

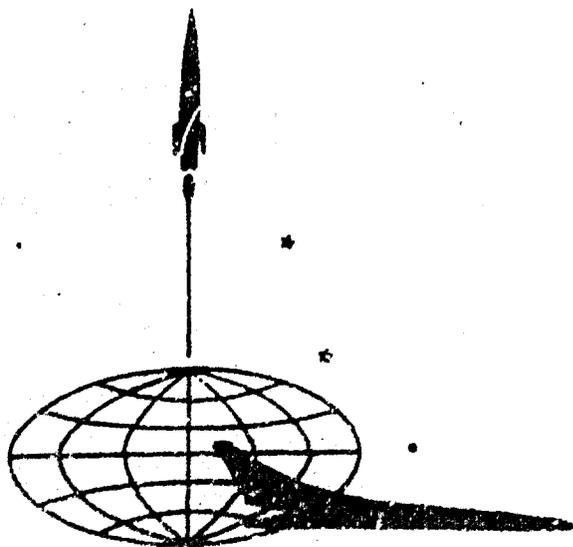
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# FOREIGN SCIENCE BULLETIN

*A Monthly Review of Selected Foreign Scientific and Technical Literature*



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# ***FOREIGN SCIENCE BULLETIN***

*A Monthly Review of Selected Foreign Scientific  
and Technical Literature*

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#### FOREWORD

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# PAPERS

## SOVIET STUDIES ON LOW-THRUST ORBITAL PROPELLANT-SCOPING SYSTEMS

by Aleksander Dolgich

*SUMMARY: A review is presented of the principal calculation methods used in orbital propellant-scooping system studies applicable to the development of low-thrust space vehicles, based on the Soviet open literature. Special attention is devoted to calculating the optimal parameters of electric low-thrust engines equipped with propellant-scooping devices. The calculation methods discussed make it possible to determine the optimal parameters of a low-thrust orbital propellant-scooping engine system which is universal for a certain assigned class of spacecraft maneuvers. A spacecraft equipped with an orbital propellant-scooping system is capable of carrying a payload up to about 2.5 times greater than that of a spacecraft without such a system.*

### Introduction

The general principles of low-thrust space engines, including electric propulsion engines and the solar sail (Fig. 1), are said to have been formulated around 1900 [1]. The scientific and engineering approaches to low-thrust space-flight mechanics, however, have been discussed in the Soviet literature only since about 1946. About 60 papers by 28 authors have discussed the applicable aspects of the theory of low-thrust mechanics. Ten of these [1-10], published during the period 1963-69, cover the state of the art in the development of low-thrust-vehicles with and without orbital propellant-scooping systems (sources covering the latter provide basic background information on the development of the former).

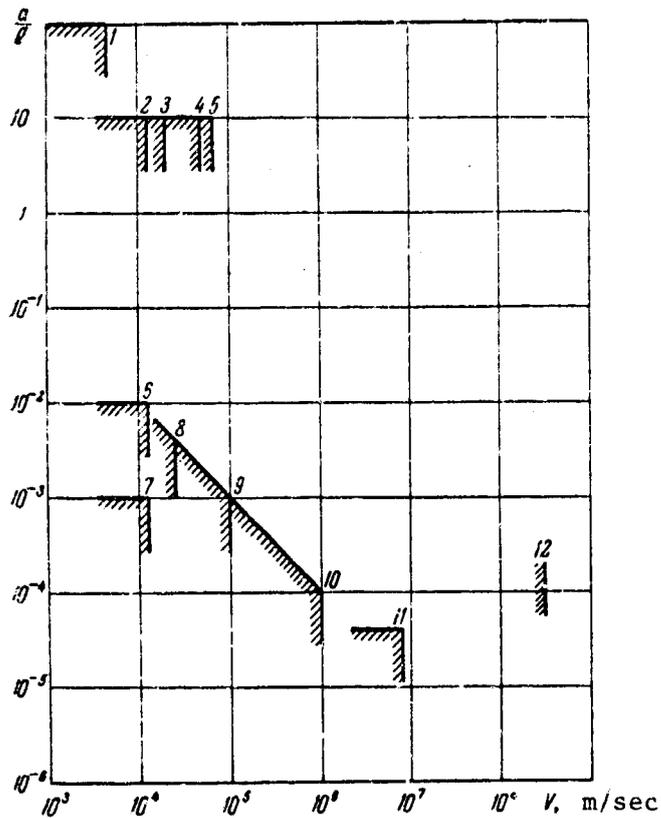


Fig. 1. Space engine systems [2]

High-thrust engines (1-5): 1 - Chemical combustion chamber; 2 - heating in nuclear solid fuel reactor; 3 - heating in nuclear liquid fuel reactor; 4 - heating in nuclear liquid fuel reactor in combination with chemical combustion chamber; 5 - heating in nuclear gaseous fuel reactor.

Low-thrust engines (6-12): 6 - Engine with solar heater; 7 - engine with isotopic heater; 8 - electric-arc engine; 9 - electrodynamic engine; 10 - electrostatic engine; 11 - isotopic sail; 12 - solar sail.

$V$  - Gas discharge velocity;  $a$  - thrust acceleration;  $g$  - gravitational acceleration at sea level.

The most comprehensive analysis of low-thrust flights without propellant-scooping engines [1] was published in 1963. This review, based on an analysis of more than 200 Soviet and foreign studies, discusses in detail both the solar-sail vehicle and spacecraft equipped with low-thrust electric engines.

The concept of low-thrust propellant-scooping orbital engines was first discussed in U. S. and British papers published during the period 1959-63\*. Reference [3] indicates that the first Soviet paper on this subject appeared in 1965 [4] (this paper also discussed a method for calculating low-thrust propellant-scooping engines and maneuvering trajectories). In discussions of low-thrust propellant-scooping space engines, Soviet writers have emphasized that it is possible to accumulate gas in the upper atmosphere and to use it as a propellant in low-thrust engines. The technological approach to the development of a propellant-scooping system has been discussed in several sources, including a 1966 monograph [2] and a 1968 paper [3] which describe in detail the methods for calculating different maneuvering flights with propellants accumulated in orbit. At the present time, special attention is being paid to the development of a universal calculation method for maneuvering vehicles with and without orbital propellant-scooping systems [3].

It should be noted that the sources used for this article discuss propellant-scooping orbits located in the upper atmosphere without indicating the optimal scooping altitudes for different flight purposes. In addition, the Soviet authors never use the word "air" in discussions of scooping engines; the general terms "gas" or "propellant" are used instead ("atmospheric gas", "gas-scooping", "propellant accumulation", etc.).

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- \* a. Demetriades, S. T. A novel system for space flight using a propulsive accumulator. IN: British Interplanetary Society. Journal, v. 17, no. 5, 1959.
- b. Berner, F., and M. Camac. Airscooping vehicle. Air Force Ballistic Missile Div. TR 59-17, Aug 1959.
- c. Reichel, R. H., T. L. Smith, and D. R. Hanford. Potentialities of airscooping electrical space propulsion systems. Progr. in Astronaut. and Aeronaut. Electrical Prop. Devel, v. 9, New York, 1963.

## Low-Thrust Orbital Propellant-Scooping Engine Characteristics

Low-thrust space flight mechanics includes studies in the determination of optimal weight parameters, optimal engine control systems, and optimal flight trajectories. In discussions of orbital propellant-scooping systems, three types of electric propulsion engines are considered: electrothermal (electric-arc); electrostatic; and electromagnetic [1]. A typical space engine system with a propellant-scooping device is shown in Fig. 2 [2].

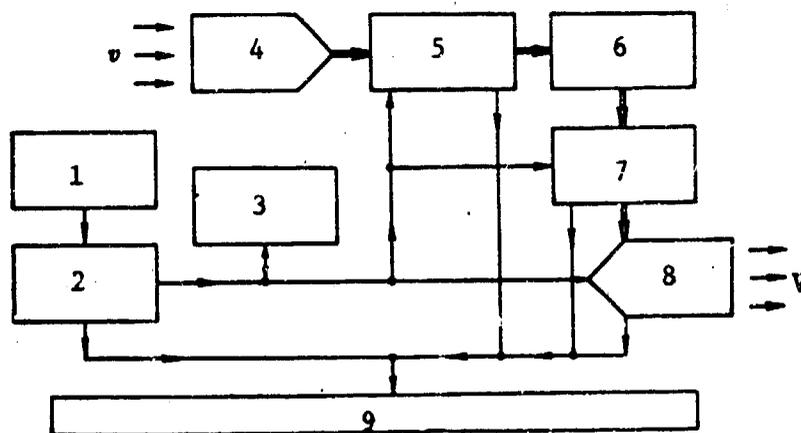


Fig. 2. Space engine system assembly [2]

1 - Energy source; 2 - energy transducer; 3 - energy accumulator; 4 - propellant scoop; 5 - propellant accumulator; 6 - propellant container; 7 - propellant supply; 8 - jet engine; 9 - energy removal;  $v$  - spacecraft velocity,  $V$  - gas discharge velocity.

A low-thrust engine is characterized by four main parameters: propellant mass consumption per unit of time ( $q$ ); gas discharge velocity ( $V$ ); thrust ( $P$ ); and gas-discharge flow power ( $N$ ); two of these parameters are considered to be independent control functions. A theoretical low-thrust engine is described by the formulas

$$P = qV, \quad \frac{1}{2}qV^2 = N, \quad 0 \leq N \leq N_{\max}$$

The weight formula for a power plant with a propellant-scooping system consists of four components

$$G_0 = G_{\pi} + G_x + G_{\nu} + G_{\mu 0}$$

where  $G_0$  is the initial weight of the power plant in a scooping orbit,  $G_{\pi}$  is the payload,  $G_x$  is the weight of a power plant with a propellant-scooping device,  $G_{\nu}$  is the weight of the gas liquefaction device, and  $G_{\mu 0}$  is the initial propellant weight.

During the scooping phase of the flight, power is consumed for production of thrust, compensation for aerodynamic drag, and liquefaction of the scooped gas. The power plant weight ( $G_x$ ) and the liquefaction device weight are expressed by the formula

$$G_x = \alpha(\frac{1}{2}qV^2 + k_{\nu}gq_0)$$

and

$$G_{\nu} = \delta g q_0$$

where  $q_0$  is the intake gas mass at the propellant scoop,  $\nu$  is the specific weight of the liquefaction device,  $k_{\nu}$  is the specific power consumption for the liquefaction process, and  $\alpha$  is the specific weight of the power plant.

For the maneuvering phase in the atmosphere the propellant consumption ( $G_{\mu}$ ) and thrust acceleration ( $a$ ) are determined from the formulas  $G_{\mu} = -gq$  and  $-a = G_{\mu} V/G$ , where  $G$  is the current weight.

The low-thrust engine characteristics discussed above make it possible to derive a differential equation for the change in weight, the integral of which from the beginning of the extra-terrestrial maneuver to the final time gives the following:

$$\left[ \frac{1}{G} \right]_{G_0+G_{\mu 0}}^{G_0-G_{\mu 0}} = \frac{1}{G_n} \Phi^* \quad \left( \Phi^* = \frac{a}{2g} \int_{T_0}^T a^2 dt \right)$$

where  $G_{\mu 0}$  is the weight of the propellant accumulated for the time  $T_0$ . For a circular scooping orbit, the propellant weight, liquefaction device weight, and payload are determined by

$$G_{\mu 0} = gq \left( \frac{2}{c_x} \frac{V}{v_0} - 1 \right)$$

$$G_0 = \frac{\kappa_0 G_n}{V + \kappa_h}$$

and

$$G_n = \frac{1 + \kappa_a c G_n T_0}{1 + \Phi^* G_n^{-1} (1 + \kappa_h G_n T_0)} - \frac{\kappa_0 G_n}{V + \kappa_h} - G_n$$

where  $v_0$  is the circular velocity in the scooping orbit,  $c_x$  is the aerodynamic drag coefficient, and

$$\kappa_a = 2g\tau / av_0^2 c_x^2, \quad \kappa_0 = 4g\delta / av_0^2 c_x^2, \quad \kappa_h = 4gk_0 / v_0^2 c_x^2$$

( $\tau$  is the characteristic time for low-thrust flight, e.g., of power plant service life);

$$\Phi^* = \frac{\Phi}{T - T_0}, \quad \Phi = \frac{\Delta v^2}{\kappa_a c_x^2}$$

where  $\Delta v$  is the relative velocity increase and  $T$  is the maneuver completion time.

Using the engine characteristics discussed above, the calculation method makes it possible to determine the optimal parameters for various engine-type numbers ( $\Omega$ ) (or energetic levels) and maneuver numbers ( $S$ ). Fig. 3 [3] shows a typical

optimal relation between payload and maneuvering parameter ( $\phi$ ) determined for various flight conditions.

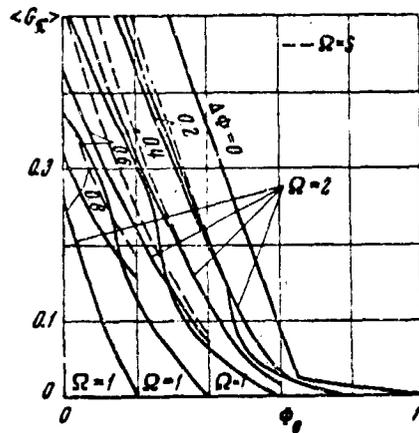


Fig. 3

As can be seen from the above maneuvering parameter  $\phi$  is expressed by different functions, including flight velocity, aerodynamic drag coefficient, characteristic time for low-thrust flight, and specific weight of power plant; therefore, this functional is used as the basic value for the analysis of low-thrust flight characteristics. In reference 3, the functional  $\phi$  is used as an abscissa in 13 graphs demonstrating the advantages of a low-thrust scooping power plant over a plant without an orbital propellant-scooping system. A comparison of the parameters obtained by the calculation methods discussed shows (Figs. 4 and 5; [3]) that a maneuvering spacecraft equipped with a low-thrust propellant-scooping engine will carry a payload about 2.5 times greater than that of a spacecraft without such a system.

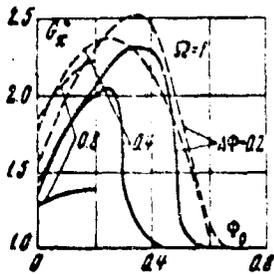


Fig. 4

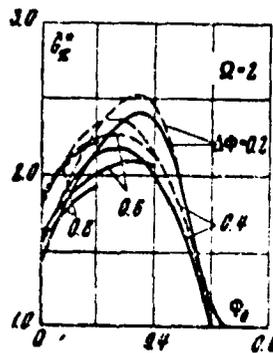


Fig. 5

Figs. 4 and 5 show the relative increases in payload of engine systems with orbital propellant-scooping in comparison with low-thrust engine systems without propellant-scooping for engine-system level number  $\Omega = 1$  (Fig. 4),  $\Omega = 2$  (Fig. 5), and  $\Omega = 5$  (dotted lines in Figs. 4 and 5).

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## DEBATE ON APPROACHES USED IN SOVIET STUDIES OF CRACK PROPAGATION

by Victor Klein

*SUMMARY: The fundamentals of the theory of crack propagation in brittle-elastic solids were established by A. A. Griffith in the early 1920's. His concepts were expanded for quasi-brittle fracture by G. R. Irwin and E. O. Orovan in the late forties and in the fifties. At approximately that time a rapid development in the study of the crack propagation mechanism and of its kinetics also took place in the USSR, utilizing various assumptions concerning the stress and strain distributions around a crack, and thus provoking scientific debates. The essentials of one such debate between two prominent Soviet scientists, which arose at the end of 1968 and which has been conducted in the publication Inzhenernyy zhurnal. Mekhanika tverdogo tela [1, 2, 3, 4], are presented below.*

The approach to the problem of crack-propagation in solids used by L. I. Sedov in his new (1968) four-volume textbook, *Mechanics of Continua*, was criticized in [1] by G. I. Barenblatt, who quoted the following sentence from the foreword to this textbook which concerns the chapter on the plane elasticity theory and the theory of cracks: "A presentation of modern crack theory suitable for a textbook has become a most urgent necessity, since a great lack of comprehension of the essence of the matter, confusion, and many erroneous and treacherous statements are prevalent in the voluminous literature in the Russian and English languages devoted to this theory."

Barenblatt states further that Sedov's interpretations of certain basic concepts of the crack theory in his textbook (mainly his assertion that within the scope of the linear elasticity theory the stresses are infinite at the crack's point in the presence of cohesion forces) contradict the known results of a number

of theoretical investigations which showed that the possibility has always existed (and was never questioned until now) of selecting such cohesion forces (or the length of the crack in a case where the cohesion forces are given) that the crack-point stresses will be of finite value.

Sedov's representation of the crack theory in his textbook is critically reviewed from the mechanical and energy viewpoints. His statement that "the existence of high, and even infinite, stresses which appear as the result of stress analysis by means of the elasticity theory does not involve an inevitable total or local failure of a solid" is opposed by Barenblatt, and the incompatibility of the presence of infinite stresses at the end of a crack with the finite strength of actual crack-weakened solids is discussed at length, and is accompanied by a sample analysis (of an intrinsically non-contradictory model of a crack with physically admissible cohesion forces acting along small distances  $d$  at its ends) showing the absence of infinite stresses.

Barenblatt then points to a crack model which he proposed in [5], where it was assumed that the crack had the shape of a slit whose edges join smoothly (cusp-like) together, forming the crack's points with cohesion forces acting there, and with the finite-stress condition (formulated by S. A. Kristianovich in 1955) satisfied. The concept of the cohesion modulus  $K$  (which is a solid's constant characterizing the effect of cohesion forces) was introduced in [5], and a new formulation was given for the problems (which can arise only in the case of stable cracks) of determining the size of a crack in a solid under a given load, and of the crack development affected by the load variation.

Barenblatt adds that he used this approach with good results in a study [6] of the brittle fracture of a solid as a whole. Thus, a consecutive force-based approach was worked out in the theory of cracks, treating the problem of equilibrium of a crack-weakened solid as a nonlinear problem of the elasticity theory. Barenblatt also states that somewhat later, but independently of him, a model of a crack based on the concept of cohesion forces and the finite-stress condition was discussed

[7, 8]. The utilization of the energy-based (A. A. Griffith) and force-based (G. I. Barenblatt) approaches in establishing the failure criteria is mentioned, and the dependence, which was derived in [5], of the cohesion modulus  $K$  on the surface energy and elasticity characteristics of a solid is given.

A thorough investigation of the association between both approaches by J. R. Willis in [9], and the advantage of the force-based approach expressed in [10], indicates that the latter will apparently be preferable in analyzing the kinetics of crack development. At the end of the article Barenblatt rebuts the criticism in [11] and [12] concerning his equilibrium-crack model and the approach he used in studying the mechanism of crack development in solids.

Sedov's rebuttal [2] of Barenblatt's criticism is written in sharp words describing Barenblatt's statements as "tangled excuses and groundless critical reproofs" and accusing him of having inexperienced readers in mind when making a certain assumption. Sedov does not concentrate his objections on Barenblatt's denial of the presence of infinite stresses at the crack's points, and primarily disputes the basic assumptions and their consequences.

After saying that "nobody will insist that a model with  $d \neq 0$  and finite stresses in the presence of suitable cohesion forces is theoretically inadmissible," Sedov states that "any criticism of my text, by introducing other models in which  $d \neq 0$ , is inadmissible and absurd, since I discuss, as Irwin did, a non-contradictory model with  $d = 0$ , which is the fundamental characteristic and definition of the brittle-body concept from the viewpoint of the elasticity theory and the accumulated practical applications. It is evident that the introduction and study of other models taking the details at the crack's end into consideration makes sense."\*

---

\* Sedov apparently means a perfectly brittle solid, whereas Barenblatt has in mind a more general case: a quasi-brittle fracture with a plastic region around the length  $d$ .

Sedov states that in his *Mechanics of Continua* and in [3] one can find the answers to Barenblatt's "unfounded criticism."\* The rebuttal ends with a statement that "in connection with Barenblatt's works, a detailed, time-consuming analysis has been carried out and is partly reflected in the press and in [3]. There is no sense in discussing Barenblatt's self-confidently compiled article in more detail; the above-noted specific features are quite enough to characterize its contents." Sedov's conclusion reads:

"In the article there is not a single note, not a single new idea which could be recognized as scientifically interesting with regard to the essence of the problem or concerning the gist of the works criticized in this article. It may seem strange that Barenblatt, knowing the irrefutable criticism of his works and of the article under discussion, defends his full infallibility and has published this article. In order to understand his action it must be considered that, on the one hand, the theory of cracks is associated with unusual refinements, and, on the other hand, there are a number of persons who do not go deeply into the pith of the theory, but who have committed themselves definitely by [having made] positive statements about Barenblatt's works."

Article [3], unlike [2], is written in an almost conventional manner, although Sedov participated in its writing, edited it, and recommended it for publication in *Mekhanika tverdogo tela*, as stated in the editorial footnote.

Articles [13] and [14] are critically analyzed, with emphasis placed on the fact that in [13]\*\* the contents of [7] and [8] are repeated, starting with the initial assumptions on the region of cohesion forces, finiteness of stresses, and smoothness of joining the crack's edges, and ending with the derivation of the Griffith formula for the case where  $d \ll l$  ( $l$  is the half-length of a crack). The Barenblatt-Khristianovich model is

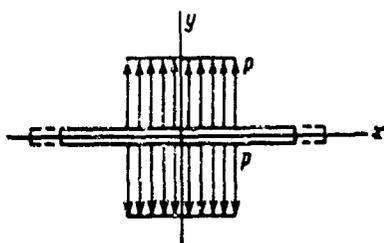
\* It is interesting to note that Sedov also complains of the "delayed [purposely, by the editor?] publication of his article [3]," which was submitted to the journal a day after his rebuttal [2].

\*\* Not to mention Barenblatt's fundamental article [5].

criticized from the energy viewpoint, as is their interpretation of the cohesion modulus  $K$  and the finiteness and magnitude of the length  $d$ . A statement at the end of article [3] reads "the model of failure within the [theory of] an elastic-plastic solid has been analyzed by many authors in great detail, including the establishment of all asymptotic laws. In comparison with these works, article [13] does not contain any new elements. The interpretation of Barenblatt's erroneous and formal concepts has taken a place in our literature which does not correspond to their actual significance."

In [4]\* the effects of the initial assumptions used in the mathematical formulations of two models (both based on the classical elasticity theory) which describe the process of crack development in solids on the results obtained in analyzing the propagation of a rectilinear crack under conditions of plane deformation are compared. One of these is referred to as the GI (Griffith-Irwin) model, and the other, as the KhB (Khristianovich-Barenblatt) model. The author does not discuss how precisely these models describe the actual crack-propagation mechanism, leaves aside the question of priority in their formulation (as well as in determining certain process parameters), and expresses the hope that in spite of its simplicity the article "will help to remove certain misunderstandings which have arisen in a part of the literature on the theory of cracks."

The development of a straight slit in an elastic plane acted upon by symmetrically located uniform loads along a part of its length, as shown in the figure, is examined as an example,



\* A. Yu. Ishlinskiy is the chief editor of the journal *Mekhanika tverdogo tela*.

using N. I. Muskhelishvili's [15] formulas for displacements and stress-tensor components, and the Clapeyron theorem for determining the potential strain energy. The rupture cracks appearing at both ends of the slit under a certain magnitude of applied load are assumed in both the GI and KhB models to be symmetrical and in line with the direction of the initial slit, whose length, with the lengths of the rupture cracks added, is designated as the length  $2l$  of the developing crack.

The GI model, in which an energy-based approach is used, is discussed first, and expressions are derived for determining the constant  $\gamma$  (which is characteristic for the material of a solid under given conditions of its deformation and represents the specific work required for its rupture), and the critical magnitude of  $\gamma$  at which the rupture cracks appear. It is proven that the developed equilibrium crack is stable. The behavior of the force-based KhB model is examined, assuming that the cohesion forces of magnitude  $q$  are distributed uniformly along the length  $d$ . Formulas for the displacements of the slit edges and for stresses  $\delta y$  along the  $x$ -axis beyond the length  $d$  are given, and expressions are derived for determining the critical stress at which the rupture cracks appear and the slit becomes a developing crack, as well as for establishing the length of an equilibrium crack and associated stresses  $\delta y = q$ , which fact leads to a smooth joining of the crack's edges at its ends. The stability of the equilibrium crack is stated, and it is proven that the crack remains in equilibrium even if it propagates for a certain distance  $\delta l$  at each end beyond length  $d$  without introducing any cohesion forces along  $\delta l$ .

The energy relationships in the KhB model are also examined, and an expression is derived for determining  $\gamma$ , which is analogous to that derived for the GI model, but here  $\gamma$  depends on certain parameters and on  $l$ , the half-length of the equilibrium crack. It is proven that if the length  $d$  is tending to zero, the equations for determining the length of a crack  $2l$  from the expressions for  $\gamma$  are identical in both the GI and KhB models. Thus, in the example discussed, the GI model is the limit case of the KhB model. It is shown that this relation remains in cases of much more complex formulations of the crack-propagation problems (such as those in [5] and [15]), e. g., when on

a certain portion of the slit shown in the figure variable arbitrary-intensity loads  $p(x)$  are applied instead of uniform loads  $p$ . The answer to the natural question of which model should be used in solving a certain problem "must be sought by [examining] the degree of suitability of the GI and KhB, as well as of other intrinsically non-contradictory models, to phenomenological investigations of crack development under complex conditions, for instance in imperfectly elastic solids."

### Conclusion

The persons who took part in the above-described debate are: Grigoriy Isaakovich Barenblatt, Professor at the Institute of Problems in Mechanics, Academy of Sciences USSR; Aleksandr Yul'yevich Ishlinskiy, Academician, Academy of Sciences UkrSSR and Academy of Sciences USSR; Ye. M. Morozov and V. Z. Parton, who are unknown to the writer; Leonid Ivanovich Sedov, Academician, Academy of Sciences USSR.

The most astonishing features of this debate are the rough, even crude manner used by L. I. Sedov in his critical article [5], and the fact that all of the papers [1 to 4] were published in the same issue of *Mekhanika tverdogo tela* (of the authors involved in the article, only A. Yu. Ishlinskiy is on the editorial staff of the journal).

Sedov undoubtedly knew of the good reputation enjoyed by Barenblatt inside and outside of the USSR, due to his participation in writing an additional chapter on the theory of cracks in [15], the attention paid to his work by J. R. Willis [9, 10], K. B. Broberg [16], and others, and the fact that his work [14] was published in the United States. Sedov's language is inappropriate in a scientific debate and one can only wonder how this article could have been published in a journal of such high scientific caliber. The analysis presented in [4] makes it clear that the Khristianovich-Barenblatt model is broader than the

Griffith-Irwin model used by Sedov. In other words, the KhE model represents a step forward in the theory of cracks, a fact which should be a source of satisfaction for G. I. Barenblatt. There are no articles on this subject in the next two issues of *Mekhanika tverdogo tela* (no. 1, and no. 2, 1969). Neither could the analyst find any articles associated with this debate in other Soviet scientific journals available to him.

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## BONDING OF POLYETHYLENE TO METALS

by Boris Ofrossimow

*SUMMARY: The high chemical stability of polyethylene (PE) makes it a promising material for the protection of metals against corrosion. However, since the adhesion strength of PE to metals is not very high, the increase of this strength is of great importance. This is a brief review of some recent Soviet studies on methods to increase the adhesion of PE to metals.*

### Filling of Polyethylene With Inert and Active Fillers

Proposed methods to increase the adhesion strength of PE to metals include filling of PE with inert and active fillers, chemical treatment of the metal surface, depositing of fatty acids on the metal surface, and graft-copolymerization of PE.

The conventional method of modifying the properties of thermoplastics involves filling with inorganic fillers. Fillers not only improve certain properties of the polymers but also reduce the cost of the material. The effect of various inert inorganic fillers on the adhesion of PE to steel was studied for low-pressure PE or nonstabilized high-pressure PE and ST3 steel. The fillers were ground talc, kaolin, graphite, quartz, or asbestos. PE-steel joints were made under slight pressure from filled PE films and cleaned steel substrates at 140°C for 5 minutes. The adhesion strength was measured in peeling tests.

It was shown that the PE-to-metal adhesion strength increases to up to 8 kg/cm with an increase in the filler content to 8—10%, whereupon the character of the failure changes from adhesive to mixed and to cohesive. The adhesion strength drops with a further increase in the filler content.

The adhesion strength of both the neat and filled PE increases with an increase in the purity and specific surface of the steel substrate, and with an increase in the boundary temperature from 130 to 280°C and bonding time from 6 to 300 minutes. The adhesion strength is always lower for neat PE than for filled PE. In the case of filled PE, adhesion strength increased in the sequence: graphite, talc, asbestos, kaolin, quartz.

The increase in adhesion strength with an increase in the degree of filling is assumed to be caused by processes associated with thermal and thermal oxidative reactions on the adhesive-substrate boundary. These processes are possibly activated by the surface of the filler and substrate particles. The above reactions can increase the polarity of the PE macromolecules via the formation of carbonyl, carboxyl, peroxide, or hydroxide groups. These groups enhance the adsorption interaction between the polymers and the metal surface (the latter is always covered with a polar oxide film). The oxygen involved in thermal oxidative reactions is present in the pores and craters on the metal surface and in the surface pores of filler particles which are incompletely wetted with the polymer [1].

The effect of active fillers (as compared to that of inert fillers) on PE-to-metal adhesion strength was studied for non-stabilized low-pressure PE filled with talc, iron powder, as copper powder with a particle size of 30—50 $\mu$ . The substrates were electrochemically degreased 08KP steel or copper foils (70 $\mu$  thick), or aluminum foil (60 $\mu$  thick).

The polymer and substrate were joined at 200°C and 20 kg/cm<sup>2</sup> for 5 minutes. The adhesion strength was measured in stripping tests. The results of the tests conducted with individual fillers (see Fig. 1) indicated that the adhesion strength of PE filled with metal powders is several times that of PE filled with talc because of the more active adhesive interaction of PE with metal particles than with particles of inert talc [2].

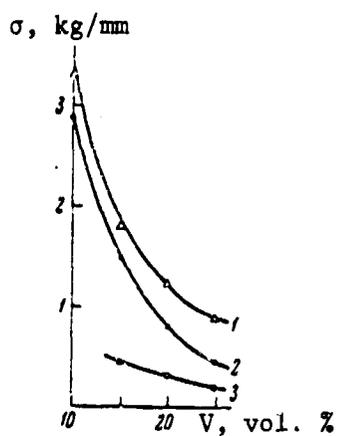


Fig. 1. Adhesion strength (determined in stripping tests) of filled PE vs. volume content of filler:

1 - Iron powder; 2 - copper powder;  
3 - talc.

### Chemical Treatment of the Metal Surface

A study of the adhesion of filled and unfilled PE to electrochemically degreased steel indicated that further chemical treatment of the steel surface has a considerable effect on the adhesion strength. The results of the study are given in Table 1.

The highest adhesion strength was exhibited by specimens treated with sulfuric acid and sodium dichromate; failure of the joints was cohesive. Enhanced adhesion strength was ascribed to an increase in the specific reactivity of the steel surface in the course of etching [2].

Table 1. Effect of the nature of steel surface treatment on the adhesion strength (measured in stripping tests) of filled and unfilled PE to steel

Type of surface treatment	Adhesion strength, kg/cm, and character of the failure*	
	Unfilled PE	PE filled with 15 vol. % talc
Untreated surface	0.22A	2.30M
Passivation	---	2.14M
Treatment with H <sub>2</sub> SO <sub>4</sub> + Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> · 2H <sub>2</sub> O	0.50A	2.38C
Phosphatizing	0.31A	2.06M
Oxidation for 3 hr:		
at 250°C	---	1.70M
at 330°C	0.03A	0.33A
at 400°C	0.05A	0.87A

\* A - Adhesive, M - mixed, C - cohesive

#### Depositing of Fatty Acids on the Metal Surface

PE to metal adhesion strength can be increased by depositing a monomolecular fatty acid layer on the metal surface. Layers of stearic, oleic, or other acids can be deposited on Kh18N9T stainless steel and D16ATV Duraluminum by immersion of metal specimens in 1% fatty acid solutions in white spirit at 60°C, or by polishing the metal surfaces with a paste containing an abrasive, white spirit, and the fatty acid. Both methods yield polymolecular acid layers. Molecules in contact with the metal can be chemisorbed by the metal surface and form salt-like compounds. The remaining molecules are only adsorbed.

To enhance the modification of the metal surface, the specimens were heated for 20 minutes at 200°C. The absorbed acid was reworked by extraction with benzene for 1 hour at 70°C. This treatment left an oriented monomolecular layer of chemisorbed fatty acid on the metal surface. Metal specimens with these modified surfaces were bonded together with high-pressure

PE films 100 $\mu$  thick at 155°C for 1 hour under a pressure of 2.3 kg/cm<sup>2</sup>. No adhesive was used because, above its softening or melting points, PE acquires the properties of an adhesive.

Stearic or oleic acid films increased the PE-to-steel bonding strength by 10—15% and 37—54%, respectively. The failure of the joints was cohesive. Modification of metal surfaces with fatty acids was shown to enhance the resistance of joints to water; the best results were obtained with oleic and other unsaturated acids.

The effect of fatty acids was explained as follows: the acids form salt-like compounds on metal surfaces which are strongly bonded to the metal, while the fatty acid hydrocarbon radicals penetrate into molten PE and, after solidification of the latter, form bonds between the metal and the polymer. In the case of oleic acid, under the bonding conditions selected (155°C, 1 hour), oxygen-containing functional groups are formed via oleic acid double bonds and similar groups on the surface-layer molecules of PE, which always contains a small number of double bonds. The reaction of these functional groups increases the PE-to-metal bond strength, which results in strong intermolecular interactions, formation of chemical bonds via the oxygen-containing groups, or copolymerization along the double bonds [3].

#### Graft-Copolymerization of Polyethylene

PE-to-metal adhesion strength can be increased by modification of the polymer surface layers by radiation-induced graft-copolymerization. Graft copolymers of PE with such monomers as isoprene, vinyl acetate, vinylidene chloride, 2-vinylpyridine, acrylonitrile, methyl methacrylate, acrylic acid, methacrylic acid, or 2,3-epoxypropyl methacrylate were prepared by various radiation-induced graft-copolymerization methods. The copolymer specimens were in the form of films 3 to 5 mm thick. The percentage grafting for individual films varied from 0.5 to 100%.

The films were bonded to mechanically treated and pickled aluminum plates with a composition of ED-5 epoxy resin and polyethylene-polyamine (curing agent). The specimens were bonded by holding under a slight pressure for 2 days at room temperature. The adhesion strength was measured in peeling tests at a rate of 18.5 cm/min.

The adhesion strength of all graft-copolymer films to aluminum specimens, with the exception of PE-poly(2,3-epoxypropyl methacrylate) (PEPM) copolymers, was below 0.1–0.2 kg/cm. The adhesion strength of some PE-PEPM copolymer films was higher than the cohesion strength of the copolymer. The high PE-PEPM adhesion strength was attributed to the formation of chemical bonds between the grafted layer and the epoxy resin. The curing agent (polyethylene-polyamine) reacts simultaneously with the epoxy groups and the grafted PEPM molecular chains.

Adhesion of PE-PEPM graft-copolymers was shown to depend on the conditions of radiation-induced graft-copolymerization. These conditions determine the structure and the topography of the grafted surface layer. High adhesion (up to 1.7 kg/cm) was exhibited by copolymers prepared by direct irradiation of PE films in PEPM solutions in poor solvents, such as methyl alcohol or dimethylformamide, in which graft-copolymers with rough surfaces are formed.

The presence of epoxy groups made it possible to introduce into the copolymers such functional groups as  $-\text{NO}_3$ ,  $-\text{SH}$ , or  $-\text{H}_2\text{PO}_4$  to improve protection of the metal against corrosion. Grafted PE-PEPM films treated with monoethanolamine were shown to adsorb various azo dyes.

Similar results were obtained on bonding PE-PEPM graft copolymers to steel, titanium, and copper. The strongest bonds were obtained for copolymer films with a grafting percentage of 30 to 40% and a thickness of the grafted layer of 0.36 mm and over. The thickness of the grafted layer was controlled by the dose rate, which should not exceed 1.0 to 1.5 rad/sec. [4, 5].

### Analyst's Comment

These methods make it possible not only to enhance the PE-to-metal adhesion strength but also, in the case of PE-PEPM, to introduce functional groups into grafted PE which will improve the protection of the metals against corrosion.

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# **SURVEYS**

## **INSTRUMENT DEVELOPMENTS AND RESEARCH TRENDS IN RADIO ASTRONOMY**

by Daniel W. Michaels

*SUMMARY: Inventory is made of existing and planned radiotelescopes in the Soviet-bloc states. First investigations conducted with the UTR-1, the RT-22, and the Pulkovo instrument are described. Comparisons with regard to resolution are made of worldwide instruments. A proposal for an international radiotelescope is examined.*

During the past few years, several new radioastronomical telescopes have been put into operation in the USSR to supplement and expand research initiated at the older radio astronomical centers in the Main Astronomical Observatory -- Pulkovo (GAO), the Scientific Research Institute of Radiophysics at Gor'kiy State University (NIRFI), and the Lebedev Physics Institute (FIAN). The technical specifications of some of these instruments, viz., the DKR-1000 at Serpukhov and the RT-15 at Zimenki, have already been described\*; those of the older instruments, described in Table I, are now common knowledge. Little information, however, has been provided on the UTR-1 and the UTR-2, which were put into operation in 1966 and 1968 by the Institute of Radiophysics and Electronics (IRE) of the Ukrainian Academy of Sciences, or of the new 22-m (RT-22), which went into operation in the Crimean Astrophysical Observatory in 1966.

The RT-22 radiotelescope, which is an improved and modified version of the 22-m instrument in operation at FIAN since 1959, has a focal length of 9525 cm and an angular aperture of  $2 \psi = 120^\circ$ . The guidance system, especially designed for the RT-22 by I. I. Pogochev, N. M. Yakimenko, Yu. N. Semenov, N. N. Voronin, I. G. Moiseyev, V. A. Vvedenskiy, and V. N. Brodovskiy, provides: 1) automatic and semiautomatic setting of the radiotelescope on given coordinates; 2) hourly

\* FSB, v. 1, no. 8, 1965, 1-8; v. 2, no. 5, 1966, 20-22.

RADIO ASTRONOMY OBSERVATORIES AND INSTITUTES

<u>Location</u>	<u>Observatory or Institute</u>	<u>Description</u>	<u>Frequency</u>	<u>Date</u>
Abastumani, Georgian SSR	Astrophysical Observatory -- Mt. Kanobili; Georgian Academy of Sciences	Satellite tracking facilities	20 mc	
Ashkhabad (Berezeni) Turkmen SSR	Physicotechnical Institute Turkmen Academy of Sciences	15-m (under construction)		
Berlin-Adlershof, GDR	Heinrich Hertz Institute; Deutsche Akademie der Wissenschaften	36-m (118') paraboloid, steer- able in altitude. Resolution 54' x 54'. Transit mount	54 cm 38 cm	1960
Baldone (Riga), Latvia	Astrophysical Laboratory; Latvian Academy of Sciences	Interferometer; satellite tracking	183 mc	
Budapest, Hungary	Polytechnical University	Satellite tracking	1.5--460 mc	
byurakan, Armenian SSR	Astrophysical Observatory; Institute of Radiophysics and Electronics (IRFE); Armenian Academy of Sciences	Four cylindrical paraboloids fixed. 10-m (32.8') paraboloid		
Simeiz (Crimea) RSFSR	Crimean Astrophysical Ob- servatory; Lebedev Physics Institute (FIAN)	18--8-m (59 x 26.2') cylindrical paraboloid, steerable, altazimuth. 19-m (62.8') paraboloid, steerable altazimuth Two 31-m (101') fixed, transit zinc-painted on concrete, used as interferometer with 800 m E--W baseline 72-m (236') steerable, paraboloid, 22-m (72') paraboloid (RT-22)	To 1.4 Gc	1966

Table I (Continued)

<u>Location</u>	<u>Observatory or Institute</u>	<u>Description</u>	<u>Frequency</u>	<u>Date</u>
Cor'kiy, RSFSR	Scientific Research Institute of Radiophysics at Cor'kiy State University (NIRFI)	Mills Cross. T-form steerable beam antenna system (UTR-1). N--S arm consisting of 80 dipoles is 600 m long; E--W arm consisting of 128 dipoles is 576 m long.	10-25 mc	1966
Khar'kov (Chuguyev), Ukrainian SSR	Khar'kov Radioastronomical Observatory; IRE (Institute of Radiophysics and Electronics); Ukrainian Academy of Sciences	Mills Cross. Steerable beam antenna system from three 900-x 90-m fields (UTR-2). N--S arm (two fields) is 1800 m long and 60 m wide; E--W arm (one field) is 900 m long and 60 m wide. Resolution beam width is 45' x 1° 30' at 12 m and 1° 44' x 3° 45' at 30 m		1968
Kislovodsk, RSFSR	Pulkovo Observatory; Southern Station	Two 10-x 2-m (33 x 7') cylindrical paraboloids. Transit mount	178 mc	
Leningrad, RSFSR	Pulkovo Observatory (GAO)	16-m (52.5') fixed paraboloid. 120-x 3-m (394 x 10') parabolic sector (adjustment in altitude only). Resolution 8' x 200' at 21 cm and 2' x 30' at 3.2 cm. Two 12-m (39.4') paraboloids. Transit mount. Used as interferometer with parabolic sector	300 mc 1000-- 3000 mc 178 mc	1958  1951

<u>Location</u>	<u>Observatory or Institute</u>	<u>Description</u>	<u>Frequency</u>	<u>Date</u>
Moscow, RSFSR	Institute of Terrestrial Magnetism, Ionosphere, and Radiowave Propagation (IZMIRAN); Main Astronomical Institute Im. Shternberg (GAISH)	Satellite tracking	20--360 mc	
Panska Ves, Czechoslovakia	Geophysical Institute			
Potsdam, GDR	Potsdam Astrophysical Observatory, Deutsche Akademie der Wissenschaften	10.5-m (34.4') steerable paraboloid. Equatorial mount	To 3 Gc	
Serpukhov, RSFSR	Serpukhov Radiophysics Observatory; Lebedev Physics Institute (FIAN)	22-m (72') paraboloid, steerable altazimuth with resolution of 50 x 50' at 21 cm and 1 x 1' at 4 mm Two 1 km x 40 m (328 x 131') parabolic cylinders steerable in altitude, used as Mills Cross (DKR-1000) to synthesize 500-m-aperture at 3 m Resolution 30 x 30' (7.9 m) and 13 x 13' (3.5 m). Transit mount.	To 37 Gc 50--150 mc	1960 1963
Warsaw, Poland	Polish Academy of Sciences	Satellite tracking	15--60 mc	
Ziminki, RSFSR	Ziminki Radioastronomical Station; Gor'kiy Physicotechnical Research Institute	Two 15.2-m (50') paraboloids (RT-15)		1962

settings; 5) automatic tracking of the Moon, planets, and artificial earth satellites; 4) the introduction of corrections; 5) automatic switching off of drives in finite positions of the reflector; 6) recording of all coordinates and sidereal time; 7) automatic scanning of sectors of the sky; and 8) rapid resetting. Observations of Jupiter and the Sun at 8 mm, conducted since 1966, have confirmed the high quality of the reflector surface and the reliability of the guidance control [6].

The Khar'kov Radioastronomical Observatory, under the direction of A. V. Men' and L. G. Sodin of the IRE of the Ukrainian Academy of Sciences, consists of two large T-form Mills Cross radiotelescopes made up of rows of 8-m-wide broad-band dipoles in staggered array, and is an excellent example of an advanced high-sensitivity and resolution instrument for investigations in the decameter wavelengths, i. e., below 30 mc. The first steerable beam instrument (UTR-1, 1966), having a N--S arm 600 m long consisting of 80 dipoles and an E--W arm of equal length consisting of 128 dipoles, provided experience for the construction of a second, larger instrument in 1968. The latter instrument is made up of three antenna fields each of which is 900 m x 60 m in size. The E--W arm is made of one such field, while the N--S arm consists of two successive fields 1800 m in length. Both instruments are intended to receive emission in the 10--25-mc range and for the observation of galactic and extragalactic radio sources [9, 10].

During 1966--1968, A. V. Men', I. N. Zhuk, B. P. Ryabov, O. M. Lebedev, and S. Ya. Braude used the UTR-1 to measure the spectra of 55 radio sources in the 12--25-mc range in an attempt to correlate spectra with discrete radio sources in the decameter wavelengths. Measurements were made simultaneously at five frequencies: 12.6, 14.7, 16.7, 20, and 25 mc. No less than 5--10 reliable measurements were made at each frequency for 38 sources. Four different spectral types were identified, though more than half of the sources yielded linear spectra in a broad frequency range from 12.5 to 1400 mc, indicating the same synchrotron emission generation mechanism [1, 2].

With regard to investigations of the radio lines of excited hydrogen, R. L. Sorochenko emphasizes the desirability of building larger radiotelescopes. Investigations at longer wavelengths and observations of the higher members of line series would make it possible to determine the maximum number of levels discernible in the hydrogen atom. Short-wave measurements will aid in correlating the results of radio observations with measurements in the optical range and in clarifying the laws establishing the population of energetic levels. Spectroscopic investigations in the radio range with high resolution are also necessary, as are observations of the recombination radio lines of other elements and the determination of the chemical composition of galactic formations [11].

The main task of future radioastronomical investigations conducted above the atmosphere (balloon, satellite, rocket), according to Getmantsev, Salomonovich, and Slysh, is to observe the various types of solar radio emission bursts with the required degree of localization. To do this, antenna systems with sufficient angular resolution are needed. In addition, the frequency spectrum must be broadened in the direction of the lower frequencies so that the lower boundary frequencies of the bursts may be determined. Submillimeter investigations must be undertaken to successfully study background relict radiation, the interstellar and intergalactic media, infrared stars, quasars, and the Sun. According to these investigators, orbital satellites and rockets are more suitable for these studies than the use of balloons. In addition, high-precision submillimeter-range mirror antennas with the necessary tracking mechanism must be built and the receiving equipment must be cooled to the temperature of liquid helium under space conditions. Experiments are currently being conducted in FIAN under the direction of L. V. Kurnosova and A. B. Fradkova on the maintenance of helium temperature (below  $10^{\circ}$  K) on spacecraft. The experiments are considered promising [5].

In a discussion of investigations of solar radio emission and solar local sources, G. B. Gelfreykh has compared the resolving power of existing and planned radiotelescopes throughout the world (see Fig. 1). A resolution of 1-3 angular minutes

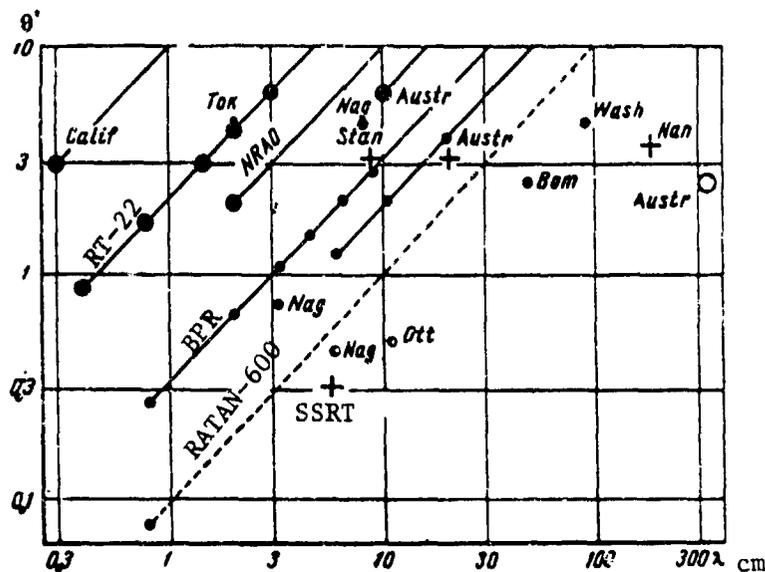


Fig. 1. Resolving power of radio telescopes in minutes of arc  $\theta'$  as a function of wavelength.

Black circle - Circular reflector; heavy dot with mark - unidimensional reflector; small circle - ring antenna; cross - cross interferometer; heavy dot without mark - unidimensional grid. Broken line refers to planned instruments, viz., the BPR (large Pulkovo radiotelescope), the RATAN-600, the RT-22 [now operative], and the SSRT (Siberian solar radiotelescope). Calif. - California; Nag. - Nagoya; Tok. - Tokyo; NRAO - National Radioastronomical Observatory of the USA; Austr. - Australia; Ott. - Ottawa; Wash. - Washington; Nan. - Nancay; Bom. - Bombay; Stan - Stanley.

is required to isolate an active solar region and obtain some idea of its structure. While there are many instruments with a resolution of this order in the centimeter range, only the BPR (large Pulkovo radiotelescope), a reflector, can make spectral observations of local sources in a broad range of wavelengths. There has been a tendency in recent years to increase instrument resolution: that of the BPR at 8 mm has reached 15 sec/arc; the solar interferometers in Japan and Canada are 0.5 angular minutes at 6 and 10 cm. Planned telescopes in the USSR, viz., the RATAN-600 of the Academy of Sciences USSR and the SSRT, the Siberian Solar Radio Telescope, will be able to conduct investigations in the centimeter range with a resolution up to 10--20" and even greater in the millimeter range. The RATAN-600 will

be able to make spectral observations, while the SSRT will contain two-dimensional radio images and track rapid changes in individual local sources. Such investigations will be useful in predicting solar activity [4].

Radioastronomical investigations require even greater telescope sensitivity and resolving power which, to date, have been achieved by increasing instrument size and refining antenna systems. To lessen the costs involved in such projects, several proposals have been advanced by Soviet investigators. G. M. Tovmasyan, for instance, has proposed a simple and inexpensive radiotelescope, essentially a two-mirror aerial system, called an annular or ring radiotelescope. The primary mirror is a stationary, horizontally mounted spherical ring several kilometers in diameter with a height of about 100 meters. The smaller secondary mirror — several meters in height — is located on the ground and can be moved on a circular railroad track along the focal line of the primary mirror. By mounting several (up to 20) such secondary mirrors on the track, it is possible to carry out quite independent and simultaneous observations in different directions. Another advantage of this instrument is that, unlike other radiotelescopes, the construction of an annular radiotelescope may proceed by sections with no interruption of observational activities. As soon as a portion of the reflecting surface of the ring has been built, it is possible, regardless of continuing construction work, to conduct observations in a specific range of declinations, with the range gradually expanded as new sections become available [12].

A group of leading Soviet radioastronomers, including Khaykin, Kaydanovskiy, Yesenkina, Korol'kov, Pariyskiy, Stotskiy, Shakhbazyan, and Shivris, have enthusiastically supported the idea of an international telescope, first advanced at the General Assembly of the International Radio Communications Union in Tokyo in 1963 and later discussed at the XII General Assembly of the Astronomical International Union in Hamburg in 1964. These investigators, after consideration of the factors involved in such an undertaking, conclude that: 1) the optimum wavelength range of such an instrument is from 3--7 cm to 1--2 m with continuous scanning of the whole range; 2) the

resolving power of the radiotelescope should be of the same order as that of optical instruments; and 3) the construction of a radiotelescope with an effective area not exceeding  $10^7$  sq meters is feasible. The telescope, further, should be a reflector in order to provide broad bands and aperture synthesis. The authors maintain that an instrument of the Pulkovo type would be more satisfactory than either a Kraus type\* or a Nancay type\*\*. A varying profile antenna with the following parameters is suggested for the international instrument: maximum geometric area,  $4.4 \cdot 10^6$  sq m; radius of basic circle, 10 km; height of elements, 100 m; width of elements, 30 m; minimum wavelength, 10 cm; maximum wavelength, 2 m; maximum resolving power, 1 sec of arc; overall weight,  $3 \cdot 10^6$  tons. It is possible that the optimum wavelength range be shifted to higher frequencies up to the short centimeter wavelength for polarization measurements, radio lines, and experiments in communications with other civilizations [7, 9].

Fig. 2 illustrates the basic principles of the 100-x 21-m radiotelescope in Ohio, designed by Kraus, as well as the 300-x 35-m Nancay radiotelescope in France. Fig. 3 depicts the operating principles of a Pulkovo-type instrument with

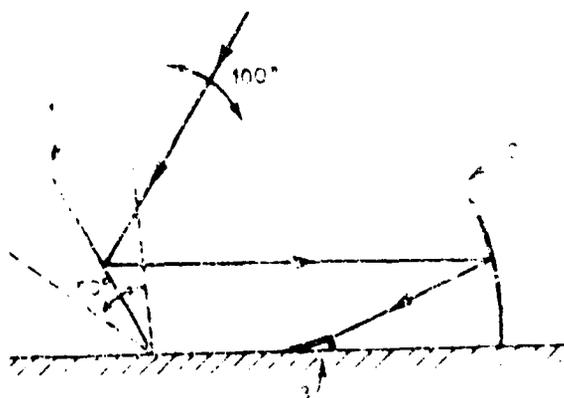


Fig. 2. Krauss and Nancay radiotelescopes

1 - Periscope, 2 - main mirror, 3 - radiator

\* Nature, 184, 1959, 669.

\*\* Nucleus, no. 2, 1960, 93.

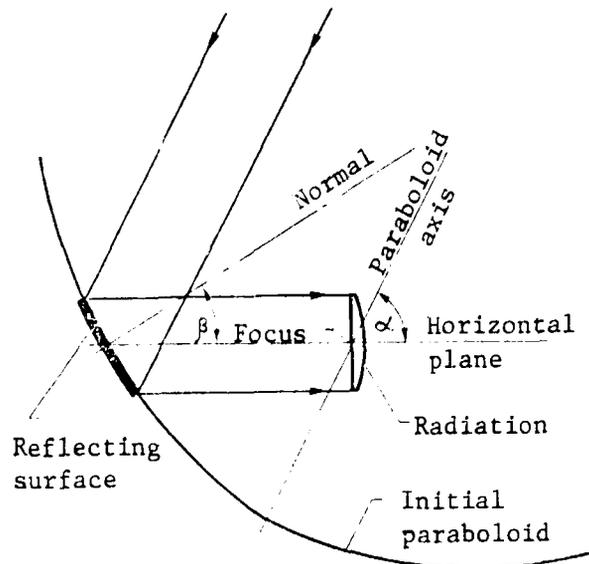


Fig. 3. Pulkovo-type radiotelescope

variable profile. The reflecting surface of this instrument, which consists of several separate almost flat-reflecting elements, touches part of the surface of the rotation paraboloid expressed by two horizontal planes symmetrically situated relative to the focus of the paraboloid.

In a recent study by these same investigators, it is noted that the large variable-profile Pulkovo radiotelescope has a horizontal resolution of about one angular minute at 3 cm, which exceeds the resolution of all presently existing parabolic radiotelescopes. It has further been established that the working wavelength can be reduced sharply by replacing the instrument's plane reflecting elements with cylindrical elements having a curvature radius of about 120 m. Operation of the instrument in the 8-mm range using only the central part of the reflecting surface with a vertical dimension of 2 m and a horizontal dimension of 112 m was evaluated. The configuration of the directional diagram and the effective area of the antenna were investigated through the use of both a ground source and the records of Venus, the Moon, and the Sun at 8--9 mm. For

operation with a ground generator, the antenna surface was given the configuration of an elliptical cylinder. The generator is located at one of the foci of the central section of the cylinder and the exciter at the other. The width of the horizontal antenna radiation pattern at 8.5 mm at half power was  $15'' \pm 1''$  with a level of the side lobes less than 10 db and a scattered background of less than 23 db. During September 1967 the instrument was used to observe Venus, the Moon, and the Sun with a resolution of  $15''$ . Further improvement of the adjustment methods, according to the authors, will make it possible to obtain an accuracy in antenna setting for high-elevation angles equal to  $15''$ . The accuracy of this radiotelescope is estimated to be 6--7 times greater than that of the best paraboloids. Theoretical studies indicate that a top resolution of 1 angular second is attainable. No further increase in resolution is considered possible, owing to atmospheric turbulence and the Earth's curvature [8].

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## HETEROCYCLIC ORGANOPHOSPHORUS COMPOUNDS

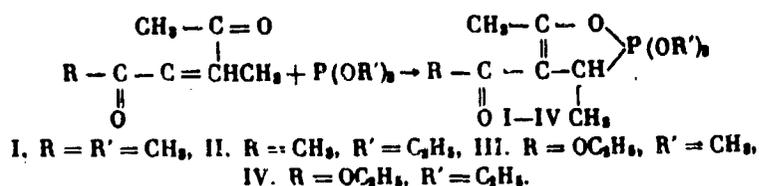
by Seraphim Parandjuk

*SUMMARY: A review is presented of some recent Soviet chemical publications (1967-1969) dealing with methods of synthesis, properties, and application of heterocyclic organophosphorus compounds (cyclic phosphoranes, phospholenes, phospholenes, and phospholine oxides).*

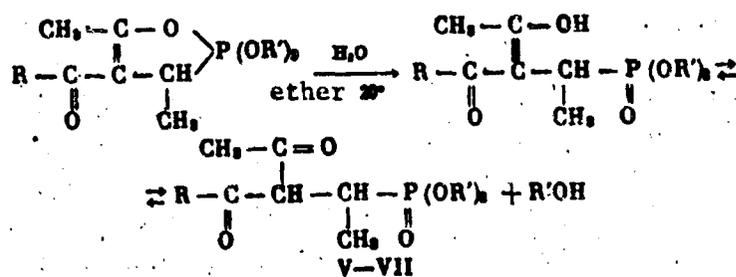
In recent years, the number of articles published by Soviet chemists on the synthesis of organophosphorus compounds has increased to the extent that in 1967 the editors of *Zhurnal obshchei khimii* (Journal of General Chemistry) published a special issue, a collection of articles, entitled "The Chemistry of Organophosphorus Compounds" [1]. In the past few years, more than 700 articles on organophosphorus compounds have been published by chemists of the A. Ye. Arbuzov School at Kazan State University and at the A. Ye. Arbuzov Institute of Organic and Physical Chemistry, Academy of Sciences USSR, Kazan [2]. The interest of Soviet chemists in organophosphorus compounds is prompted by their importance in defense, agriculture, and industry. Most important chemical warfare agents, such as tabun, sarin, soman, V<sub>2</sub>, V<sub>3</sub>, V<sub>4</sub>, V<sub>5</sub>, etc., are organophosphorus compounds [3, 4]. Organophosphorus compounds also include important insecticides, defoliants, herbicides, fungicides, drugs, plasticizers, surfactants, extracting agents, thermostable polymers, oil additives, fertilizers, etc. [5, 6].

Due to the wide scope of research and to the large number of articles dealing with the synthesis, properties, and application of organophosphorus compounds, review articles have usually included literature only on certain groups of organophosphorus compounds. Since 1964, the Soviet chemical review journal *Uspekhi khimii* (Advances in Chemistry) has published

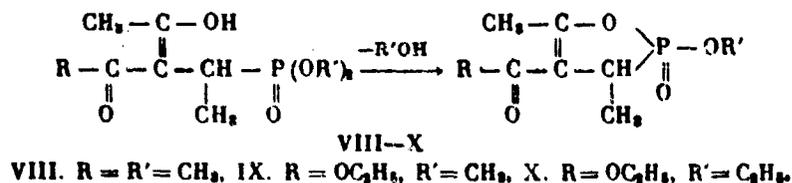




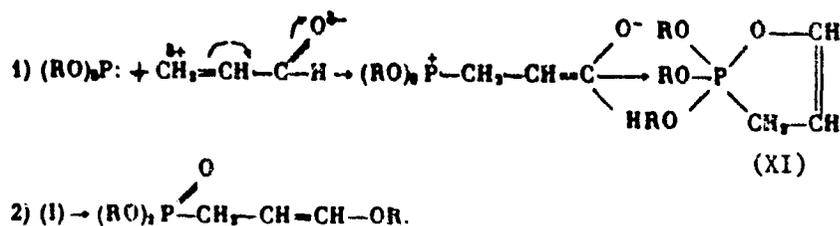
which takes place in dry nitrogen at 20--40°C. At room temperature in ether, aqueous hydrolysis of the cyclic phosphoranes proceeds with ring cleavage to form dialkyl alkylphosphonates (V--VII):



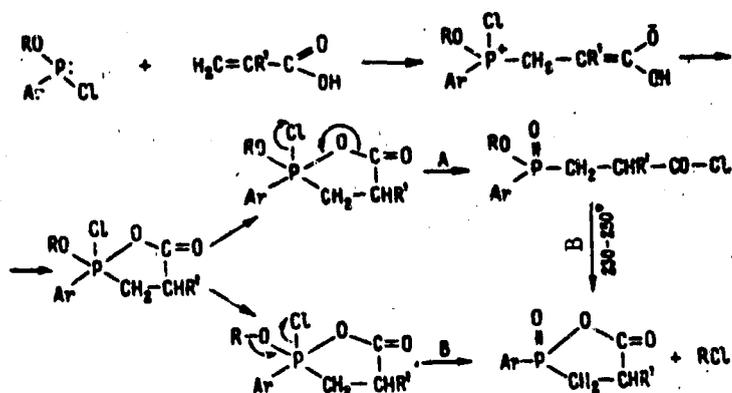
On distillation in vacuum, the phosphoranes are converted to cyclic esters with the elimination of alcohol:



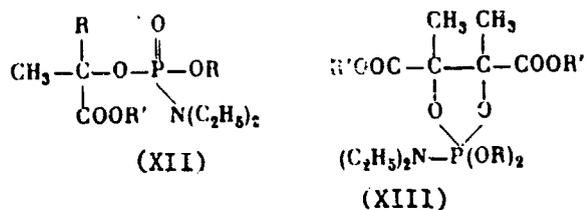
The addition of trialkyl phosphites to acrolein to form cyclic phosphorane (XI) proceeds in two stages with Arbuzov rearrangement [22]:



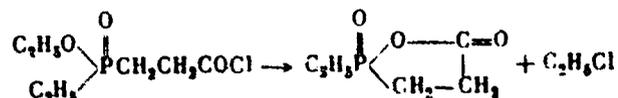
Another team of organophosphorus chemists, headed by A. N. Pudovik at the A. Ye. Arbuzov Institute of Organic and Physical Chemistry, Academy of Sciences USSR, Kazan, studied the reactions of chlorinated alkyl phosphites, alkyl arylchlorophosphites, and amidophosphites with unsaturated and carbonyl-containing compounds. The reactions of alkyl arylchlorophosphites with acrylic and methacrylic acids to form heterocyclic organophosphorus compounds, depending on conditions proceed according to the following two mechanisms [23]:

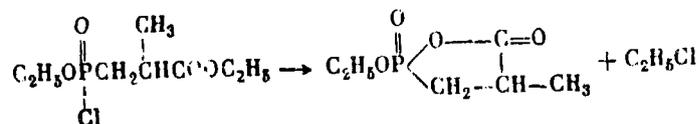


The reactions of dialkyl amidophosphites with methyl and ethyl esters of pyruvic acid proceed, depending on conditions, with the formation of phosphates (XII) and dioxaphospholanes (XIII) [24]:

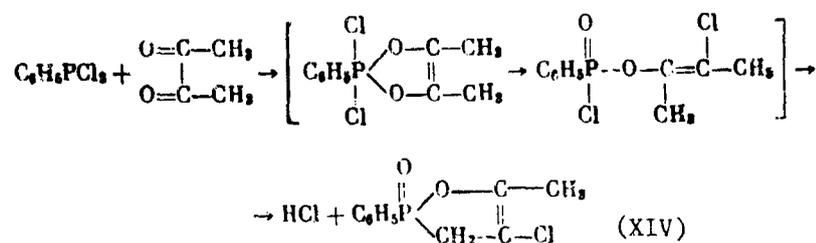


Phospholanes were also obtained by the cyclization of ethyl ethyl( $\beta$ -chloroformylethyl)phosphinate and chlorides [25]:

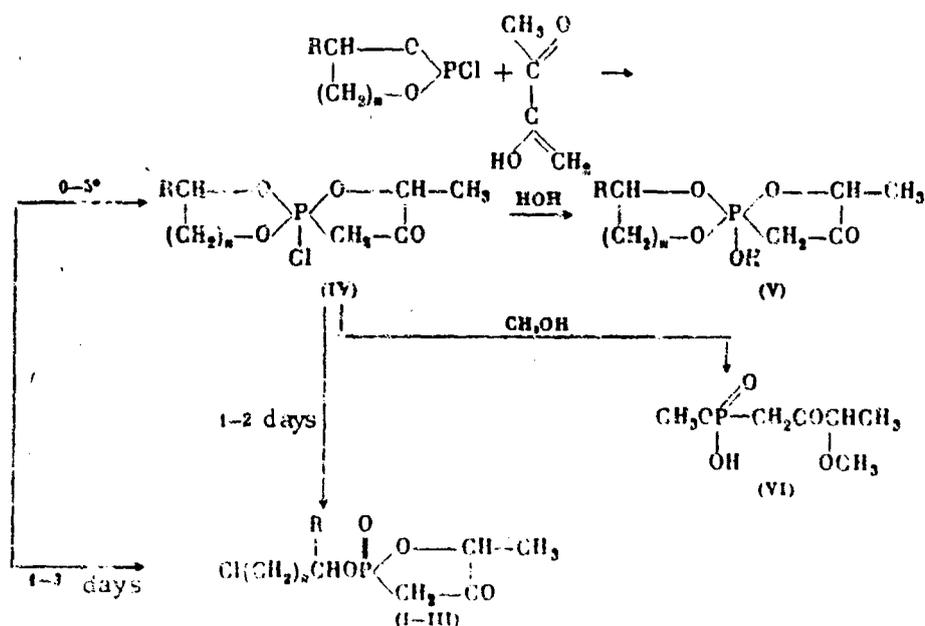




5-Methyl-2-phenyl-4-chloro-2-oxo-1, 2-oxa-4-phospholene (XIV) was synthesized according to the reaction [26]:



A series of 23 articles entitled "Phosphorus-containing heterocycles" was published during the last 6 years by a third team of Soviet organophosphorus chemists (N. A. Razumova, A. A. Petrov, and others) at the Leningrad Institute of Technology, Leningrad. The preparation and properties of sulfur-containing derivatives of phospholene oxide by the condensation of monothioethylglycolphosphorous acid chlorides with  $\alpha, \beta$ -unsaturated ketones is reported [27]. A series of chlorinated P-containing heterocyclic compounds was synthesized according to the following reaction scheme [28]:



(I) R = H, n = 1; (II) R = CH<sub>3</sub>, n = 1; (III) R = CH<sub>3</sub>, n = 2; (IV, V), R = H, n = 1.

The preparation of brominated phospholine oxide derivatives by the reactions of bromides of glycolphosphorous acid with diene compounds is reported [30].

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## NOTES

### THE PROGRAM AND THE INSTRUMENTATION OF THE "KOSMOS-149" SATELLITE

On 21 March 1967 the Kosmos-149 satellite was launched into an orbit with the following parameters: apogee, 297 km; perigee, 248 km; and inclination to the equator, 48.8°. A general view of the satellite is shown in Fig. 1. An aerogyroscopic system, providing a three-axis orientation in space with an error not exceeding 5°, is used for satellite stabilization.

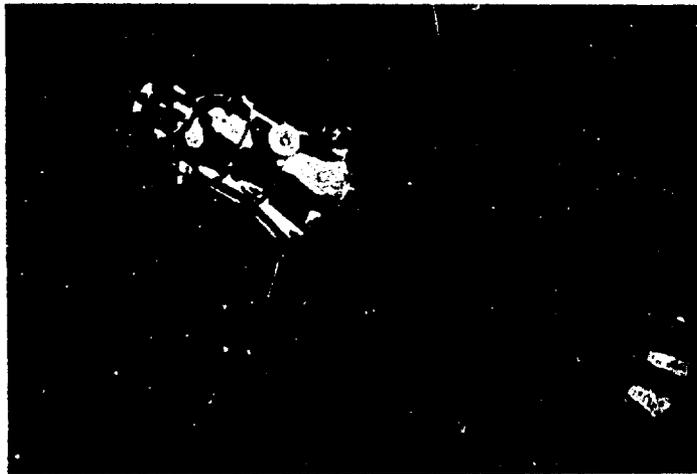


Fig. 1. General view of the "Kosmos-149" satellite showing location of instrumentation

1 - SA radiometer; 2 - TV illuminator; 3 - TF-3A telephotometer; 4 - TF-3B telephotometer; 5 - RB and TS transducers; 6 - antennas; 7 - stabilizer advance mechanism; 8 - aerodynamic stabilizer rods; 9 - aerodynamic stabilizer.

The basic scientific objectives of the satellite were to measure the spatial, angular, and spectral distribution of solar radiation reflected by the Earth, and to measure the Earth's outgoing radiation [1].

NOT REPRODUCIBLE

## Instrumentation

The measuring equipment consists of TF-3A and TF-3B telephotometers for the visible region of the spectrum and an SA radiometer and RB radiation balance meter for the infrared regions.

The TF-3A telephotometer ( $3^\circ$  viewing angle) is mounted in the satellite's nose cone. It scans in a plane perpendicular to the direction of flight and measures the intensity of solar radiation reflected from the Earth in narrow regions of the spectrum centered at  $0.34$ ,  $0.47$ , and  $0.74 \mu$ . The second telephotometer, the TF-3B (which is identical to the FT-3A), scans along the flight path and measures the intensity of the reflected solar radiation in the regions of absorption of water vapor ( $0.72 \mu$ ) and molecular oxygen ( $0.76 \mu$ ) and in a comparison region ( $0.74 \mu$ ). Fig. 2 is a general view of the TF-type telephotometer. The telephotometers measure the reflected solar radiation within  $0.5-60 \text{ mw/cm}^2 \cdot \text{sterad} \cdot \mu$ .



Fig. 2. TF telephotometer

An exploded view of the telephotometers is shown in Fig. 3 [2]. The measured radiation, after passing through a cover made of synthetic quartz, is reflected from a plane mirror, which performs circular scanning by rotating with a period of 1.8 sec. The radiation then passes through a tubular diaphragm, a system of interference filters, and the aperture of a

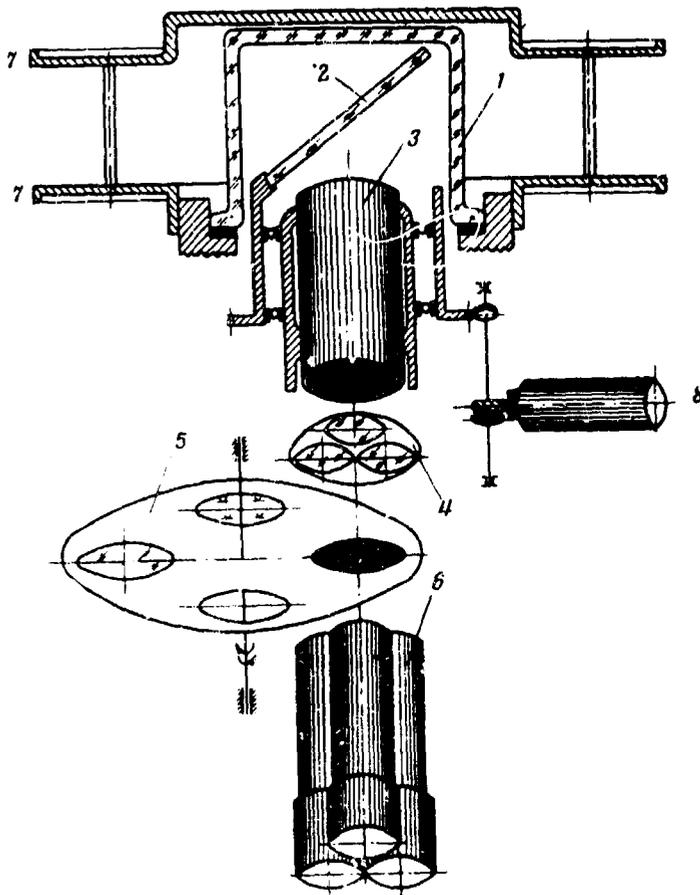


Fig. 3. Exploded view of telephotometer

- 1 - Protective quartz cover; 2 - scanning mirror;
- 3 - collimator; 4 - interference light filters;
- 5 - programmed disk; 6 - photomultipliers; 7 - protective blinds; 8 - reversible motor.

programmed disk, and falls simultaneously on three photomultipliers. The output signals from the load impedances of the photomultipliers are sent to EMU-9 electrometer amplifiers. Signals from each of the three amplifiers can in turn be sent either to a telemetry system or to any of the registering devices. The rotation of the motor is transmitted to a scanning head and a cam, which controls the motion of the programmed disk. The electrometer amplifiers are d-c amplifiers with a parallel negative voltage feedback. They use both vacuum tubes and transistors. The range of currents which can be measured is about  $4 \cdot 10^{-9}$  to  $10^{-5}$  a, and the voltage gain is about  $10^4$ . The upper limit of the transmission band, which depends on the time constant of the feedback circuit, is 100 Hz. The output impedance of the amplifiers is 10 kohm. The rated power consumption is 40 mw. The total measurement error of the amplifiers for a year's operation without adjustments at  $10^\circ$  to  $40^\circ\text{C}$  was within  $\pm 5^\circ$ . The spectral characteristics of the amplifiers, filters, and telephotometers were determined by 0.34- $\mu$  and 0.47- $\mu$  spectrometers with resolutions of 20  $\text{\AA}$  and 2  $\text{\AA}$ , respectively.

The Earth's radiation in the 8—12 $\mu$  range is measured by SA-type radiometers (see Figs. 4 and 5). The radiometers were designed on the principle of a two-beam circuit which periodically compares the measured radiation intensity with the cosmic radiation, which was considered to be the zero level. The mirror parabolic lens (1) has a focal length of 30 mm, while the effective bolometer area is 1 x 4 mm. The radiation flux is interrupted by a modulator in the form of a polarized relay, on whose curvature a modulator (2) is mounted. The modulation is placed symmetrically with respect to both optical channels and the detecting element. This arrangement eliminates the effect of the temperature of the modulator on the measurements. An interference filter (3) is mounted between the modulator and the detecting element. The self-radiation of the filter is not modulated and, therefore, has no effect on the variable component of the signal detected by the bolometer. The bolometer is equipped with a thermistor for measuring the temperature of the instrument. To reduce the effect of

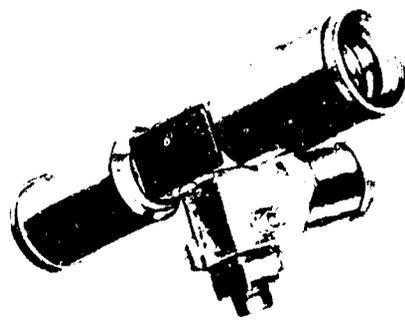


Fig. 4. SA radiometer

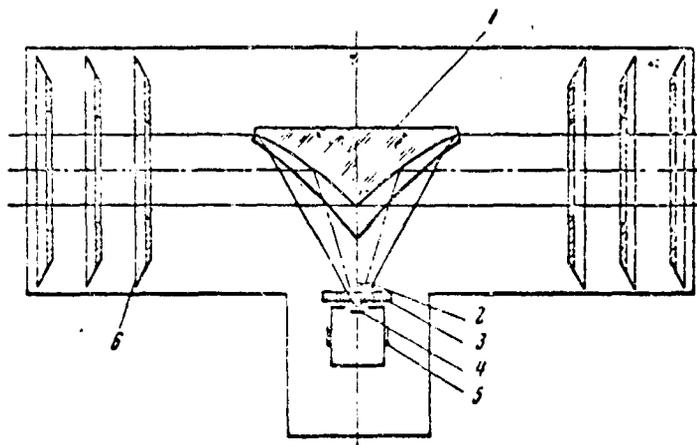


Fig. 5. Schematic diagram of the SA radiometer

1 - Parabolic lens; 2 - modulator; 3 - filter;  
4 - bolometer detecting plate; 5 - thermistor;  
6 - blind.

side illumination, blinds with diaphragms (6) are placed in front of the lens. The amplifier of the radiometers consists of the following components: an input resonance transformer, an a-c amplifier, a resettable detector, and an output d-c amplifier. The sensitivity of the entire amplifier system with an S/N ratio of 1 is not less than  $2 \cdot 10^{-8}$  v. The measurement error of the amplifier, for a year's operation at  $10^{\circ}$  to  $40^{\circ}\text{C}$  was within  $\pm 5\%$ . The required power consumption is 380 mw. The radiometers are calibrated to measure radiation intensities of 0.1 to 1.2  $\text{mw} \cdot \text{cm}^{-2} \cdot \text{sterad}^{-1} \cdot \mu^{-1}$  in the  $8-12\mu$  spectral range, corresponding to temperatures of  $200-320^{\circ}\text{K}$  [3].

A general view of the RB radiation balance meter, designed to measure shortwave ( $0.3-3\mu$ ) and longwave ( $3-40\mu$ ) radiation fluxes, is shown in Fig. 6. The absolute sensitivity of the radiation detectors was controlled by measuring the radiation balance [4]. Basically, a radiation balance meter consists of two sections, radiation transducers and electronic circuitry. During measurements, one part of the transducer is directed toward the nadir and the other toward the zenith. Each set of transducers contains three radiation detectors for measuring integral fluxes. A radiation detector (Fig. 7) contains a balloon filled with xenon up to 400 mm Hg with a semispherical filter. The detector plates, together with a thermopile, are rigidly attached to a copper base. A disk-shaped detector plate to which "hot" junctions of the thermopile are attached, is placed

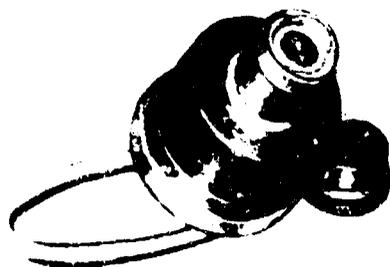


Fig. 6. RB radiation balance meter

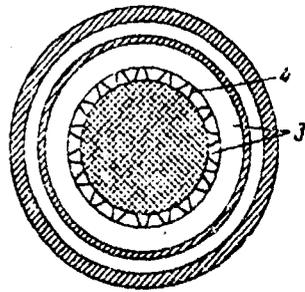
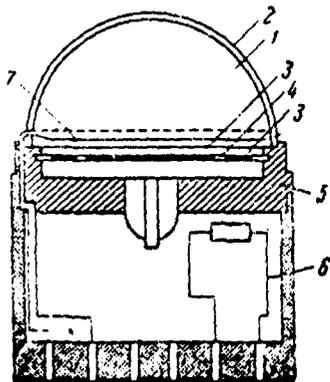


Fig. 7. General view of the radiation thermoelement

- 1 - Xenon-filled balloon; 2 - filter;  
 3 - detecting plates; 4 - thermopile;  
 5 - copper base; 6, 7 - resistance thermometers.

in the center. Another ring-shaped detector plate, to which "cold" junctions are attached, is placed around the disk. The detectors, which measure the short-wave solar radiation ( $0.3-3\mu$ ), contain filters made of uvicl glass, and those which measure the near-infrared radiation ( $0.8-3\mu$ ) contain IKS-3 filters. The use of a filter made of the KRS-5 crystal and the shiny white coatings of the detector plates makes the detectors virtually insensitive to short-wave solar radiation and transparent to long-wave radiation ( $3-30\mu$ ). The total detecting area of the thermal-radiation elements is  $1.9 \text{ cm}^2$ . Their average sensitivity is  $15-20 \text{ mv} \cdot \text{cal}^{-1} \cdot \text{cm}^{-2} \cdot \text{min}$ , and the coefficient of thermal sensitivity, about 0.5% per degree. The electronic circuitry of the measuring devices includes a mechanical switch for the sequential interrogation of the detectors, bridge circuits with resistance thermometers for measuring the

temperature, and amplifiers. A typical amplifier of the radiation balance meter is a transistorized d-c amplifier, consisting of a transistorized modulator, a blocking generator, an a-c amplifier, and detectors. The amplifier has the following basic parameters: input voltage, - 10 mv to + 30 mv; output voltage, 0 v to 6 v, and voltage gain, 150.

### Results

An analysis of the experimentally obtained data has shown that the instrumentation aboard the satellite has functioned as planned, and that the measured quantities are within the anticipated limits. Examples of photometric cross sections obtained with the TF-3A and TF-3B instruments are shown in Figs. 8 and 9. These data make it possible to construct spectral and angular distributions of the brightness of the Earth and to determine statistical characteristics of the spatial structure of the field of reflected solar radiation [5]. Fig. 9 also shows that the intensity of the reflected solar radiation in the water absorption band ( $0.72\mu$ ) considerably exceeds that at  $0.74\mu$  (comparison region), which cannot be explained by the accepted method of computation. This fact points to the possibility that a daytime glow of the atmosphere, comparable in intensity to the solar radiation reflected from the Earth, exists in the  $H_2O$  region. The results obtained with the SA radiometers and the RB radiation balance meters are shown in Figs. 10 and 11. The high accuracy of the SA radiometers has made it possible to detect the presence of an aerosol component in the transformation of the outgoing radiation of the underlying surface into the atmosphere.

[JR]

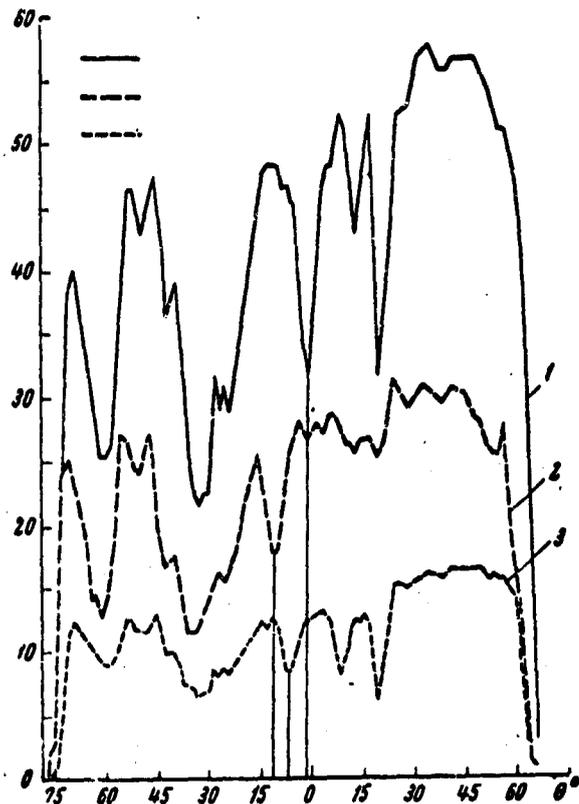


Fig. 8. Spatial distribution of the Earth's brightness in three spectral regions as measured by the TF-3A telephotometer

1 -  $0.47\mu$ ; 2 -  $0.74\mu$ ; 3 -  $0.34\mu$  ( $\theta$  - angle between the optical axis of the telephotometer and local vertical).

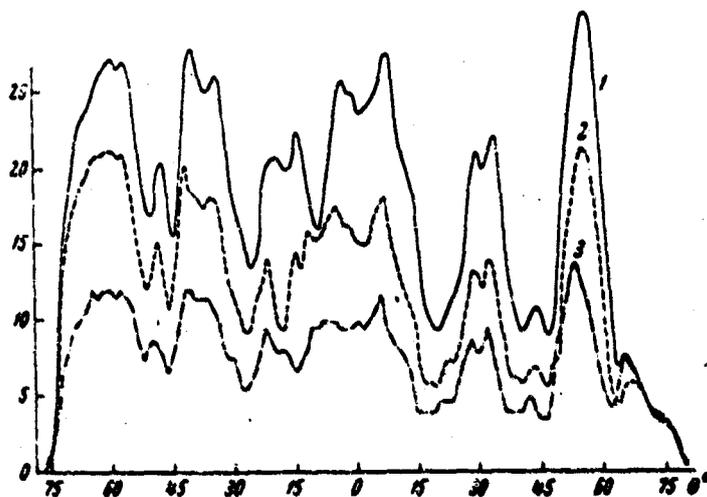


Fig. 9. Spatial distribution of the Earth's brightness in three spectral regions as measured by the TF-3B telephotometer

1 -  $0.72\mu$ ; 2 -  $0.74\mu$ ; 3 -  $0.76\mu$ .

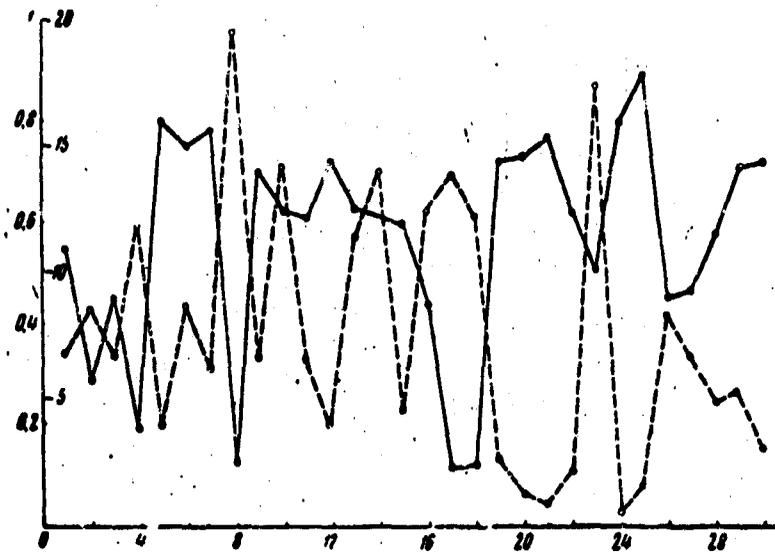


Fig. 10. Relationship between the reflected solar radiation  $I_{TF}$  at  $0.74 \mu$  (solid line) and the Earth's outgoing radiation  $I_{SA}$  (dotted line); N - number of cycle.

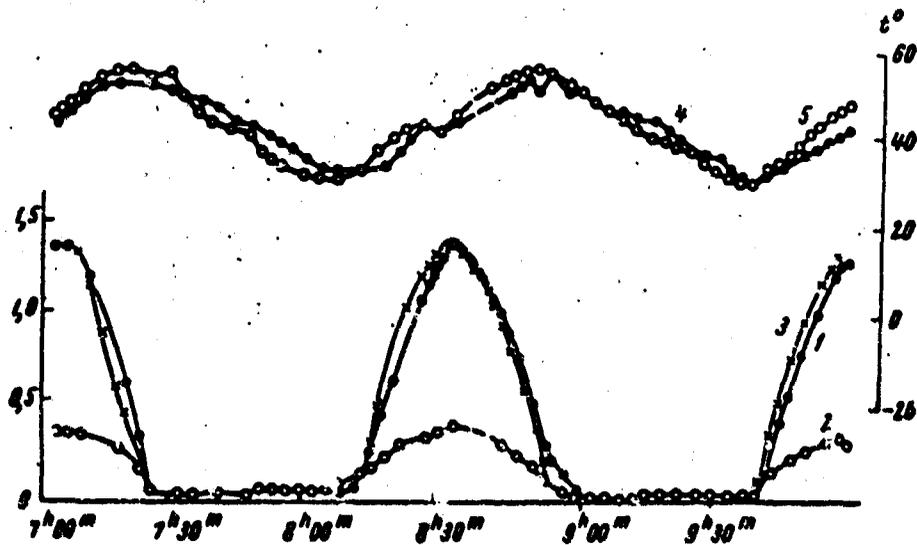


Fig. 11. Variation in time of radiation fluxes measured by the upper radiation balance meter

1 -  $0.3-3.0 \mu$ ; 2 -  $0.8-3.0 \mu$ ; 3 - calculated solar radiation fluxes ( $0.3-3.0 \mu$ ); 4, 5 - temperatures of corresponding receivers.

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## CONFERENCES

### SEMINAR ON THE PHYSICS AND CHEMISTRY OF PROCESSING MATERIALS WITH HIGH-ENERGY LASER BEAMS

The 16th Seminar on "The Physics and Chemistry of Processing Materials With High-Energy Beams," devoted to the effect of a laser beam on materials, was held 8-9 October 1968 at the Institute of Metallurgy im. A. A. Baykov, Academy of Sciences USSR, under the chairmanship of N. N. Rykalin. The seminar was attended by 113 scientists representing 42 organizations.

A. G. Solov'yev (Moscow), in a paper entitled "The effect of ambient media on the interaction between laser radiation and metals," reviewed a two-dimensional problem on how such characteristics of the interaction as evaporation rate and pressure vary, depending on the counterpressure of air, of an inert medium or, in a free-running mode, of metal vapors. Analysis revealed that the counterpressure of evaporation products due to a free-running laser pulse is of the same order as in the presence of a medium. A system of nine equations is used to describe the process. Elastic and inelastic interactions of atoms returning to the surface are discussed. The temperature difference between the two interactions does not exceed 5%. The magnitude of the pressure pulse in air at a flux intensity of  $10^{13}$  erg/cm<sup>2</sup>·sec differs from that in vacuum by as much as 30%.

In the paper "Energy characteristics of ruby-laser radiation" by N. V. Grevtsev, V. G. Karabutov, and Yu. L. Krasulin (Moscow), experimental data on the structure of the radiation of a free-running laser were discussed. A diaphragm with a minimum diameter of 2.5 mm was placed in front of the exit mirror, which made it possible to separate out the simplest modes. It was found that during the onset of generation, the simplest modes were set up first, followed by higher-order modes. The relative energy was evaluated from the film darkening. With increasing energy the number of diffraction maxima decreased. The average duration of micropulses, determined from the image contrast, was nearly 0.2  $\mu$  sec.

The divergence of each diffraction spike,  $4-6 \times 10^{-4}$  rad, was less than the total pulse divergence of  $2 \times 10^{-3}$  rad. Analysis of the experimental data showed that the spatial distribution of specific flux in a diffraction spike is Gaussian. The values of the concentration coefficient varied within  $1.2-20 \times 10^{-3}/\text{cm}^2$  and the average flux density within  $5 \times 10^5-5 \times 10^6$  w/cm<sup>2</sup>. Results of these experiments indicated that the spatial and temporal microstructure of radiation should be taken into account in many cases of materials processing.

V. F. Loskutov and P. I. Ulyakov (Moscow) presented the paper "Application of the similarity and dimensionality methods in describing the process of metal damage by laser radiation," which dealt with some theoretical aspects of the process. On the basis of the theory of similarity, a model function for the recoil pulse was constructed, the possibility of transition to extreme conditions (explosion or evaporation) was analyzed, and experimental verification of the relationships between the depth of penetration, the mass of ejected material, and the pulse power in zinc and molybdenum specimens was presented. It was noted that the thermal diffusivity of material has no significant effect on the magnitude of the recoil pulse; the latter changed by 10% when the former increased or decreased by one order.

In the report "On the possibility of iron carburization by means of a laser beam," L. I. Mirkin presented experimental data on the distribution of carbon in the beam-target interaction area of graphite-coated iron. Mirkin opined that the stirring which occurs in a liquid layer formed under the effect of radiation plays a significant part in the formation of the carburized case.

The report of V. P. Garashchuk, V. B. Zaytseva, and M. M. Nishchenko (Kiyev) on "The effect of laser-beam parameters on the depth of penetration in metals" concerned experiments in achieving deep penetration, a case which does not conform to the general theory of heat conductivity in solids. Experiments were performed with aluminum, nickel, copper, molybdenum, and stainless-steel specimens  $10 \times 10 \times 10$  mm in size using a free-running 15-16 joule ruby laser with a

well-defined spike structure and a pulse duration of 1.45 msec. The depth of penetration was found to be asymmetrical in relation to the focal point. No significant evaporation of material was observed. The maximum penetration was achieved with a specific radiation power of over  $10^3$  w/cm<sup>2</sup>, i. e., approaching the critical value at which specimens began to break down. Apparently, vapor recoil and convection in molten metal play a significant part in achieving a "dagger-shaped" penetration. With pulse duration increased to 3 msec, the shape of the penetration zone was still different from that which would have been achieved if the process conformed to the theory of heat conductivity.

The subject of deep penetration was also discussed by V. I. Trubitsyn (Moscow) in the paper "An experimental study of metal penetration with a laser beam." Experiments on nickel, molybdenum, and stainless-steel specimens 1 mm thick using a 2-4-joule laser equipped with a plane-mirror resonator at a pulse duration of 1.5-4.5 msec revealed that the depth of penetration depended primarily on the pulse duration. Trubitsyn believes that ejection of a portion of the molten metal from the target area is a basic mechanism promoting deep penetration, since it facilitates the passage of the beam through the metal. He presented interesting data on the penetration of three 0.2 mm-thick nickel plates located at a distance of 0.5 mm from one another by a laser beam focused on the surface of the last plate.

The report of M. L. Voshchinskiy, V. V. Zhukov, and I. V. Kupriyanov (Moscow) dealt with laser welding of copper wires 50  $\mu$  in diameter to copper films deposited on various glasses and "protositalls" coated with chromium. The welding was done with SU-1 and UL-2 lasers with a beam spot diameter of 100  $\mu$ . The intermediate resistance of laser-welded contacts was one order of magnitude lower than that of contacts bonded by any other method.

The results of an attempt to determine the recoil pulse generated by the action of a laser beam on a material were reported in the paper "Piezoeffect as a tool for investigating the interaction between pulsed lasers and metals," by B. M. Zhiryakov, A. K. Fannibo, and N. N. Yuryshv (Moscow). The authors used a barium titanate crystal as a pickup, with one end rigidly mounted and the other supporting the target material (copper, aluminum, tungsten, or titanium). The laser was used in free-running and Q-switched modes with a pulse duration of 1.5 msec. Two maxima were observed on the curves showing the dependence of the recoil pulse on the distance between the target and the focusing lens. The first maximum corresponded to the focal length and the second occurred at a distance well beyond the focus. The first maximum of the free-running laser was lower than the second maximum; for the Q-switched laser, the first maximum was higher than the second. This effect was observed at low energy densities (0.5-joule unfocused pulse). The analysis showed that the effect could not be explained by optical pressure, heating of air molecules close to the target, or photoeffect (pyroeffects were not considered). Therefore, it was assumed that the recoil pulse is a result of evaporation of the target material, which occurs even at flux densities as low as  $10^3 - 10^4$  w/cm<sup>2</sup>. The evaporation in such a case is explained by the fact that the flux density in an individual spike is very high, which leads to a severe heating of the target material even in an unfocused beam.

In the paper "An investigation of the threshold and specific features of the breakdown of nearly transparent dielectrics by free-running laser radiation," A. A. Orlov and B. F. Ponomarenko (Moscow) discussed the effect of laser radiation on numerous polymers and glasses. Polymers were found to have the lowest breakdown threshold and glasses, the highest. No correlation between mechanical and optical strength was observed. The results of the experiments confirmed the existence of a relationship between the heterogeneity of the material and its optical strength, and also the fact that damage begins at defects, where the optical beam causes microcracks to form.

In the paper "Kinetics of metal breakdown by radiation of a free-running laser," V. M. Kirillov and P. I. Ulyakov (Moscow) dealt with an experimental study of the kinetics of crater formation by x-ray techniques. The authors used a 400—500-joule, 2—2.5-msec neodymium-glass laser focused on the surface of metal specimens. The rate of crater growth was found to decrease due to beam defocusing and scattering in the metal vapors. In the last stage of crater formation, a significant role was played by "washing out" of molten metal from the crater walls.

V. I. Smilga, M. I. Kuchinskiy, and G. R. Levinson (Moscow) presented a paper "On some technological applications of gas lasers" in which new types of gas lasers and their possible industrial applications in the processing of metal and dielectric films were discussed. A laser intended for sizing resistors which operates on a mixture of carbon dioxide, helium, and air has been developed.

G. V. Babyakin reported on forming deep channels (up to 60 mm) in quartz glass by melting. At the initial stage, a conical crater is formed which changes into a narrow channel accompanied by a short-lived pulsed plasma. A pulsation of molten glass was observed in the channel. At the final stage, the rate of channel formation decreased.

The 17th Seminar will deal with the physics of an electric arc.

[DV]

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## **SYMPOSIUM ON ELECTRICAL DISCHARGE MACHINING OF MATERIALS**

A symposium on the theoretical fundamentals of electrical discharge machining of materials was held in Kishinev from 21 to 24 October 1968. The symposium was sponsored by the Institute of Applied Physics of the Moldavian Academy of Sciences, the Institute of Problems of the Science of Materials of the Ukrainian Academy of Sciences, the Tomsk Polytechnic Institute, Leningrad University, and the Committee on Electrical Discharge Machining at the Central Office of the Scientific and Technical Society of the Machine-Building Industry. The Symposium was attended by 170 representatives of academic and industrial institutes, institutes of higher learning, and industrial plants, who had participated in the development of the theoretical fundamentals of electrical discharge machining of materials; several representatives from the German Democratic Republic were also present.

The Symposium was opened by Ya. S. Grosul, President of the Moldavian Academy of Sciences, who stressed the ever-increasing attention of scientists to electrical methods for the machining of metals and their applications. Academician B. R. Lazarenko (Institute of Applied Physics, Moldavian Academy of Sciences) reported on the development of the electrodynamic theory of the electrical erosion of materials, the validity of which was proved experimentally by direct measurement of the force produced by an electron bunch hitting a metal surface, and by the complete correlation of the dimensions of craters formed by electrical erosion with those produced on the surface of solids by falling meteorites. He also formulated some basic physical problems in the electroerosion of materials which require further research.

A. A. Vorob'yev (Tomsk Polytechnic Institute) discussed the destruction of solids by bombardment with high-velocity electrons and the physical resistance of materials to electrical erosion. He analyzed several possible mechanisms of the electrosark erosion of metal and stated that ejection of metal from

the crater is caused by the plasma formed within the metal. High (over 1.4 Mbar) pressure developed by the impinging electron bunches disrupts the electron structure of atoms which lose some of their electrons. The mixture of electrons and atom residues forms a plasma. The plasma is also formed as a result of the penetration of fast electrons into the body. In another report, Vorob'yev recommended electrospark machining of materials as a method of physicochemical analysis of hard alloys.

G. V. Samsonov (Institute of Problems of the Science of Materials, Ukrainian Academy of Sciences) opined that resistance of materials to breakdown decreases with decreasing statistical weight of atoms possessing stable configurations of the localized portion of valence electrons, with decreasing stability of these configurations, and with increasing number of unlocalized electrons. The resistance also depends substantially on the composition of the interelectrode medium.

G. A. Ostroumov (Leningrad University) discussed problems associated with the physical fundamentals of the initiation and development of electric discharges in electrolytes and pointed out the absence of a satisfactory theory of the liquid state of a substance. As a consequence, electrical phenomena in liquids have been studied much less extensively than those in gases and solids. The author discussed in detail the problem of the hydrodynamics of an electrical discharge and showed that the chemical nature of the solute has no significant effect on the initiation of a discharge in an electrolyte.

G. N. Meshcheryakov (Odessa Polytechnic Institute) reported on the role of the surface and thermoelectric phenomena in electrical erosion of metals. Yu. N. Kotov (Tomsk Polytechnic Institute) spoke on the volume energy density reached in a conductor before its explosion. I. G. Nekrashevich (Physico-technical Institute, Belorussian Academy of Sciences) discussed the migration theory of electric erosion of materials. Kh. Melhorn (GDR) reported on the effect of the electrolyte composition on the amount of electrical erosion.

The Symposium recommended that the Institute of Applied Physics of the Moldavian Academy of Sciences initiate a five-year plan of scientific research on the problems of electrical machining materials and its introduction into the national economy.

[MS]

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Lazarenko, B. P. Electrical discharge machining of materials. (Symposium in Kishinev). IN: Akademiya nauk SSSR. Vestnik, no. 3, 1969, 136-137.

#### THE SECOND ALL-UNION CONFERENCE ON LOW-TEMPERATURE PLASMA PHYSICS

The conference, organized jointly by the Department of Physico-Technical Problems of Power Engineering of the Academy of Sciences USSR, the Scientific Council on Methods of Direct Conversion of Thermal Energy into Electricity, and the Institute of Physics of the Belorussian Academy of Sciences, was held from 18 to 22 November 1968 in Minsk. M. D. Millionshchikov, Vice-President of the Academy of Sciences USSR, presided. There were 800 participants from 160 organizations. Four hundred papers were read, of which 380 were divided among 6 sections dealing with: 1) methods of diagnostics; 2) methods of production and properties of low-temperature plasma; 3) methods of production and properties of beam fluxes; 4) elementary processes and kinetics; 5) interaction with surfaces; and 6) oscillations and waves in plasma.

The topics discussed at the general sessions included a review of the results of studies of a self-supporting T-layer whose formation was explained by the existence of nonlinear bonds between the electrical and the gas-dynamic quantities (A. N. Tikhonov, A. A. Samarskiy). Basic problems of non-equilibrium ionization were treated according to the diffusion theory developed by L. M. Biberman, V. S. Vorob'yev, and I. G. Yakubov, and a system of equations was presented describing the distribution of the energy levels of atoms and electrons.

General problems on electron energy levels and the ionization of atoms were treated in a paper by Yu. M. Kagan et al. Equilibrium problems of various types of low-temperature plasma were discussed by I. V. Podmoshenskiy et al. Elementary processes in molecular-beam lasers were analyzed by N. N. Sobolev and V. V. Sokovnikov and elementary processes in argon-ion lasers, by N. N. Sobolev et al. L. I. Kiselevskiy dealt with the production of a controlled-parameter plasma within the 20,000—100,000° K temperature range. Holographic methods of diagnostics were the subject of a paper by A. N. Zaydel', G. V. Ostrovskaya and Yu. I. Ostrovskiy.

Some points in the sectional papers and discussions deserve mention here. In the first section, much attention was given to the development and production of special super-high-frequency devices for plasma diagnostics. The use of lasers in diagnostics was said to be hampered by a shortage of equipment. The second section dealt with the necessity to stress studies of dense nonideal plasmas. In the papers of the third section, main interest was concentrated on the problem of MHD power production (A. P. Favorskiy, O. A. Sinkevich, A. S. Pleshanov, L. Ye. Tsvetkova, Ye. V. Lazareva et al). In the fifth section, Ye. S. Trekhov's report on erosion caused by powerful pulse discharges drew much attention. In connection with this problem, the inadequacy of experimental data was blamed for the lag in this important field. In the discussion of materials during the sixth section, it was noted that theoretical work in this field was also lagging.

The conference, in its concluding resolution, recommended an All-Union Conference on Low-Temperature Plasma every other year, and formed a preparatory committee for organizing a Third Conference in late 1970. [FP]

#### REFERENCE

Adzerikho, K. S. The Second All-Union Conference on Low-Temperature Plasma Physics. Zhurnal prikladnoy spektroskopii, v. 10, no. 3, 1969, 526-532.

#### PREDICTING THE SERVICE PROPERTIES OF POLYMERIC MATERIALS

Three conferences on methods for predicting the service properties of polymeric materials were organized in 1967 and 1968 by the Committee for Predicting the Service Properties of Polymeric Materials under the All-Union Council of Scientific and Technical Societies. The Committee is headed by G. M. Bartenev (President), Yu. V. Zelenev (Vice-President), and A. P. Molotkov (Scientific Secretary), and is concerned with the behavior of polymeric materials and plastic products in service and storage.

Current methods for predicting the service properties of polymeric materials are based on extrapolation, expert evaluation, or modeling. There is no scientific basis for predicting service properties which would take into account the specific features of interdependent changes of the structure and properties of polymers in various conditions. At present, the development of theoretical (calculation) prediction methods is behind that of experimental methods, although calculation methods are faster and less expensive.

It is expected that the work of the Committee will result in an accumulation of data which will make it possible to develop a scientific basis of methods for predicting the service properties of polymeric materials.

The first of the three conferences was held in Leningrad at the Scientific Research Institute of Polymerization Plastics. The second and third conferences were held in Moscow at the Problem Laboratory of the Physics of Polymers, MGPI im. V. I. Lenin.

The first conference dealt with methods for predicting the service properties of plastics.

V. R. Regel' described methods for predicting the strength properties of plastics. The effect of various factors (including UV irradiation) on the service life of plastics was discussed on the basis of S. N. Zhurkov's concepts concerning the mechanism of the temperature-and-time dependence of the strength of plastics.

A paper by Yu. V. Zelenev was devoted to methods for predicting the deformation properties of plastics in the course of their physical and chemical aging, considering the temperature dependence of the activation energy of the respective processes.

S. B. Ratner discussed a method for predicting the wear-resistance of plastics in various service conditions. The authors noted that the wear of plastics is a very complex process which depends on the structure, physical state, and deformation properties of polymers. As accelerated methods for determining the wear-resistance, the author recommends laboratory abrasion tests using abrasive paper or steel grate with simultaneous measurement of weight losses.

The second conference was devoted to methods for predicting the service properties of vulcanized rubbers.

P. V. Melent'yev discussed nondestructive methods for predicting the mechanical properties of polymeric materials at low deformations. The author has developed approximate calculation methods for determining changes in the deformation properties of rubbers. The calculated results were in satisfactory agreement with experimental data obtained with precision devices designed by the author for measuring stress and deformations.

Yu. S. Zuyev described methods for determining changes in the strength properties of rubbers in aggressive media. The author noted the shortcomings of studies on the estimation of storage and service life of vulcanized rubbers subjected to the action of aggressive (especially aqueous) media, high temperature, and irradiation. Analysis of experimental data obtained by the author and his associates indicated the possibility of predicting the service life of vulcanizates in various service and storage conditions.

Also at the second conference, N. N. Lezhnev discussed problems connected with prediction of the deformation and strength properties of vulcanizates filled with carbon black. As a result of structural changes, the aging of filled vulcanizates is much more intense than that of unfilled vulcanizates. This fact manifests itself, e. g., in a sharp increase in the modulus of elasticity of filled rubbers, both on short-time and long-time (up to 100 hr) aging. These phenomena are connected with the structure of blacks, whose surface modification can considerably change the deformation and strength properties of filled vulcanizates.

The third conference dealt with methods for predicting the service properties of fibers. A paper by N. V. Mikhaylov was devoted to analysis of the effect of morphologic forms on the service properties of fibers. These forms, which always originate on stretching of fibers, undergo modifications in service under the effect of external forces which affect the mechanical properties of fibers. Prediction of the service properties of fibers requires knowledge of the laws governing the structural modifications of polymers.

V. A. Bertenev discussed special features of the structure and mechanical properties of cord fibers, and methods for predicting changes in cord fibers used in the tire industry. Quantitative methods developed by the author and his associates for predicting the deformation and strength properties of cord fibers were described. These methods take into account structural changes occurring in the course of the exploitation of cord-fiber-containing products.

A paper by A. M. Stalevich was devoted to a comparative review of calculation methods for predicting the deformation properties of fibers. These methods are based both on empirical relationships and on formulas derived on the basis of linear and nonlinear theories of the viscoelasticity of polymers. Experimental verification of individual calculation methods showed that a reliable prediction is impossible without taking into account structural changes occurring in fibers under actual service conditions.

[BO]

#### REFERENCE

Zelenev, Yu. V. Conferences on Methods for Predicting the Service Properties of Polymeric Materials. Mekhanika polimerov, no. 6, 1968, 1138-1139.

## CONFERENCE ON ORGANOSILICON COMPOUNDS

The Fourth Conference on the Chemistry and Application of Organosilicon Compounds was held in Tbilisi, 9—13 December 1968. The conference was sponsored by the Ministry of the Chemical Industry USSR, the Academy of Sciences USSR, the Georgian Academy of Sciences, the Ministry of Higher and Secondary Special Education USSR, and Tbilisi State University.

The conference was divided into five sections: 1) Main preparative methods for monomers; 2) Synthesis of new organosilicon and heteroorganosilicon compounds; 3) Oligomers. Physicochemical study methods of oligomers and polymers. Thermal stability and thermal degradation; 4) Polymers; and 5) Materials from organosilicon compounds. About 300 papers were read at the conference, including the following:

K. A. Andrianov. Some development trends in the chemistry of organosilicon compounds.

Ye. F. Bugerenko, A. S. Petukhova, and Ye. A. Chernysheva. Synthesis of phosphorus-containing organosilicon compounds from four-membered silacyclobutane heterocyclic compounds and phosphorus trichloride.

A. V. Zimin and B. I. Vaynshteyn. Radiation-induced chemical synthesis of organochlorosilanes.

K. A. Andrianov and N. N. Makarova. Preparation of organosilicon ladder polymers from polycyclic compounds.

V. N. Gruber, A. L. Klebanskiy and N. V. Kozlova. Synthesis of organosilicon rubberlike polymers.

G. I. Belik, N. G. Morozova, et al. Synthesis of chlorotrimethylsilane with the use of metallic zinc as the chlorine acceptor.

V. V. Moskovtsev, N. P. Lobusevich, et al. Development and putting into production of a specific synthesis method for chloroethyl- and chloromethylsilanes.

The proceedings of the conference indicated that the scientific theoretical level of studies on organosilicon compounds has risen, and that the use of modern study and material-test methods has increased. A number of papers dealt with the kinetic laws and the synthesis mechanism of organosilicon compounds, and described the results of IR, PMR, NMR spectroscopic, thermodynamic and chromatographic studies. The conference noted with concern that Soviet industry does not produce certain organosilicon monomers and polymers.

[BO]

#### REFERENCE

Kaplan, E. B. Conference on organosilicon compounds. *Khimicheskaya promyshlennost'*, no. 3, 1969, 76-77.

## PERSONALITIES

### NIKOLAY NIKOLAYEVICH MEL'NIKOV

Professor Nikolay Nikolayevich Mel'nikov, Doctor of Chemical Sciences and laureate of the State Prize, was born in Moscow on 18 November 1908. Among Soviet chemists and foreign specialists in the field of biologically active compounds, Mel'nikov is best known by his books *Khimiya pestitsidov* (Chemistry of pesticides), published in 1968 [1] and *Khimiya gerbitsidov i regulyatorov rosta rasteniy* (Chemistry of herbicides and plant growth regulators) [2]. He has published more than 480 scientific articles and holds more than 280 patents dealing with the synthesis, properties, and application of herbicides, pesticides, plant growth regulators, repellents, attractants, chemosterilizers, and molluscocides.

Research projects initiated and directed by Mel'nikov at the Scientific Research Institute of Fertilizers and Insectofungicides and at the All-Union Scientific Research Institute of Chemicals for Plant Protection have resulted in the development of a series of well-known new insecticides, herbicides, and fungicides (butiphos, granosan, chlorophos, mercuran, metaphos, etc.) [3, 4]. Mel'nikov has published a series of outstanding articles and monographs on organophosphorus compounds, the mechanism of action of biologically active compounds, and the directed synthesis of biologically active compounds.

[PS]

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3. Granov, A. F., Ya. A. Mandel'baum, and B. A. Khaskin. Nikolay Nikolayevich Mel'nikov (on his 60th birthday). Zhurnal obshchey khimii, v. 39, no. 2, 1969, 458-460.
4. Sixtieth birthday of N. N. Mel'nikov. Khimiya v sel'skom khozyaystve, no. 11, 1968, 77.