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BORIS PAVLOVICH KONSTANTINOV

A. P. ALEKSANDROV, L. A. ARTSIMOVICH, B. A. GAEV, Ya. B. ZELDOVICH, V. M. TUCHKEVICH, and V. Ya. FRENKEL'

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ACADEMICIAN Boris Pavlovich Konstantinov, vice president of the USSR Academy of Sciences, outstanding physicist and organizer of Soviet science, died in Leningrad on 9 July 1969. His colleagues and friends knew that he was critically ill, but any meeting with him, who was always energetic and full of the joy of living, did not admit the thought of his coming end. His death was utterly and tragically unexpected. He died full of scientific ideas, projects of forthcoming experiments; although he has seen, experienced and did very much, he left so much undone!

Undoubtedly, the first sensation is pain resulting from the recognition of the irreparable loss. There is the feeling of an unjust fate, the regret that it will no longer be possible to see Konstantinov again, to tell him something and to hear a thoughtful answer or well-wishing interested advice.

When our thoughts turn again to this great and unique person, we attempt to understand the guiding principle of his life, which of his scientific efforts and accomplishments are bound to be long-lived and remembered. There are several basic questions that always worry scientific workers. These concern the relation between the human qualities of the scientist and his personal contribution to science, the group effort and the contribution made to it by the individual, the personal scientific creativity and leadership in the development of science. The answer to these questions can be given only by reviewing the scientist's entire life.

Konstantinov's life is part of the history of our times and of our country. It can be used as an example to trace the continuity and genealogy of our science.

Konstantinov was born in Leningrad in 1910. His parents were peasants from the Kostroma Province. The traditional seasonal occupation of the peasants of that province was painting. This path had to be followed by Konstantinov's father, Pavel Fedoseevich Konstantinov. Because of natural aptitude, he soon became a foreman, and then a superintendent. Although he himself did not go beyond the fourth grade, he instilled in his children (which there were nine, not counting three who died in childhood) interest in knowledge. They subsequently all received a higher education. In 1918, when there was hunger in the city, the Konstantinovs moved to a farm. It is there where Konstantinov's education began, helping as much as he could his widowed mother (his father died of typhus in 1919) with running the farm. All this was told by him in his autobiography, written in splendid literary language; he always had a mastery of words, a fact we well remember, particularly, from his many publications.

In 1924 Konstantinov moved to Leningrad. At that time his older brother, Aleksandr Pavlovich Konstantinov (1895–1945), a man of great ability, worked at the

State Physico-technical X-ray Institute (now the A. F. Ioffe Physico-technical Institute—FTI); he subsequently became one of our greatest radio engineers. A. P. Konstantinov worked in the laboratory of L. S. Termen, where applied problems were dealt with, among others, particularly the development of signal devices for the protection of state banks and museums. Boris Pavlovich Konstantinov began his working career at the age of 14 as a wireman in this protective service. At the same time he studied at the Workers' School, which he completed in 1926.

In the fall of 1924 his older brother brought Konstantinov into the FTI. All the marvels he saw there were firmly impressed in his memory, and he reported this in lively fashion in his foreword to M. S. Sominskiĭ's book on A. F. Ioffe[1].

In 1927, he started working at the FTI as an assistant in the laboratory of D. A. Rozhanskiĭ, and since that time all his activity was uninterruptedly connected with this institute, the role of which in the development of Soviet science cannot be overestimated.

During the celebration of the 50th anniversary of the Institute, in 1968, much was said concerning this amazingly creative environment, the atmosphere of mutual help and camaraderie, which always characterized the institute. Under these conditions, Konstantinov matured rapidly as a physicist. He was simultaneously an extension student of the Physico-mechanical Department of the Polytechnic Institute (from which, incidentally, he was not graduated). In 1929, in spite of his youth, he already worked independently, performing his first investigation—"Development of a method for frequency calibration of a stabilized acoustic generator."

Konstantinov's first steps in physics were guided by the "collective teacher" comprising the FTI with its system of seminars, departmental courses, and friendly well-wishing discussions. His direct mentors, whom he always recalled with deepest gratitude and respect, were A. P. Konstantinov and N. N. Andreev. "Work under N. N. Andreev served in my case as true school of experimental and theoretical research," wrote Konstantinov in his autobiography in 1951.[2] We shall stop to discuss here in relatively great detail Konstantinov's acoustic work, since it dates back 3—4 decades and is relatively little known, whereas the work of the recent ten years is sufficiently fresh in our memory.*

While working intensively and successfully, Konstantinov did not publish frequently. His first printed paper (jointly with A. I. Belov) is dated 1934[3]. In those days it was still permissible to describe the results of an investigation and its method in a non-concise form, and the article contains a masterful description of vital details of the performed experiments. The very style of the paper and its exposition automatically recall the classical papers of Rayleigh, the spiritual teacher of an entire generation of acousticians, including Konstantinov himself.

This article proposed a method for investigating the operating conditions of turbine blades. Its publication was brought about by the experimentally confirmed fact that the breaking of turbine blades occurs, as a rule under normal turbine operation (and not at the maximum stress). Since each turbine blade falls periodically, at the frequency of the turbine-rotor rotation, under the high-power steam jet, it operates naturally in a pulsed periodic loading mode, with a rich frequency spectrum. Indeed, the experimental analysis performed by the authors of[3] has revealed that even a very remote (71-st) overtone has an appreciable amplitude. One of the high frequencies of this spectrum is in resonance with the turbine blade, and this causes its fracture. To determine safe operating conditions (an overestimate of the static strength margin), it was necessary to perform a large number of precision measurements of the blade vibrations, particularly at low amplitudes (down to 10^{-5} cm). These measurements were performed by Konstantinov and Belov using an aggregate of electronic and acoustic means. Thus, the aforementioned amplitudes were measured by the sand-grain method proposed by N. N. Andreev (and further developed by the members of his laboratory, including Konstantinov's wife Nina Nikolaevna Ryabinina). If fine sand grains are sprinkled on an oscillating body, then when the sand grain reaches a vibrational acceleration $\ddot{x}_{max} = \omega^2 a$ (ω is the circular frequency of the vibrations and a is their amplitude) equal to the acceleration due to gravity, the sand grain begins to jump on the surface, and the amplitude can be determined by measuring the instant when this process begins.

We note that even this investigation already revealed the persistent attention paid by Konstantinov to practical problems of industry. His paper contained clearcut recommendations pertaining to the choice of methods of testing steam turbines and their operating conditions.

Equally connected with the direct needs of production were other investigations by the young physicist. In one of them, the procedure developed in[3] was employed to determine the natural frequencies and damping decrements of propeller blades, and another was devoted to the study of the acoustic characteristics of grinding wheels and their connection with hardness[4].

Special notice should be taken of a book published in 1936.[5] It contains a detailed report of an investigation of physical methods of sterilizing water, performed for the Water Supply Department of the city of Baku. One can sense in this book a distinct "biophysical bent,"* for it reports investigations of the effect exerted on the bacteria colonies in the water by various methods of "physical" water treatment, such as irradiation with ultrasonic vibrations, the passage of electric current, the action of ultraviolet and infrared rays. We see here Konstantinov's characteristic ability of rapidly delving into a set of problems that are new to him, and of formulating appropriate practical recommendations.

Konstantinov's further work in acoustics was devoted already to architectural and musical acoustics, and was carried out first in the Acoustics Division of the Leningrad Electrophysical Institute (which was split off from the FTI and headed by Academician A. A. Chernyshev), and later at the Institute of Musical Industry, where he started to work in 1937. Besides heading the laboratory and performing basic research, he was also in charge of graduate work and delivered lectures to graduate students and colleagues on complex problems of acoustics, especially nonlinear acoustics. In addition, in the late 30-s Konstantinov worked on acoustic projects typical of the "pre-radar" anti-aircraft defense problems. On the basis of this work, which was continued also during the war, Konstantinov defended his Candidate's dissertation (1942).

In 1943 he presented to the FTI Council a doctoral dissertation "On hydrodynamic sound production and propagation of sound in a bounded medium," written mainly on the basis of pre-war experimental and theoretical researches, and supplemented by calculations performed already during the years of evacuation to Kazan'. The official opponents of the dissertation, appointed by the Council, were Ya. I. Frenkel', A. A. Kharkevich, and G. A. Grinberg.

According to the recollection of the FTI staff mem-

*After the war-caused interruption and the associated change of interests subsequent work on atomic energy, Konstantinov's first paper was published in 1956; he resumed continuous publication of papers only in 1959.

*Konstantinov was also interested in biophysics later, and the organization of biophysical research at the FTI in the late 50's was due to a great degree to his foresight and initiative.

bers present at the defence, and also judging directly from its stenographic transcript, this was a truly brilliant defense. Konstantinov constructed a theory of self-oscillations of acoustic resonators in an air stream (modulated in musical instruments by special valves or reeds) with allowance for the reaction (feedback) of the resonator on the modulator. He thus developed a theory of coupled acoustic and mechanical resonators. Of particular importance were the results obtained by him on sound production by jets, and on the interaction between the jet and the acoustic resonator, which leads, as also in the case of valve instruments, to the occurrence of self-oscillations. In one of the chapters of the dissertation, Konstantinov proposes to use a jet as an amplifier and detector of oscillations, illustrating his ideas by means of simple and lucid experiments. The ideas developed by Konstantinov during those days turned out to be very fruitful and are now used in practice in pneumatic automation systems.

A. A. Kharkevich took special notice of "the author's exceptional abilities, consisting of rich physical intuition, manifest in the fact that a qualitative understanding of the problem is produced in his mind, apparently, almost simultaneously with the formulation of the problem. He therefore proceeds with confidence along little trodden paths, where many of his predecessors moved gropingly"[2]. It must be noted that among these predecessors were such leading figures of 19th-century physics as W. Weber, H. Helmholtz, Rayleigh, and W. Wien! Speaking of Konstantinov's experiments, which comprised an appreciable fraction of his dissertation, A. A. Kharkevich emphasized that they are "as lucid as some of the classical experiments of the earlier scientists—they contain nothing that is superfluous, but the gist of the matter appears in them quite distinctly and pronouncedly. His inventiveness in this respect is amazing, as is also the level of experimental technique attained by him."

"The theory of self-oscillation as given by the author is mathematically faultless," remarked Ya. I. Frenkel'. He and G. A. Grinberg especially emphasized Konstantinov's mathematical capabilities.

Another circle of problems touched upon in the dissertation concerns the propagation of sound and its absorption in flat and cylindrical walls, with allowance for the influence exerted by the viscosity and thermal conductivity of the medium. As noted in the discussion, the material provided by Konstantinov would suffice, with some to spare, for several doctoral dissertations!

It must be stated that although subsequently Konstantinov did not return directly to acoustical research, he continued to be vitally interested in the progress of "the science of his creative youth," and liked to use acoustical analogies in the discussions of other problems, particularly plasma physics. We add that he was thoroughly acquainted with the history of acoustic research performed both in the USSR (the schools of P. N. Lebedev and N. N. Andreev) and abroad. It is probable that a significant role in Konstantinov's choice of acoustic research for 15 years of his life was played by his love for music.

No matter what he engaged in, his approach to the problem, its analysis and consideration of the possible technical applications always conformed to the evaluation of the capabilities of the young scientist in the comments of his dissertation opponents. These capabilities reflected not only his talent, but also in the best possible way the traditions of the Leningrad school of physicists. The emphasis on the deep study of general problems of physics and mastery of the mathematical background helped the best of its representatives to enter rapidly into the mainstream of new problems, even those far remote from those with which they had to deal earlier.

Starting with the first post-war years, these problems were, in Konstantinov's case, those of physical chemistry and the then created physics of isotopes, a thorough investigation of which was initiated at FTI at the initiative of I. V. Kurchatov. Konstantinov was in charge during those years of the work on isotope separation, first heavy ones and then light ones. The problem consisted of developing commercial methods of separation, i.e., it was not confined to the principal solution of the corresponding physical problems. During the course of formulation and solution of these problems there was revealed the distinct approach, characteristic of the FTI, wherein the scientists worked directly in the commercial enterprises, bypassing the intermediate link (the research institute) in the customary "academic institute—research institute—factory" chain of new developments.

Konstantinov performed this work jointly with B. A. Gaev, G. Ya. Ryskin, et al., at the Research Laboratory for Physico-chemical Properties of Isotopes, which was organized and headed by him. Konstantinov plunged into the unknown field, knowing that he not only must master it, but also obtain a perfectly practical production yield, and furthermore within a very tight time schedule. The specialists in the corresponding fields many times exhibited scepticisim concerning the feasibility of the method proposed by Konstantinov for the solution of the problem—the difficulties faced by him were too large. Konstantinov's intuition in conjunction with the faith that any problem can be solved, provided, as he noted half-jokingly, it does not contradict the laws of thermodynamics, guided the tremendous staff of scientists and commercial workers under his leadership to complete success. During all stages of this very vital work, which made for extreme nervous tension, Konstantinov exhibited high organizational and moral qualities, encouraging his colleagues in their work and inspiring in them faith in its successful conclusion. In fact it was indeed necessary to solve a large number of purely technical and commercial problems, but Konstantinov's intuition showed him the correct and optimal path to the end result.

As a result, the Soviet atomic industry acquired the badly needed inexpensive and high-grade raw material. This project was highly valued by the Party and by the Soviet Government, and the entire group received state prizes. Konstantinov was awarded the title of Hero of Socialist Labor (1954) and a Lenin Prize (1958).

Konstantinov's accomplishments in the field of the physics of isotopes are not limited to the foregoing. A major role in the development of the appropriate investigations was the Division of Isotope Physics of the

Physico-mechanical Department of the Leningrad Polytechnic Institute, which provided the country with the needed and highly skilled staffs of specialists.

Konstantinov's physico-chemical researches have found important applications also beyond the needs of the atomic industry. Among the examples are the high-power mercury-cathode electrolyzers, now successfully in operation, resulting in a many-fold increase of the production of chlorine and pure caustic soda, and in a reduction of their cost.

Another product of the aforementioned work were numerous inventions and researches, by Konstantinov, towards development of methods of measuring the physical constants of materials, quantitative chemical analysis of numerous compounds and solutions, various methods of purifying materials and synthesizing chemical reagents, and finally the development of new instruments, which were patented by him and his co-workers and successfully shown many times in Soviet and foreign exhibitions. Konstantinov continued to work on physico-chemical problems even later, although the range of his scientific interest greatly expanded.

During the last 10 years these interests were focused on three fundamental problems:

1. The first was connected with research on controlled thermonuclear fusion, which began in the USSR in the early 50's. This raised the general problem of developing procedures for physical research and measurements of plasma installations, particularly measurements of concentrations of charged particles, which was never encountered earlier in the ultrahigh-temperature laboratory practice. In 1958 the Research Institute for Electrophysical Apparatus was entrusted with the construction, within a record short time, of the "Alpha" apparatus[9]. The performance of the appropriate physical and diagnostic research with this apparatus was assigned to Konstantinov at the FTI, whose director he became by that time. He concentrated the efforts of his co-workers towards this research in the newly created Laboratory for Plasma Diagnostics. At the same time, a seminar on plasma physics was organized, headed by Konstantinov during its first two years of existence. It is remarkable that within as little as a year and a half after the start of the work publications pertaining to the development of principles of high-frequency diagnostics of plasma already appeared (a paper[10] by Konstantinov, V. E. Golant, and their co-workers described a procedure for determining the electron density distribution in the cross section of a plasma pinch and the dynamics of this distribution; the aggregate of physical research performed with the "Alpha" apparatus was summarized in[9,11]). Konstantinov advanced an idea which turned out to be very fruitful, namely that of corpuscular plasma diagnostics. This idea was subsequently developed by N. V. Fedorenko, V. V. Afrosimov, and their co-workers. Also enrolled in the plasma research were the spectroscopists of the FTI (A. N. Zaĭdel' and his co-workers). As a result, the FTI became one of the leading organizations engaged in plasma diagnostics.

2. Konstantinov with his alert mind and interest in the latest trends of physical thoughts could not remain indifferent to the rapid development of astrophysics in the last 15—20 years. It should be stated that problems of astrophysics, and particularly the physics of comets, occupied him much earlier, but his active work began in the early 60's.

After antiparticles were theoretically predicted by Dirac (1929), and especially after the experimental observation of the positron (1932), the question of the charge symmetry in the universe was naturally raised. The topic of antiworlds moved from the fields of phantasy and poetry into the field of science.

Our planet, the sun, and the moon undoubtedly consist of "ordinary" matter, but what do we know about other stars or other galaxies? Although the possible existence of antimatter in the macrocosmos was mentioned quite long ago (by the American physicists W. Rojansky in 1940), only recently did these researches become systematic. A major role in this field were played by the studies of O. Klein, H. Alfven, and B. P. Konstantinov.

Towards the end of the 50's, Konstantinov advanced the bold hypothesis that antimatter should be sought not only far in the universe, but that it penetrates also the boundaries of the solar system in the form of meteor streams. We note immediately that this hypothesis encounters serious difficulties, and remains speculative to this day. It is important, however, that the thorough and unprejudiced analysis, stimulated by the very formulation of the problem, has shown that classical astronomy has no absolutely convincing or decisive proof of what has always been accepted as perfectly obvious, namely, it is impossible to exclude the possibility of existence of antimatter in our galaxy.

Inspired by the antimatter hypothesis, Konstantinov undertook, with his customary energy, astrophysical research at the FTI. Many people were attracted to this research, both from other institutes and from the FTI laboratories (M. M. Bredov, N. S. Ivanova, A. M. Romanov, V. A. Romanov, and others). Since 1963, all these investigations are carried out in the newly organized Astrophysical Division of the FTI, headed by Konstantinov until his death. From speculative thought experiments pertaining to the problem in question, he proceeded to concrete physical researches, using all modern means of outer-space study—airplanes, aerosondes, and artificial earth satellites. These researches have been the subject of a number of his publications[12-13]. The first investigations of Konstantinov and his co-workers were based on the hypothesis that comets consist of antimatter. A special measurement technique was developed (circuit for coincidences between radar signals from meteor streams and γ-radiation signals; the γ radiation may be the product of annihilation of the micrometeors with ordinary matter). We repeat, the hypothesis itself is still a debatable. The solution of the problem, as is frequently the case, turned out to be much more difficult than originally assumed; work in this direction is continuing to this very day. During all the stages of this research, Konstantinov revealed great cleverness and boldness in the formulation of the problems and in the performance of the experiments. He was very objective and cautious in the final evaluation of the results.

But it can be boldly stated that regardless of what the results of the entire cycle of this research may be in the future, one of these results has already turned out to be important and positive. Namely, a strong staff of scientific workers has been organized at the Physico-

technical Institute, and is engaged in the solution of a large number of important astrophysical problems. Many researches have been stimulated by research on charge symmetry, but these researches are not dependent on this problem. This possibility, of course, was taken into account by Konstantinov at the very start of the work, and was directly pointed out during the planning of future research. Thus, the study of collisions between micrometeors and satellites has led to refutation of the hypothesis that a dust belt exists around the earth[14]. The Astrophysical Division of the FTI is successfully engaged in γ-ray studies with satellites and balloons, in studies of nuclear reactions in thick-layer emulsions exposed on satellites, in laboratory research on phenomena in comets, work on neutrino astrophysics, and in theoretical research on the motion of particles and quanta in outer space.

3. Finally, in the very latest year Konstantinov paid constant attention to problems of holography, being particularly interested in problems of transmission of the holographic imagen and non-photographic methods of its reproduction.*

Konstantinov became interested in these questions long ago, for his brother, A. P. Konstantinov, invented back in the 30's an original television system with charge storage.

In accordance with his well-proven practice, Konstantinov concentrated the research on holography in a special laboratory, which he headed. The first paper on this topic were published in 1966[15]. The February 1969 issue of "Zhurnal tekhnicheskoi fiziki (the August 1969 issue of Sov. Phys.-Tech. Phys.) contains the last paper published in Konstantinov's lifetime[16], on the transmission of holograms over the Leningrad-Moscow facsimile line. The transmission objects were both line diapositives and three-dimensional objects. These experiments demonstrated the suitability of standard telephone channels for the realization of such transmissions.

The holographic research led to work pertaining directly to the physics and technology of lasers[17]. Konstantinov devoted his weekly trips from Moscow to Leningrad during the last three years to this subject, and planned further expansion of his research. The wor has barely started...

Konstantinov was not only a great physicist, but also an outstanding organizer of science. This aspect of his activity was reflected during the postwar years primarily in his work on isotope separation, which was of great importance to the state.

His great organizing ability and broad scientific vision were used to a full extent when he was elected vice president of the USSR Academy of Sciences. In this post, Konstantinov directed for many years and with great success the very important division of scientific and scientific-technical problems of the Academy.

Konstantinov always regarded himself a student of A. F. Ioffe. In the 60's he was in many respect Ioffe's successor. As the director (1957–1967) of the Physico-technical Institute, he developed and reinforced the institute's traditions, which date back to the 20's, expanded the scope of its research, never forgetting its connection with the direct needs and interests of the industry, and at the same time expanded in every way possible work in fundamental research, the direct practical results of which are not always obvious at first.

Backtracking in time, we should mention here that Konstantinov was a member of that old Physico-technical Institute group, who started to work at the institute when many of its leading workers were transferred during the war and the first postwar years to newly organized scientific centers of the country. These new centers and institutes were charged by the Soviet government with tasks connected with the defense of the country and with solving the problem of uranium (I. V. Kurchatov left the institute already in 1943, and was soon followed by A. I. Alikhanov, then by A. P. Aleksandrov, L. A. Artsimovich, and many others). Konstantinov's name is connected primarily with the active participation of the FTI in atomic research. Namely, the researches by the staff headed by him were among the first that have made it possible to demonstrate that in spite of the departure of many leading workers the institute is capable of retaining its position of a major scientific center of the country, the value of which again resumed to grow incessantly.

Konstantinov's election, by the General Assembly of the Academy of Sciences as the director of FTI (1957) is now seen (as was indeed seen even then) as a perfectly natural manifestation of the succession and development of this institute. During the first stage of his work in this responsible post Konstantinov frequently consulted with A. F. Ioffe, who was by then already the director of the Institute of Semiconductors of the USSR Academy of Sciences, to whom he confided his plans. It was precisely then that A. F. Ioffe was again elected a member of the Scientific Council of the Physico-technical Institute.

Konstantinov's scientific accomplishments were highly valued by the USSR Academy of Sciences. In 1953 he was elected a corresponding member, and in 1966 a full member.

In 1962 he became dean of the Physico-mechanical Department of the Polytechnic Institute organized by A. F. Ioffe, and in 1959 the editor-in-chief of "Zhurnal tekhnicheskoi fiziki," replacing Ioffe when the latter organized the new journal "Fizika tverdogo tela (Sov.-Phys.-Solid State).

The outstanding results accomplished in the last decade by the FTI are inseparable from Konstantinov's name; they were always contributed to by his friendly support, his lively interest in the scientific aspect of the problem, and his ability to accelerate the rate of all investigations.

Konstantinov's social activity (he was a member of the Leningrad City Council and Regional Council of the Communist Party, a deputy of the Leningrad City Executive Council, and a deputy of the Superior Soviet of RSFSR) was always characterized by exceptional devotion to his duties. The same pertains also to his work as vice president of the USSR Academy of Sciences, the chairman of many commissions in the academy itself, and in the Committee on Science and Technology of the Council of Ministers of the USSR.

Konstantinov was also a very responsive and demo-

*A paper by B. P. Konstantinov, "Holography in Motion Pictures and Television," is published in this issue.

cratic person. The recognition of his work, the high posts which he occupied during the last years, and the prizes awarded to him, did not change his attractive qualities in any way. It was always possible to turn to him in a difficult hour, his help was real, and his high position merely gave him the opportunity of rendering this help more effectively, provided he thought the help was needed.

It is as such a person, a great scientist and government worker, a well-wishing and a modest person, that Konstantinov will remain in our memory.

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