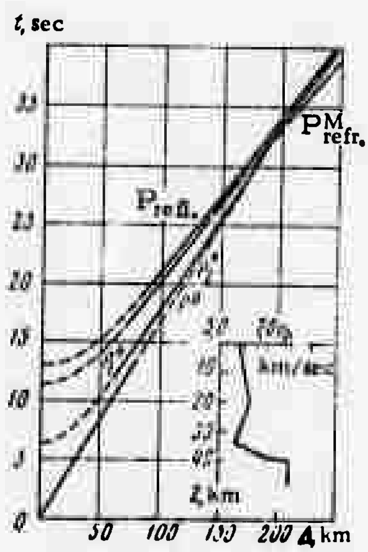

Fig. 1. Proposed mean velocity model of the continental crust and theoretical time-distance curves for principal wave groups.

Ponomarev, V. S. Elastic energy of rocks and seismicity. IN: AN SSSR. Institut fiziki Zemli. Eksperimental 'naya seysmologiya (Experimental seismology). Moskva, Izd-vo Nauka, 1971, 75-87.

It is proposed that hydrostatic compression plays an important role in the accumulation of potential elastic-deformation energy in crustal material, which may be released by seismic activity. The equilibrium field of elastic energy in rocks, and its disruption due to hydrostatic unloading, are discussed. In the process of denudation of terrain, which is regarded as hydrostatic unloading of rocks, redistribution of stresses is non-elastic. As a result of inhomogeneities of rock microstructure, the equilibrium of the internal stresses is unstable; therefore, relatively insignificant changes in loads may cause rupture (fracture occurring in the process of denudation, cleavage in mining). Similar phenomena occur to a limited extent within rock affected by an external system of forces causing a fracture. In addition to the energy released due to external forces, part of the energy of hydrostatic compression is also released, and a local minimum of energy occurs. The redistribution of stresses in the proximity of the fracture is non-elastic. In the case of differentiated dislocation of rock blocks (formation of mountains), significant difference of stresses occurs in the contact zone and equilibrium is disrupted. As a result, the total force proportional to the dislocation exceeds the shear and tensile strengths of the materials. Unloading of rocks as a boundary process is discussed and characteristics of a boundary zone have been analyzed. The seismic process is discussed from the viewpoint that it originates as a consequence of disturbance of the equilibrium field of elastic energy due to hydrostatic unloading. From this view point, explanations are given for deformation characteristics in an earthquake focus, the differing seismicity of regions with similar tectonic activity, and the coincidence of global epicentral zones with stress zones.

Aptikaev, F. F. Determination of the energy of seismic sources. IN: AN SSSR. Institut fiziki Zemli. Eksperimental 'naya seysmologiya (Experimental seismology). Moskva, Izd-vo Nauka, 1971, 59-65.

The structure of seismic sources is investigated and a new scale for the energy classification of earthquakes is proposed. A seismic source model consisting of the focus (as defined by Gurevich et al) and surrounding zones within which the crustal material undergoes deformation under high dynamic stresses has been developed. The term radiator (emitter) is used for a zone within which the elastic moduli are changed. The seismic energy of the source E_i, is defined as the energy flux through the surface of radiator. The boundaries between zones of source are determined in the terms of a change of characteristics of attenuation and apparent period of motion with distance as observed on the seismograms of nearby explosions. Graphs showing energy attenuation vs distance and apparent period of oscillations vs distance, as obtained from explosions, are given in the article. Two boundaries between zones surrounding the seismic source are identified: The radiator boundary R_I, and another one at $R_p = 6R_I$. Three zones separating the focus and the determined boundaries are designated as: the inner zone enclosed between the focus and radiator boundary; the intermediate zone enclosed between the radiator and the R_p boundary; and the outer zone. The relation $R \sim E^{0.4}$ is obtained. A seismic source model based on a circular dislocation model of the focal mechanism is described in the text, and a correlation between seismic energy E_i and energy class K (scale used by the USSR Comprehensive Seismic Expedition) is given in the form of a table.

Gal'perina, R. M. Some results of a study of converted transmitted waves, using the vertical seismic profiling method. IN: AN SSSR. Institut fiziki Zemli. Eksperimental 'naya seysmologiya (Experimental seismology). Moskva, Izd-vo Nauka, 1971, 239-254.

Necessary conditions have been studied surrounding the generation of converted transmitted waves at interfaces within the upper part of the Earth's crust and their recording, separation, and identification at the diurnal surface. The purpose is to evaluate the reliability of the seismic prospecting and seismological research methods based on the use of converted transmitted waves. Seismograms obtained by the vertical seismic profiling method for a section up to 1400 m in depth and shot points at 0 - 30 km, as well as seismograms recorded by three component system on the diurnal surface in the same locality, have been analyzed. It was found that:

1) Separation and tracing of converted transmitted waves are dependent upon the structure of the upper part of the section near both the source and the detector.

2) Intensive converted transmitted waves are generated at sharp interfaces in the upper part of the section at depths not exceeding 1000 - 1500 m.

3) The criteria for correlation of P and S waves cannot be used confidently for the determination of the nature of converted waves.

On the basis of the results of a study of converted waves generated at interfaces up to 300 m deep, some assumptions on conditions of their generation at deep interfaces have been made. The maximum conversion coefficient for the Mohorovicic and Conrad discontinuities are estimated to be 0.2. Converted waves generated at shallow interfaces with conversion coefficients exceeding 0.3 - 0.5 have been reliably recorded, so that the probability for the generation of very intensive waves at deep interfaces is very low. These conclusions are verified by theoretical calculations. Thus, the reliability of methods for the study of deep crustal structure based on converted waves has been questioned.

Momaklov, F. N. On the organisation of earthquake prediction research. IN: AN SSSR. Institut fiziki Zemli. Eksperimental 'naya seysmologiya (Experimental seismology). Moskva, Izd-vo Nauka, 1971, 407-415.

Experiences of Soviet and non-Soviet scientists in the study of possible effects preceding strong earthquakes have been reviewed, their prospects in earthquake prediction discussed, and the following conclusions made: The most prospective precursors of strong earthquakes are deformation and tilting of the Earth's crust, observed on its surface, and variation of the main geomagnetic field. Encouraging indicators are geoacoustic noise, changes in the ground water constituents and, perhaps, microforeshocks. All research efforts at this moment should be concentrated on these effects. Observations should be made in epicentral zones and immediately after a strong earthquake.

Drobyshev, Yu. P., J. P. Lebedeva. Analysis of seismological data by methods of classification theory. IN: AN SSSR. Institut fiziki Zemli. Eksperimental 'naya seysmologiya (Experimental seismology). Moskva, Izd-vo Nauka, 1971, 403-407.

An attempt has been made to apply statistical methods to earthquake prediction, using data from the earthquake catalog for the Germ region. The problem of earthquake prediction has been regarded as a classification problem, with the time series of weak earthquakes in some period T considered as characteristic of the seismic state during that period. The F and G class of "states" are defined as corresponding to the period preceding a strong earthquake and the period after which a strong earthquake does not occur. The classification problem is reduced to comparing observed current seismic state to F and G classes using some criteria, and thus determining its class. The following problems of classification are discussed:

1) Selecting the description of the state of the seismic regime.

2) Selecting the space-time area in which weak earthquakes can be regarded as casually connected with strong earthquakes.

3) Selecting of characteristics of state which are to be compared.

4) Determining G class of state.

5) Selecting classification criteria.

Five calculations of the F class of state, using five randomly selected strong earthquakes out of 25, have been made. The G class of states was determined in two ways and the results of the calculations are shown in two tables. It was assumed, that in spite of the small number of events, weak shocks directly preceding strong earthquakes are poorly related to the latter, and that the problem of earthquake prediction cannot be solved by using only data from catalogs.

Simbireva, I. G. Focal mechanism of weak earthquakes in the Naryn River basin. IN: AN SSSR. Institut fiziki Zemli. Eksperimental 'naya seysmologiya (Experimental seismology). Moskva, Izd-vo Nauka, 1971, 360-375.

The focal mechanism of weak earthquakes in the Naryn River basin has been determined using Vvedenskaya's dislocation model. The distribution of dislocation vectors in two possible fault planes and stress axes in the foci of weak earthquakes has been analyzed, as well as its relationship to strong earthquakes occurring in the same region. Observational data on 286 earthquakes with energy class K = 7 - 10 in 1965 - 1967 have been used. Determination of two possible fault planes with their dislocation sign are shown in the form of tables and maps. The fault planes in the region are characterized by dip angles of 45° - 65° and uniformly distributed dip azimuths. The zones of subsidence are identified with respect to the hanging wall of two possible fault planes.

Determinations of the orientation of compressive, tensile and intermediate stresses are summarized in the form of tables, maps, and azimuthal histograms. It was found that within zones having the same motion sign, the system of stresses is fairly uniform and differs from that within zones of opposite sign. An investigation of the variation with time(1. 5 - 2 months prior to and after a strong earthquake) of the orientation of the principal stresses in the foci of weak earthquakes and its relation to stress orientation in the foci of strong earthquakes has been accomplished. The following conclusions are made:

1) There exists a definite regularity in the orientation of principal stress axes and in the characteristics of the distribution of dislocations in the fault planes of weak earthquakes.

2) Zones and blocks of uplifting and downwarping with respect to the hanging wall of faults are identified. A different orientation of stress axes corresponds to these zones.

3) Strong earthquakes are confined to the boundaries between these zones, and it is supposed that these sections are, seismically, the most dangerous.

4) A change of stress axis orientation prior to strong earthquake is verified. New orientation occurring 1.5 - 2 months prior to a strong earthquake coincides with stress axis orientation in the focus of the latter. It is suggested that the change in orientation can serve as a precursor of a forthcoming strong earthquake.

B. Recent Selections

Belotserkovets, Yu. I. Method of computing the mean velocities of elastic-wave propagation in rock, based on laboratory measurement results. Geologiya i geofizika, no. 10, 1971, 107-109.

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Zhdanov, V. V. Nature of the Conrad discontinuity. IN: AN SSSR. Nauchnyy sovet po kompleksnym issledovaniyam zemnoy kory i verkhney mantii. Priroda seysmicheskikh granits v zemnoy kore (Nature of seismic boundaries in the Earth's crust). Moskva, Izd-vo Nauka, 1971, 102-106.

4. Particle Beams

A. Abstracts

Malkin, O. A., and A. V. Pyshnov. Current and initial pressure dependence of the parameters of a high-intensity pulsed discharge. TVT, no. 5, 1971, 884-889.

Measurements are described of a quasistationary dense plasma created by a rectangular pulsed electric discharge in nitrogen at initial pressure p_o = 1-50 torr and current density $\bar{J}$ = 1-6 ka/cm^2. The experiment was undertaken to develop a technique of producing such a plasma with controlled parameters at a temperature to hundreds of thousands of degrees and near-atmospheric pressure. The plasma was studied in connection with the development of equipment such as MHD generators, and high-power pulsed light sources for laser pumping. Plasma in a state of local thermodynamic equilibrium resulting from a high-intensity rectangular pulsed discharge acts as a particularly effective light source. Cylindrical 19 x 160 and 30 x 190 mm quartz tubes were used for discharge formation in a gas flow across a gap between aluminum end electrodes with centrally-positioned 5 mm dia apertures. Only axisymmetric discharge was studied, under conditions described earlier by the authors /̲ Sb. Teplofizich. svoystv nizkotemperaturnoy plazmy, 1970, 156; ZhPS, v. 14, 1971, 198; TVT, 1971, 633/̲. Up to 140μsec length pulses were used. The current intensity of a 60μsec pulse fluctuated within 0.5 - 15%, and pulse rise time varied within 10-15μsec. The pulse trailing edge increased from 4μsec at lower currents to about 15μsec for currents above 24 ka.

By use of high-speed photography and oscilloscope recordings of current and potential across the electrodes, duration of the quasistationary phase of discharge was determined in a first approximation as the difference (t_v - t_f) between the onset of vaporization of tube material and formation of a discharge channel. A typical high-speed photograph of a discharge shows that t_v - t_f decreases with an increase in $\bar{J}$, because of quartz vaporization. Quartz vapors in a 19 mm dia. tube propagate toward the tube axis at 90-140 m/sec when p_o = 1-10 torr, and up to 500 m/sec when p_o = 0.1 torr. The plots in Fig. 1 reveal that t_f increases with an increase in p_o and a decrease in $\bar{J}$; at equal average $\bar{J}$, t_f also increases with an increase in tube diameter. Metallic discharge tubes were substituted for quartz tubes in preliminary experiments.

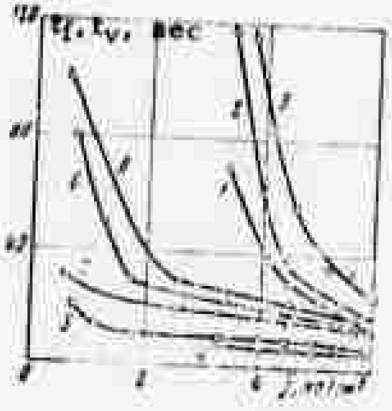

Fig. 1. t_v and t_f versus p_o, $\bar{j}$, and tube diameter: 1, 2, 3 - t_v versus j for a 19 mm dia. at p_o of nitrogen equal to 0.1, 1, and 10 mm Hg, respectively; 4, 5, 6 - t_f versus j for a 19 mm dia. at 0.1, 1, and 10 mm Hg, respectively; 7, 8 - t_f versus j for a 30 mm dia at 1 and 10 mm Hg, respectively.

Electron density $N_e = (0.1\text{-}9) \times 10^{17}$ cm^{-3} was measured in nitrogen plasma with 1-2% of trace H, using $H\alpha$ and $H\beta$ spectral lines. Discharge phase spectra were recorded by a rotating disc spectrochronograph developed by the authors. The time dependence of N_e indicated that the duration of the stationary discharge phase is equal to the difference between t_f and time of establishment of stationary N_e. Values of N_e measured with a 30-40% accuracy are plotted in Fig. 2.

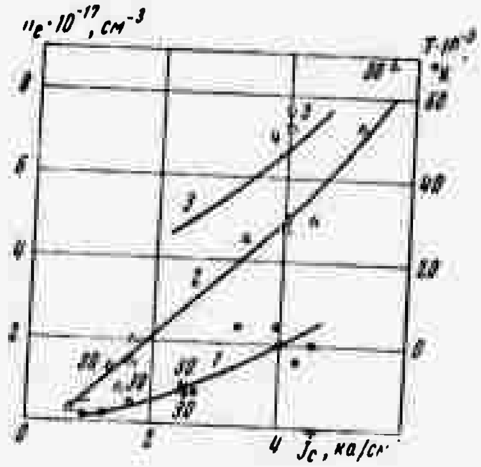

Fig. 2. Stationary N_e (1, 2, 4, 5) and temperature T (3) versus $\bar{j}_c$ in nitrogen discharge; 1, 3 - p_o = 1, 2 - p_o = 10, 4 - p_o = 30, 5 - p_o = 50 torr (Index 30 indicates measurements in a 30 mm dia. tube).

Plasma temperature T at p_o = 1 torr was calculated from experimental electrical conductivity σ values at different j_c (Fig. 3). Comparison of the T versus j_c plots (Fig. 3) with an earlier T = 36,000°K value at p_o = 1 torr and j_c = 2.5 ka/cm^2 shows that T near the discharge axis was underestimated by 7,000°K. This was due to a predicted underestimation of the mean ionic charge $\bar{Z}$ value which enters into the calculation of T. The calculated maximum T was

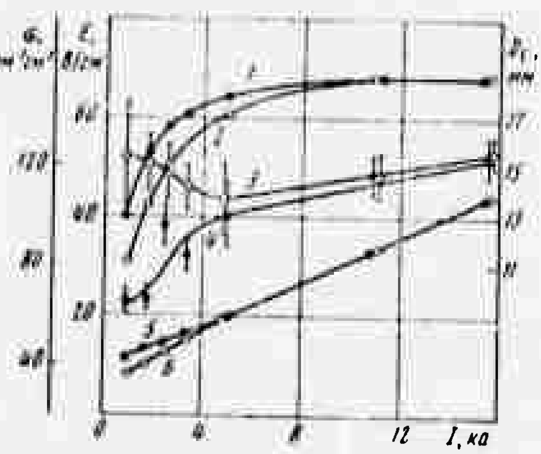

Fig. 3. Glow diameter D_c of discharge channel in nitrogen (1,2), plasma electroconductivity σ (3,4) and electric field intensity E (5,6) in the plasma versus current and pressure. For tube of 19 mm dia, the curves 2,3,6 and 1,4,5 are plotted for p_o = 1 and 10 mm Hg, respectively.

56,000°K (Fig. 2). Temperature estimates from axisymmetric wave velocity, at j_c = 1.7 - 5 ka/cm^2, were ~40,000°K at p_o = 1 torr, and 30,000 to 42,000°K at p_o = 10 torr. Plasma power density in the 7 to 230 kW/cm^3 range was calculated from σ and E values.

Kotenko, V. G., and Yu. A. Litvinenko. Generation of strong pulsed magnetic fields i.. solenoids of bimetallic wires. ZhTF, no. 1, 1972, 183-186.

The possibility of producing a strong pulsed magnetic field in solenoids has been investigated by using reinforced bimetallic wire as the winding material. One bimetal component forms a highly electrically conductive part, with the other being highly rigid, thus forming a reinforced winding. Experience in using such a winding is outlined. The main design problem is to transfer electrodynamic stress produced in the conducting element to the more rigid part. The degree of loading of the rigid part depends on the construction and the bonding characteristics between the two component metals. Theoretical relationships are derived for determining the amplitude of magnetic field corresponding to the stability limit, and for the tolerable pulse duration of the magnetic field. Computed relationships are reduced to the calculations of a nonreinforced ordinary solenoid, i.e., using only the current-carrying part of the bimetal, so that the basic principle can be applied to any type of reinforcing element. Fig. 1 shows the form of characteristic curves for the relationships obtained.

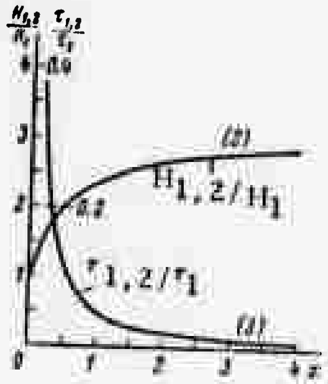

Fig. 1. Design limits of bimetal winding. $H_{1,2}$ - magnetic field corresponding to the stability limit of the reinforced solenoid; H_1 - magnetic field corresponding to the yield point of ordinary nonreinforced solenoid; $x = S_2/S_1$, where S_2 - cross-sectional area of rigid metal and S_1 - cross-sectional area of conducting metal; $\tau_{1,2}$ - pulse duration of magnetic field $H_{1,2}$ and τ_1 - pulse duration of magnetic field H_1

$\lambda_{1,2} = \lambda_1$

Experiments were conducted with a NbZrTi (main) + copper (coating) wire, having stability limits $\sigma_{2lim} \approx 200$ kg/mm^2 and $\sigma_1 \approx 20$ kg/mm^2, respectively. At x = 1, the magnetic field can be increased by 2.3 times, while pulse duration decreases by 20 times. Results of experiments using liquid nitrogen and liquid helium along with the calculated results are tabulated (Table 1). The experimental results are in good agreement with the calculated ones, proving the applicability of bimetallic wires for winding materials of a reinforced solenoid.

Cooling	$t_{1,2}$ Calculation	$t_{1,2}$ Expt	$H_{1,2}$ Calculation	$H_{1,2}^{**}$ Expt	No. of Pulses	Remarks
N	0.3	0.25	400	410	~15	Thermal destruction of wires.
He *	0.55	0.25	400	500	~10	

Table 1.

* cooling of solenoids lower than liquid hydrogen is not considered.

** voltage of condenser battery - 4 kv.

From the experimental and calculated results, it may be deduced that use of aluminum as one and steel, tungsten, etc. as the other constituent of the bimetallic wire may make it possible to obtain a relatively long pulse duration of magnetic field on the order of 500~600 koe. A further selection of optimum solenoid forms may increase the magnetic field by an additional 1.2~1.5 times.

Kolesnikov, P. M., N. S. Kolesnikova, and I. B. Gavris. Inductive acceleration of a conductor in plasma. I-FZh, v. 21, no. 6, 1971, 1115-1116.

A brief analysis is given of transient e-m processes which occur during acceleration of an inductively-coupled plasma. The analytical model assumed a fixed inductive ring which generates a field from the main capacitive discharge, and coaxial with it a movable ring which is accelerated by the discharge. Equations of plasma motion and circuit equations are given in dimensionless form, from which the transient acceleration process can be assessed. Results show that the plasma reaches its terminal velocity relatively quickly, and in a time which is little dependent on several circuit parameters. This is seen in Fig. 1, which gives plasma displacement y (τ) for six sets of dimensionless parameters.

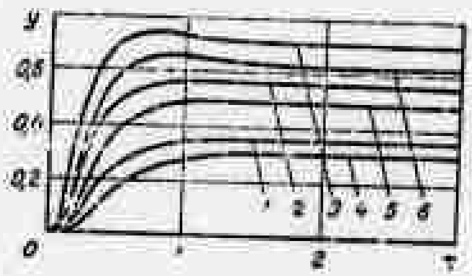

Fig. 1. Plasma motion in a ring accelerator; relative units.

The current in the moving coil is of the same order as in the fixed discharge coil. This model is seen as useful for dealing with stratified plasmas where layers have different velocities relative to each other.

Ivanov, Yu. S., V. V. Ryukkert, G. V. Sklizkov, and S. I. Fedotov. A sharply-focused source of short pulse soft x-radiation. KSpF, no. 7, 1971, 34-37.

Efforts in pulsed x-ray technology have recently concentrated on refining the control of pulse parameters, such as duration and size of the focal area. The authors propose a method for obtaining soft x-radiation of controllable pulse length in the nanosecond range, by using the explosive field emission method reported by Fursey and others. The apparatus of Fig. 1 is used,

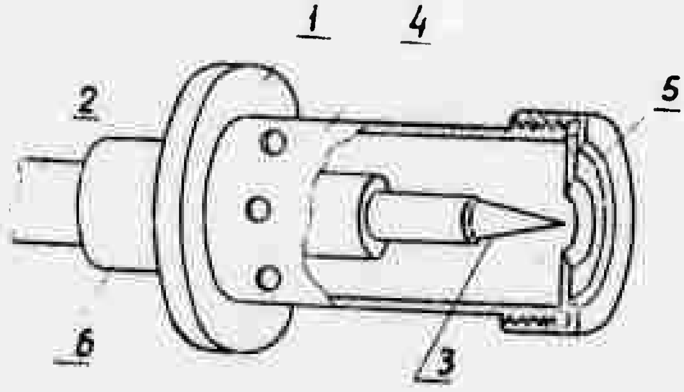

Fig. 1. Pulsed x-ray source: 1 - coupling flange; 2 - high voltage coax; 3 - tungsten anticathode; 4 - brass shell; 5 - tantalum cathode; 6 - hermetic seal.

in which bremsstrahlung from explosive emission is generated and emerges through a beryllium foil aperture in cathode (5). When the interelectrode gap fills with vapor products from the explosion, the current rises sharply but voltage and hence x-radiation fall nearly to zero. Thus the x-ray pulse length is adjusted simply by varying the needle-to-cathode spacing. The nominally linear pulsewidth characteristic obtained is seen in Fig. 2. The apparent lower

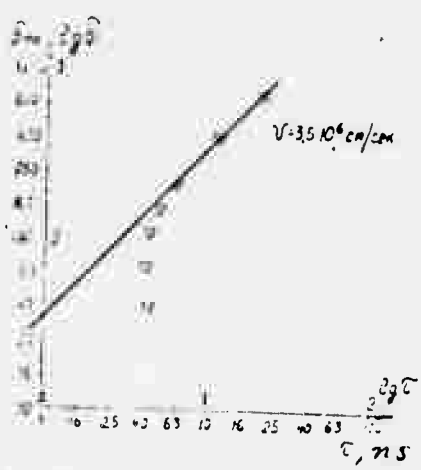

Fig. 2. Pulsewidth vs. electrode spacing δ.

limit at 4 n s is misleading since it results from the response limitation of measuring instruments. The extrapolation shows that at a 35 micron spacing, a 1 nsec pulse should be obtainable. Output x-radiation was evaluated photometrically and found to have an effective wavelength λ_{eff} = 1.65 Å; intensity was determined from cumulative film darkening.

Barinov, V. I. Forming short plasmoids.
KSpF, no. 6, 1971, 8-12.

The problem of detaching a small portion of a plasma flow is considered, and a technique is proposed for doing this. The method avoids some limitations of cited earlier attempts at similar segregation of plasmoids, and in theory will permit development of plasmoids on the order of a few centimeters in length while maintaining an electron density close to n_{max} of the main plasma. The technique uses a combination of a detaching grid and a magnetic gate, with the critical factor being the ability to develop a rectangular pulsed magnetic field from a current ~10 ka and ~0.1 μsec rise time, coincident with the leading portion of the main plasma. A negative potential on the order of a few tens of volts is simultaneously applied to the grid, acting to drain excess ion current off and avoid breakdown in the plasmoid. Fig. 1 gives a

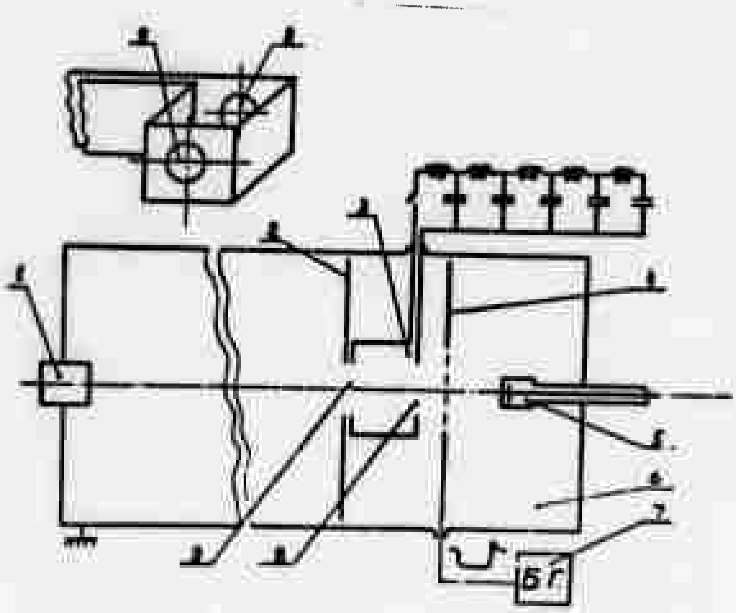

Fig. 1. Plasmoid generator.
1 - plasma injector with plexiglas face;
2 - dielectric diaphragm, 2 cm aperture;
3 - magnetic gate; 4 - copper diaphragm with
3 cm dia. isolation grid, 0.03 mm mesh;
5 - shielded probe; 6 - vacuum vessel, 10^{-6} torr;
7 - blocking oscillator pulse generator; 8, 9 -
detail of magnetic gate.

schematic of the system developed. Grid voltage was variable from 10--100 v at 16μs duration; the magnetic field attained 1 kgs with a rise time of about 0.3μs, generated by a 2 kv, 5 ka capacitive source. The relative effect of the trapping action can be seen in the synchronized waveform of Fig. 2. Results show that plasmoids 3 cm long x 3 cm dia. can thus be

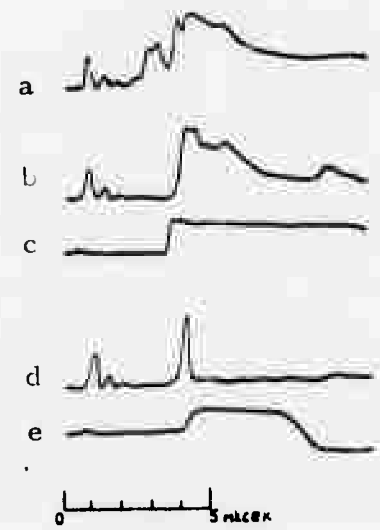

Fig. 2. Waveforms of plasmoid generator.
a - probe signal with trap not energized;
b - probe signal with blocking oscillator pulse applied to grid; c - blocking oscillator pulse;
d - probe signal with gate and grid energized;
e - magnetic field pulse.

picked off, retaining a density $\cong 10^{11}/cm^3$ from an initial $10^{12}/cm^3$ in the parent plasma.

B. Recent Selections

Abramov, V. A., and L. Ye. Ivanova. Determination of the concentration of charged particles in a pulsed electromagnetic accelerator. ZhPS, v. 15, no. 3, 1971, 405-409. (JPRS 55382, March 8, 1972)

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5. Material Science

A. Abstracts

Polyakov, L. M. Effect of uniform pressure on the plasticity of rock salt crystals. UFZh, v. 17, no. 2, 1972, 210-217.

Results are described of tests on the effects of uniform pressure on plastic deformation of rock salt crystals. The tests correlated pressure with the appearance of defects affecting dispersion and deflection of light, and also with threshold and type of crystal destruction. An experiment was conducted with natural optically homogeneous rock salt crystals of 6 x 6 x 12 mm. Measurements of the intensity of light dispersion, i, corresponding to the plastic deformation at given values of uniform pressure showed a peculiar process of destruction of NaCl crystals. In the beginning stage deformation takes place without a significant change in light dispersion;then at some deformation ϵ_{1p} intensity starts increasing and at some further deformation ϵ_{2p}, the $i(\epsilon)_p$ curve reaches a saturation region, which finally concludes in the ultimate destruction of the crystal specimen at deformation ϵ_{3p}. The relationship between intensity of light dispersion and extent of deformation is shown in Fig. 1. With increase in uniform

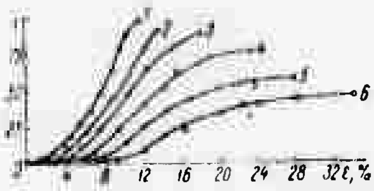

Fig. 1. Relationship between intensity of light dispersion, i and deformation stage ϵ: 1 - 0; 2 - 500 kg/cm^2; 3 - 1000 kg/cm^2; 6 - 5000 kg/cm^2.

pressure, the intensity of light dispersion decreases, and its distribution in the crystal becomes homogeneous. The appearance of light dispersion coincides with the formation of crystal defects, dimensions of which are significantly less than the wavelength of light ($c \approx 250$ - 350 Å). In the case of a uniaxial compression, dispersion is detectible at a deformation level $\epsilon_1 \approx 0.65\%$; if deformed under pressure of 5000 kg/cm^2, then deformation increases to $\epsilon_{1p} = 8.9\%$. Mathematical expressions are derived to determine the influence of pressure on plasticity and the value of deformation corresponding to light dispersion. The mechanism of destruction is described in detail and microphotographs are presented.

B. Recent Selections

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6. Miscellaneous Interest

A. Abstracts

Tyurikova, L. A., B. G. Averbukh, N. I. Moskvitin, and N. A. Krotova. Study of the parameters of r-f radiation from breakdown of a polymer bond to a solid. DAN SSSR, v. 201, no. 4, 1971, 833-836.

The relationship of adhesion mechanical properties to r-f radiation parameters in film + steel and film + glass bonds was studied under atmospheric conditions. The films were: KLT polymer (a mixture of polyethylene terephthalate and natural rubbers), adhesive plaster, cellulose esters, and PVC. An experimental apparatus was used to: (1) strip the polymer film at a variable rate, (2) measure the energy of adhesion and duration of film stripping as well as emitted r-f pulse length; (3) photo record radio signals; (4) determine emission frequency; and (5) study the shape and estimate the length of the r-f pulses. The radiation detector (Fig. 1) permitted observation of pulses with a rise time of at least 0.1 sec.

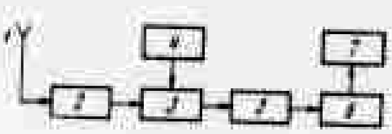

Fig. 1. Diagram of radio wave recorder:
1 - antenna, 2 - input circuits, 3 - mixer,
4 - heterodyne, 5 - I-F, 6 - detector,
7 - oscilloscope.

Sensitivity was 30 μV, transmission band width was Δf = 10 kHz, and the intermediate frequency was f = 460 kHz. A 1 m telescopic antenna was placed at a maximum distance of 1.5 m from the film separation opening.

Pulsed radiation of a minimum 1 MHz frequency was detected during stripping of all of the films, with the exception of cellulose esters. A pulse was detected however, during the instantaneous separation of a cellulose aceto-butyrate film from glass. The rate of stripping consequently is a definite factor in the generation of r-f. The intensity I of radiation increases with an increase of discharge current from the electrical double layer. This was confirmed by an

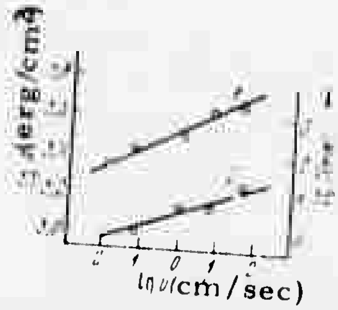

Fig. 2. Energy A (1) and radiation intensity I (2) versus peeling rate v of a KLT rubber film from a metal.

experimentally observed increase in pulse amplitude with increases in stripping rate v. At a given v, I is higher when adhesion is stronger (Fig. 2). The magnitude of I in film separation from metal is lower than in dielectric separation. An oscilloscope trace of 10 MHz radiation during stripping of a KLT film from a dielectric, e.g. glass, at v = 1 m/sec shows high-amplitude periodic pulse packets in addition to smaller amplitude pulses. The period T between high amplitude pulses is constant, i.e. dynamic resistance is constant for a given gas and gas pressure. Electromagnetic phenomena observed in adhesion breakdown generally follow the same pattern as in a gas discharge, but also display certain unique characteristics. The presence of the interval T is related to accumulation of a static charge along a considerable portion of the stripped film; surface electrical conductivity must thus play an important part in adhesion breakdown. The time dependence of radiation amplitude remains uniform within a 1-10 MHz range of frequencies. Radiation intensity oscillations in sectors of small and high-amplitude pulses reveal the discrete nature of discharges which occur in microregions of a stripped film, where field intensity is critical.

In agreement with earlier findings, the length of an elementary stripped region of rubber film on glass was determined to be 300μ. Generation of r-f oscillations is considered to be the most convincing proof of gas discharge development in a propagating crack. Visible radiation and acoustic vibrations were recorded along with r-f in all cases. At stripping rates of 0.1 - 1 cm/sec, the visible and r-f pulses were synchronized as determined from an oscilloscope trace of rubber film stripping at v = 0.1 cm/sec. Oscillatory emission of "mechanoelectrons" was also observed during adhesion breakdown in vacuum. This confirms the oscillatory nature of the breakdown and associated phenomena.

Tsukerman, V. A., L. V. Tarasova, and S. I. Lobov. New x-ray sources. UFN, v. 103, no. 2, 1971, 319-337.

State-of-the-art and applications are reviewed of x-ray sources as reported in Soviet and Western literature from 1953 through 1970. Soviet sources comprise about 53% of the 79 references. Flash x-ray sources based on field emission, exclusive of three-electrode systems, are examined initially. M. I. Yelinson, G. N. Shuppe, I. L. Sokol'skaya, G. N. Fursey, V. N. Shrednik, and G. A. Mesyats are cited as principal Soviet theoretical and experimental investigators of field emission. Yelinson has dealt with the technical problems of achieving stable field emission, and the causes of a decrease in breakdown voltage. Fursey is studying the breakdown mechanism in an ultra-high vacuum. In contrast with American x-ray tubes, Soviet tubes were designed for emission at 10^{-6} - 10^{-7} torr residual gas pressure and have featured a tapered edge tubular cathode and a needle-shaped anode. Development of such devices was started in 1948 by Tsukerman and Manakova and continued by Zyuzin, Tarasov, and others. The former researchers developed a technique of 2 to 8 successive x-ray recordings of a hypervelocity event (e.g., an explosion) at predetermined time intervals. They as well as other researchers later used field-emission tubes in x-ray structural analysis. Soviet-developed type IRA devices manufactured in Leningrad are used primarily for x-ray flaw detection in inaccessible locations. The characteristics of a recent model IRA-2D device are given in Table 1 along with a photographic view. The IRA-2D uses a pulse transformer to produce high voltage and delivers 5 pulses/sec. Fifty flashes (10 sec exposure) are required for x-ray metallography of 20 mm thick steel at a distance of 100 cm from the film. A more advanced RING generator of nanosecond x-ray flashes was developed by N. V. Belkin, E. A. Avilov, and V. I. Kolesov using a miniature (20 cm^3) x-ray tube analogous to the Fexitron. Photographs of a portable (140 x 100 x 60 mm^3) RING generator and a miniature x-ray tube are given.

Generators of high-intensity hard x-ray bremsstrahlung flashes are treated in detail. These are used for material analysis and generation of powerful relativistic electron beams. In a 1967 model, Zelenskiy, Zavada, et al incorporated two synchronized Marks capacitor impulsed circuits to reduce discharge circuit inductance (Table 2).

A 1969 model RIUS-5 resonance pulse accelerator (Fig. 1) incorporates a discharger to increase the high-voltage pulse rise rate to 10^{14} - 10^{15} v/sec versus 2×10^{13} v/sec in the earlier model. A 1970 generator of short x-ray flashes, developed by Pecherskiy et al, features a water reservoir insulator to reduce generator dimensions and internal resistance. This generator is based on liquid dielectrics research results obtained by Kulikov et al, and Mesyats and Vorob'yev. The generator stores 30 kj at 3 Mv potential in a small (100 cm dia x 50 cm) water-dielectric capacitor.

Country	Name of device, company	Potential KV	Current, amp	X-ray flash length, nsec.	Dia. of focal pt, mm	Max no. of switch-ings	Weight kg
USA	Fexitron, model 846-2 (Field Emission Corp)	100-150	-	60	1,8	10^4	25
USSR	IRA-2D, "Burevestnik" plant	300	100-200	100-200	2	$2 \cdot 10^4$	25
Eng	X-ray generator of Hivotronic	150	1000	50	-	-	11,3
USSR	RING	150	700	8	3	$2 \cdot 10^5$	1,4

Table 1. Characteristics of various portable flash x-ray devices.

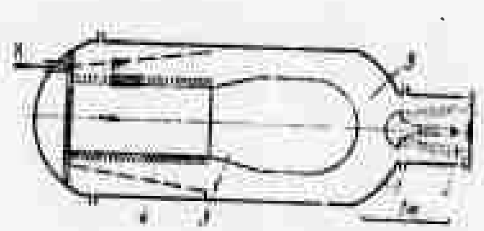

Fig. 1. Cross-section of a RIUS-5 hard x-ray bremsstrahlung pulsed source: 1 - steel reservoir, 2 - accelerator flash tube, 3 - metallic cylinder, 4 - Tesla coil, 5 - discharge gap, K - input terminal from capacitor battery source.

Country	Author and model	High-voltage source	Stored energy, kj	Potential, Mv*	Current across the tube, ka	Flash x-ray dosage at 100 cm distance, r	Flash length, nsec	Date
USA	Denholm FX-25	Electro-static generator	1,7	3,5/2,3	19	2	20	1965
USSR	Zelenskiy, et al	Marks capacitor circuit	200	5/4	50	250	500	1967
USSR	Abramyan, et al, RIUS-5	Tesla resonance transformer	5,4	7/4	15	10	40	1969
USA	Martin, et al, "Hermes-2"	Marks capacitor circuit	1000	24/13	200	6800	70	1969
USSR	Pecherskiy, et al	Marks capacitor circuit with H_2O-resevoir	30	3/1,5	100	10	60	1970

Table 2. Characteristics of generators of high-power hard x-ray bremsstrahlung flashes.

* Potential of the conductor or idling generator over the potential across the accelerator tube electrode gap.

The generation of short x-ray flashes by pulsed discharge in air, hydrogen, and other gases at nearly atmospheric pressure is next considered. Research is cited done by Stankevich and Kalinin, and Tarasova and Khudyakova on the generation of soft x-rays by an electric discharge in air, as well as by

Luk'yanov et al; Artsimovich et al; T. I. Filippova et al; and Agafonov et al, on high-temperature H, He, and Xe plasma as a source of short flashes of soft and hard x-rays. A cylindrical pinch was initially produced, followed in later experiments by a noncylindrical Z-pinch. A 0.1-1 r. dose of hard x-rays was produced by a 100 nsec pulse at a 100 cm distance from the target. Discharge on or near the right branch of the Paschen curve is suggested here as a promising method of x-ray generation.

Summaries of data are also presented on the growing application of radioactive isotope sources of characteristic x- and γ-rays of 4.5 - 100 KeV intensity.

Comments on future trends in x-ray sources include a reference to the promising data reported by Pavlovskiy, et al on a pulsed nonferrous 100 MeV betatron, which can generate bremsstrahlung flashes several tens of nanoseconds long. The use of tubes with a field-emission cathode is preferable however, when miniature portable devices are required. Greater utilization of very high-intensity flashes of hard x-ray bremsstrahlung and accelerated relativistic electrons is predicted.

Zelenskiy, K. F., N. I. Zavada, I. A. Troshkin and V. A. Tsukerman. High-power pulse generator of short x-ray flashes. PTE, no. 4, 1969, 177-180.

A high-power generator of hard x-ray flashes for the study of radiation resistance of materials is described. The generator (Fig. 1) includes a 200 kj high-voltage capacitor and a metallic discharge, two-electrode x-ray tube. An increase in apparatus power is achieved by: 1) using two pulsing circuits of 46 capacitor elements each and designed for discharge at 5 Mv; 2) arranging the intersectional discharge gaps so that current flows in opposition through adjacent capacitor elements, and 3) arranging the capacitor elements to minimize the length of current leads. Discharge circuit inductance was thereby reduced to 12 μh.

The x-ray tube in Fig. 2 is larger but otherwise similar to one that was described earlier by two of the authors and Pecherskiy /ZhTF, no. 9, 1968, 1581/. The tube can sustain voltages up to 4 Mv. In the electrode arrangement of Fig. 2a, an axially mounted tungsten spike is the anode and the tapered edge of a truncated cone is the emission cathode. In the 2b arrangement, a thin tungsten or tantalum plate, located in the immediate vicinity of the output window, functions as the anode. The 2b arrangement enhances production of high dose rates. The cylindrical

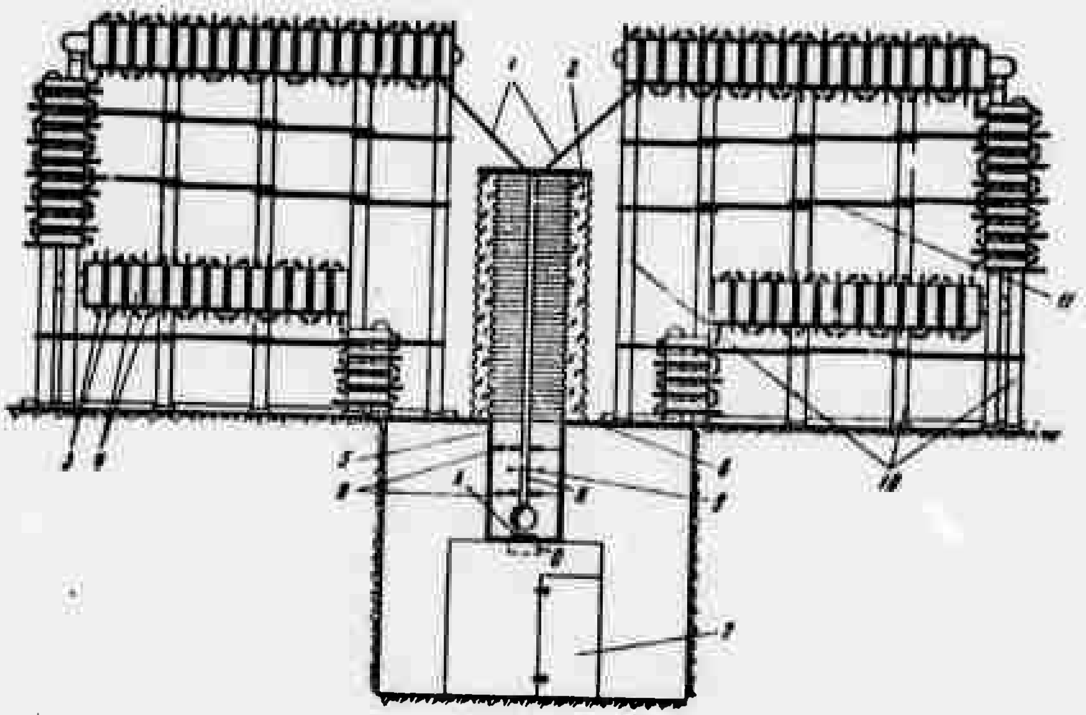

Fig. 1. Cross-section of flash x-ray apparatus. A - anode, K - cathode, O - target specimen, 1 - tube current leads, 2 - insulation, 3 - intersectional discharge gaps, 4 - capacitor elements, 5 - tube envelope, 6 - steel cover plate, 7 - instrumentation compartment, 8 - diaphragm, 9 - disc, 10 - insulated support columns, 11 - dielectric tie rods.

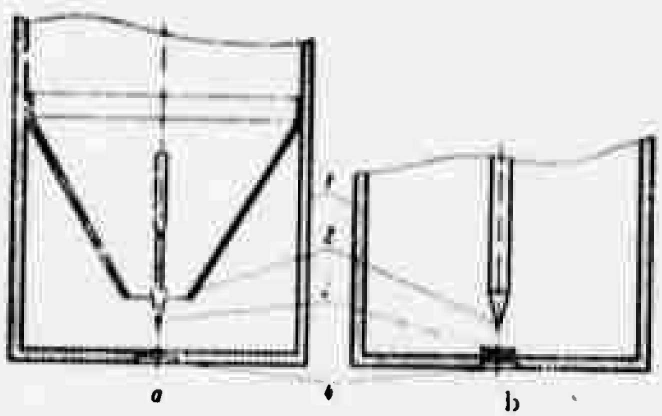

Fig. 2. Flash x-ray tube cross-section: a - geometry of electrodes for positive high-voltage pulses, b - negative pulse electrodes arrangement, 1 - grounded tube envelope, 2 - cathode, 3 - anode, 4 - output window.

3m high x 1 m O.D. tube insulation is made of epoxy resin. The grounded tube envelope is a steel cylinder, 1.2 m long, I. D. = 0.8 m. Metallic diaphragms and a disc are fastened to the envelope and the high-voltage terminal K, respectively, to prevent metal vapor deposition on insulator walls. In the 2b electrode arrangement, a special design feature makes it feasible to replace the anode plate without disturbing the vacuum.

Trial oscilloscope traces of a high-voltage applied pulse and an x-ray pulse are given in the article. The discharge current amplitude, measured with a Rogowski belt, was between 30-60 ka, depending on the experimental conditions; the 0.5 sec flashes were measured at the half-power points. X-ray doses of 50kr and 100 kr were obtained at distances of 1 m and 2-3 cm, respectively, from the anode in the Fig. 2b arrangement. Depth of x-ray penetration into lead at 1 m from the anode was 18 cm in the 2a and 20 cm in the 2b arrangements. The higher penetration depth in the latter case was attributed to an increased intensity of the hard x-ray component of the flash.

Sokolov, R. N., F. A. Kudryavitskiy, and G. D. Petrov. Underwater laser device for determining size distribution of suspended particles in the sea. FAIO, no. 9, 1971, 1015-1018.

The importance is stressed of experimentally determining particle size distribution functions in sea water for solution of many hydrophysical problems. An underwater laser designed for this purpose is described and data obtained with it are reviewed. The device (Fig. 1) is based on small-angle approximation, and is composed of a laser 1, a collimator 2, a rotating prism system 3, a scanning device 4, a focusing lens 5, an interference light filter 6, a photomultiplier 7, and a cable which connects the submerged part of the device to an onboard recorder. Scanning of the scattered laser beam may be done either continuously (Fig. 1b) or discretely (Fig. 1c). In the latter system, the scanning disc, with

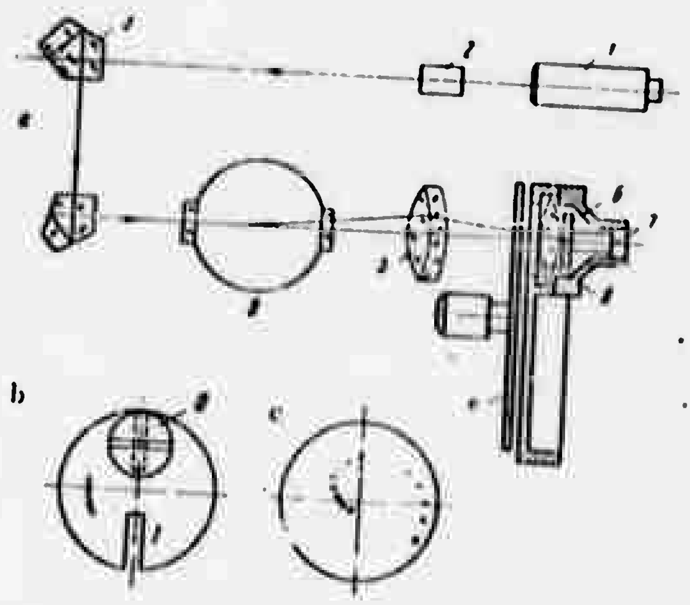

Fig. 1. a - schematic diagram of the device, b - arrangement for continuous scanning; I - moving slit, II - fixed slit, dashed line indicates one of the positions of I in gliding motion over II, c - discretely scanning disc.

apertures arranged in a spiral, rotates in front of a fixed diaphragm. The greater the distance from the optical axis, the larger is the diameter of an aperture. The beam transmitted through the aperture and diaphragm is focused by the lens 8 on the photomultiplier cathode. The maximum area of the light spot on the cathode is 3 x 0.5 mm. The photomultiplier signal is transmitted by cable to an oscilloscope on board a research vessel. The length of a single pulse in the continuous sweep mode is 25 msec and the total length of 18 pulses in a discrete sweep is 300 msec. Scattered light intensity I was measured at an angle $\Theta = 0.01 - 0.15$ rad, with a resolution better than 10^{-4} rad. The sensitivity of this method is sufficient to detect several 5 micron particles in a 6.5 x 6.5 x 180 mm volume. The submerged part of the device is enclosed in a hermetically sealed container designed to withstand a 20 atm maximum external pressure.

The particle size distribution function was calculated from

$$f(\alpha)\alpha^2 = -c \int_0^\infty \frac{d}{d\theta}(\theta^3 I) F(\alpha\theta)\, d\theta,$$

where $\alpha = \pi D/\lambda$, D = particle diameter, $\lambda = 0.6328$, and C is a constant. The error due to small angle approximation was within $\pm C/2\alpha\pi$ limits. The magnitude of $\Phi(\Theta) = d/d\Theta(\Theta^3 I)$ was analyzed each time and those values introducing a large error were discarded.

The device was tested in May 1970 in the Black Sea on board the research vessel "Kapitan Chumakov". The scattering phase function was determined at 500 m, 1 km, and 2.5 km distances from the shore, where respective water depths were 60, over 400, and 200 m. Typical plots of the scattering phase function (I versus Θ) are shown for 1.5, 50, and 1.5 m immersion depths at 500 m, 1 km, and 2.5 km from the shore. The narrowest scattering phase function, corresponding to the least attenuation of the incident beam, was found at 2.5 km from the shore and at a 35 m immersion depth. This function was therefore adopted as the null reference signal in calculations of particle size distribution. The calculated plots of $f(\alpha)$ versus D (Fig. 2) show that particle concentration at 1 km from the shore increased with an increase in immersion depth.

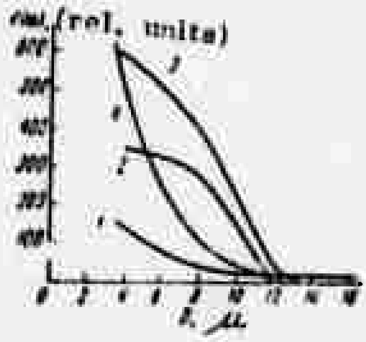

Fig. 2. Size distribution of particle suspension in sea water: 1-3 - 1 km from the shore at 2 m (1), 15 m (2) and 50 m (3) depth, 4 - 500 m from the shore at a 2 m depth

At greater distances from the shore, concentration remained practically unchanged. A significant increase in particle concentration, which resulted in a noticeable attenuation of the light beam, was observed at 500 m from the shore and at a 55 m immersion depth near the sea bottom.

Poltavtsev, Yu. G., V. P. Zakharov and V. N. Chugayev. Structural studies of graphitization of thin carbon films induced by powerful light impulses. Kristallografiya, v. 16, no. 2, 1971, 415-419.

An electronographic analysis of graphitization kinetics in thin amorphous carbon films exposed to powerful light pulses was performed. The optical source in this case was an IFP type xenon flashlamp, operating at voltages up to 1.7 kv. Carbon films were obtained by thermal diffusion of carbon rods onto cold glass substrates; samples were then placed on a copper grid and exposed to various energy light pulses, and in this manner various stages of graphitization were obtained. Kinetics of graphitization was studied from the nearest order parameters, which were determined for each graphitization stage from the radial atomic distribution curves. Radial atomic distribution curves were calculated from the electronograms obtained by means of an electron microscope and processed according to techniques described by I. D. Nabitovich et al. (Kristallografiya, no. 4, 1967, 584.) Experimental data and theoretical calculations indicate that there is a definite similarity in the structure of amorphous and graphitized carbon films. Amorphous carbon has a partially ordered hexagonal lattice structure, similar to that of the graphite crystalline lattice. However, there are different atomic layer arrangements in amorphous carbon and graphite. Based on the analysis of the structure of original amorphous carbon films and radial atomic distribution curves, the authors suggest the following graphitization kinetics. During the first graphitization stages a certain number of carbon hexagons with a single C-C bond are destroyed. Predominantly double and triple carbon bonds are formed among the released carbon atoms. During the subsequent graphitization stages the hexagonal and structural ordering takes place. The atomic layers are formed in such a manner that every atom has one neighbor in the adjacent layers. (In amorphous stage every atom has on the average four neighbors in adjacent layers.) In the final graphitization stages the hexagons get somewhat distorted; however, there is no change in relative positions of the atoms. It is suggested that the cause for the hexagonal distortion is the formation of double carbon bonds between certain adjacent carbon atoms, which thus coexist with single carbon bonds in the final graphitization stage.

Zaytsev, A.V. A new theory of ball lightning. ZhTF, no. 1, 1972, 213-216.

The author expounds a theory of ball lightning formation based on published research data on the formation of extremely fine electroconductive structures in an electric field. Such structures are composed of fine metallic or partly burned ash and soot particles. Analogous structures combined with a corona space charge may form a streak lightning embryo. Discharge current from the structure in a static earth - cloud electric field flows through the structure resistance and heats it. The heated structure then emits visible light which might be perceived as ball lightning. The embryonic structure is visualized in the form of a nucleus having a spatial network structure with spatially interconnected chain structures grown out of it (see Fig. 1). The

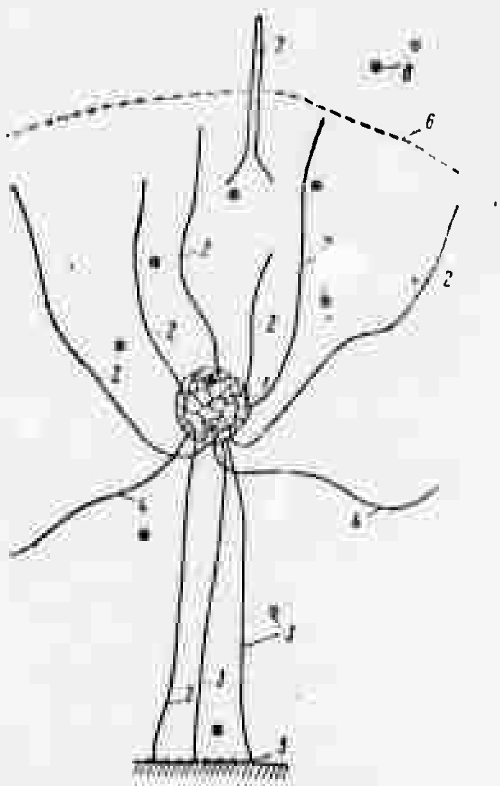

Fig. 1. Spatial distribution of ball lightning structures: 1 - spatial network structure and space charge; 2 - upper structures and space charge; 3 - lower structures and space charge; 4 - separate ascending lower structure chains; 5 - lower discharge boundary of lower structures; 6 - upper discharge boundary of upper structures in the pre-leader discharge phase; 7 - leader channel; 8 - charges ascending to the cloud.

mechanism of formation of a ball lightning is described on the basis of this model as follows. Discharge currents from separate chains of the upper and lower structures accumulate on the nucleus. Given a sufficient number of chains, of the appropriate length, the total current across a nucleus is able to heat the nucleus structure to the point of visible light emission. At this stage, a quiet luminescence of the nucleus may be observed. A further increase in current across the upper and lower structures results in the accumulation of a significant space charge within the embryonic structures, which periodically forms a short current leader channel of streak lightning. The leader current flows across the embryonic structure. A series of short leaders is perceived by an observer as flashes and explosions of the luminous nucleus. A long leader, resulting from a sudden decrease in structural resistance at the instant of partial burning, is perceived as a strong explosion along with the disappearance of the luminous nucleus. The latter appears to be the ball lightning energy source, although the true source is the static earth-cloud electric field. The leader pumps the field energy from regions at a great distance from the structures. Charged embryonic structures sometimes alternately fall and rise from the ground in a "jumping ball" pattern without breaking away from the earth. This kind of embryo moves only along the earth's surface, subject to the mutually balancing forces of weight and charge attraction by the cloud. In this case the charge of the lower structure breaking contact with the earth is neutralized by the discharge current; the structure falls back to the earth until it is repolarized by the earth-cloud field. The predominance of the charge attraction over the weight of the embryonic structure manifests itself if the structure is heated sufficiently by the dipole discharge current to rise in ascending air streams. In that case, the embryo may be lifted far from the earth.

Optimum conditions for ball lightning formation are a combination of high particle concentration, a strong electric field and high temperature. Such a combination may occur when a layer of ash or soot particles is polarized by a discharge (10^6 - 10^7 v) of streak lightning. The polarized particles form a nucleus which is sintered into a conducting network by corona and arc discharges. The existence of a layer of particles is however not a necessary precondition. The particles may form in an induced discharge channel by partial combustion or vaporization of carbon-containing material or metals. Growth of the upper structures in this case is explained by accumulation after a discharge of the residual particles on the polarized upper part of a spatial structure. A strong electric field created by a current breakdown on the attached particles reestablishes the contact broken by the discharge and promotes growth of the structures. The burned-out spatial structures are reconstructed from ground material particles by current breaks generated between the spatial structure and earth at the instant of separation from the earth. The particles remaining below the spatial structure after a discharge form the lower structures and close the discharge circuit across the nucleus to the earth. Ball lightning lifetime is limited only by those conditions favorable to structure formation, as long as the nucleus structure is not burned out completely.

Examples are given of other ball lightning characteristics which might be forecast on the basis of the cited mechanism.

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7. SOURCE ABBREVIATIONS

DAN AzSSR	-	Akademiya nauk Azerbaydzhanskoy SSR. Doklady
DAN BSSR	-	Akademiya nauk Belorusskoy SSR. Doklady
DAN SSSR	-	Akademiya nauk SSSR. Doklady
EOM	-	Elektronnaya obrabotka materialov
FAiO	-	Akademiya nauk SSSR. Izvestiya. Fizika atmosfery i okeana
FGiV	-	Fizika goreniya i vzryva
FiKhOM	-	Fizika i khimiya obrabotka materialov
F-KhMM	-	Fiziko-khimicheskaya mekhanika materialov
FMiM	-	Fizika metallov i metallovedeniye
FTP	-	Fizika i tekhnika poluprovodnikov
FTT	-	Fizika tverdogo tela
IAN Arm	-	Akademiya nauk Armyanskoy SSR. Izvestiya
IAN Az	-	Akademiya nauk Azerbaydzhanskoy SSR. Izvestiya
IAN Energ	-	Akademiya nauk SSSR. Izvestiya. Energetika i transport
IAN Fiz	-	Akademiya nauk SSSR. Izvestiya. Seriya fizicheskaya
IAN Met	-	Akademiya nauk SSSR. Izvestiya. Metrologiya
IAN Metally	-	Akademiya nauk SSSR. Izvestiya. Metally
I-FZh	-	Inzhenerno-fizicheskiy zhurnal
IT	-	Izmeritel'naya tekhnika
IVUZ Aviatsionnaya tekhnika	-	Izvestiya vysshikh uchebnykh zavedeniy. Aviatsionnaya tekhnika
IVUZ Fiz	-	Izvestiya vysshikh uchebnykh zavedeniy. Fizika

IVUZ Radioelektr	-	Izvestiya vysshikh uchebnykh zavedeniy. Radioelektronika
IVUZ Radiofiz	-	Izvestiya vysshikh uchebnykh zavedeniy. Radiofizika
Kristall	-	Kristallografiya
KSpF	-	Kratkiye soobshcheniya po fizike
LZhSt	-	Letopis' zhurnal'nykh statey
MP	-	Mekhanika polimerov
MTT	-	Akademiya nauk SSSR. Izvestiya. Mekhanika tverdogo tela
MZhiG	-	Akademiya nauk SSSR. Izvestiya. Mekhanika zhidkosti i gaza
OiS	-	Optika i spektroskopiya
Otkr izobr	-	Otkrytiya, izobreteniya, promyshlennyye obraztsy, tovarnyye znaki
Phys abs	-	Physics abstracts
PM	-	Prikladnaya mekhanika
PMM	-	Prikladnaya matematika i mekhanika
PTE	-	Pribory i tekhnika eksperimenta
RiE	-	Radiotekhnika i elektronika
RZhElektr	-	Referativnyy zhurnal. Elektronika i yeye primeneniye
RZhMekh	-	Referativnyy zhurnal. Mekhanika
RZhMetrolog	-	Referativnyy zhurnal. Metrologiya i izmeritel'naya tekhnika
RZhRadiot	-	Referativnyy zhurnal. Radiotekhnika
TMF	-	Teoreticheskaya i matematicheskaya fizika
TVT	-	Teplofizika vysokikh temperatur
UFN	-	Uspekhi fizicheskikh nauk
UFZh	-	Ukrainskiy fizicheskiy zhurnal

VAN	-	Akademiya nauk SSSR. Vestnik
VLU	-	Leningradskiy universitet. Vestnik. Fizika, khimiya
VMU	-	Moskovskiy universitet. Vestnik. Seriya fizika, astronomiya
ZhETF	-	Zhurnal eksperimental'noy i teoreticheskoy fiziki.
ZhETF P	-	Pis'ma v Zhurnal eksperimental'noy i teoreticheskoy fiziki
ZhPMTF	-	Zhurnal prikladnoy mekhaniki i teoreticheskoy fiziki
ZhPS	-	Zhurnal prikladnoy spektroskopii
ZhTF	-	Zhurnal tekhnicheskoy fiziki
ZhVMMF	-	Zhurnal vychislitel'noy matematiki i matematicheskoy fiziki

8. AUTHOR INDEX