Physics – Uspekhi **43** (3) 299 – 300 (2000)

PERSONALIA PACS number: **01.60.+q**

Vitaliĭ Dmitrievich Shafranov (on his seventieth birthday)

DOI: 10.1070/PU2000v043n03ABEH000763

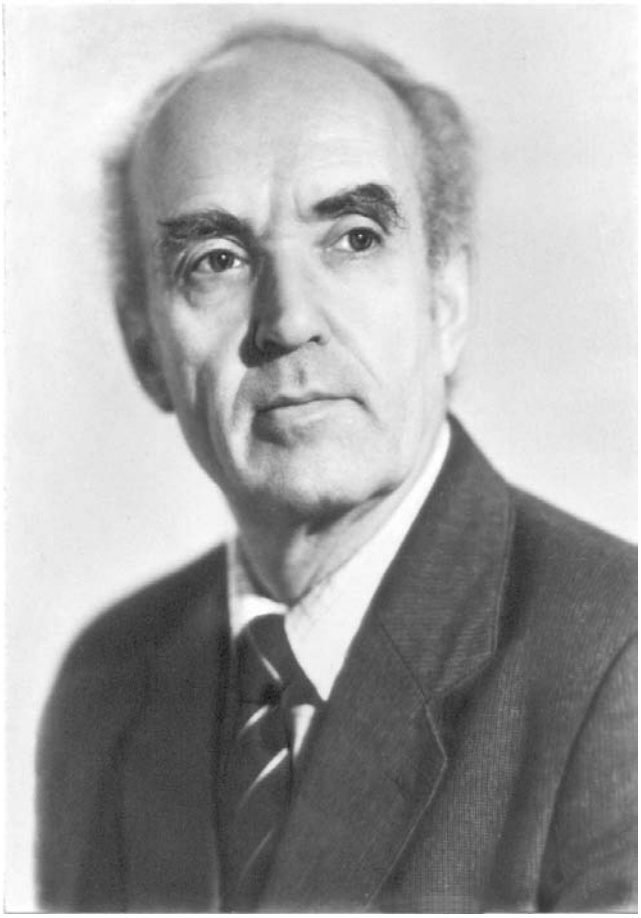
Vitaliĭ Dmitrievich Shafranov, Member of the Russian Academy of Sciences, a distinguished theoretical physicist and one of the acknowledged leaders of the world's scientific community in the field of plasma physics and controlled fusion, celebrated his seventieth birthday on 1 December 1999.

Its relatively recent origin notwithstanding, plasma physics has an enormous influence on such venerable giants as astronomy and chemistry. There is a historically established tradition in science to name fundamental natural phenomena, equations, formulas, theorems, methods, etc. after researchers who pioneered in their discovery or discussion. Plasma physics keeps names of many our compatriots such as L A Artsimovich, G I Budker, A A Vlasov, B B Kadomtsev, L D Landau, M A Leontovich, and A D Sakharov. The name of Vitaliĭ Dmitrievich Shafranov has rightfully taken its place on this list too.

A powerful incentive to the progress of plasma physics in this country was given by the Decree of the Soviet Government on the development of thermonuclear research issued in spring 1951. This was a major turning point in the history of high-temperature plasma physics, a new branch of science of the fourth state of matter. Coincidentally, the beginning of the scientific career of Vitaliĭ Shafranov, a young graduate of the Physics Department at Moscow State University, fell on exactly the same time.

V D Shafranov was born in the village of Mordvinovo, Ryazan' province, in 1929. He received a higher education at the Physics Department of Moscow State University which he entered in 1946, soon after the difficult wartime years. Following graduation in 1951, V D Shafranov was sent to work at LIPAN headed by I V Kurchatov. He was enrolled in the theoretical sector under Academician M A Leontovich and immediately involved in research on a magnetic thermonuclear reactor (MTR). That was the dawn of the golden times in the history of high-temperature plasma physics when the foundations of this now mature science were laid. In a team where each member was literally a creator of a new science, V D Shafranov performed a series of pioneering studies concerned with the propagation of electromagnetic waves through magnetized plasma, stabilization of pinch discharges in a longitudinal magnetic field, and the front structure of the strong shock wave in plasma. These works have already been demonstrated the remarkable style of V D Shafranov combining a profundity of physical approaches with simple and elegant solution of complicated plasma problems. For example, his paper on the structure of strong shock wave fronts (*Zh. Eksp. Teor. Fiz.*, 1957) did not only pose a physical task in the framework of the then recently formulated dissipative 'two-fluid' magnetohydrodynamics (MHD) but also reduced it to an elegant mathematical problem which was completely solved by the classical method for qualitative analysis of ordinary differential equations.

Uspekhi Fizicheskikh Nauk **170** (3) 343 – 344 (2000)
Translated by Yu V Morozov



Vitaliĭ Dmitrievich Shafranov

The initial period of making the high-temperature plasma physics was characterized by a rapidly growing number of newly-invented magnetic traps for the confinement of such an unpredictable substance as plasma. It was necessary to run in an experimentation with the 'solar matter' under laboratory conditions on the Earth. For many years, the theoretical studies of V D Shafranov have been devoted to this problem.

It is sometimes said in jest that all magnetic traps were proposed in the 1950s-1960s. There is a large enough grain of truth in this. Just at that time, the Russian term tokamak (an acronym derived from the Russian words for toroidal chamber with magnetic coils — TOroidal'naya KAmera MAgnitnye Katushki) entered the English language, Spitzer proposed the stellarator, Budker and Post proposed the magnetic mirror, Shafranov considered the equilibrium and stability of tori with closed magnetic lines, etc. In the beginning, it was necessary to demonstrate the possibility, in principle, to realize experimentally the relevant parameters of hot plasma. Always being on thermonuclear science's front line, V D Shafranov devoted most of his efforts and time to tokamak research, since he considered tokamak facilities to be the technically simplest type of magnetic traps and their

priority development to ensure the shortest route to the ultimate goal of plasma confinement. He deduced the necessary criterion for the stability of plasma column in a magnetic field, known as the Kruskal – Shafranov criterion, whereby the physical parameters of tokamaks were defined. In a study elucidating the equilibrium condition for a toroidal plasma, V D Shafranov derived the now famous equation (the Grad – Shafranov equation) which underlies the theory of plasma equilibrium in axially symmetric magnetic systems. Generalizations of this equation are used in the analysis of tokamaks, open traps, and also the plasmas of astrophysical objects. In 1958, V D Shafranov presented a thesis in accordance with the requirements for the degree of candidate of science, but it immediately earned him the higher scientific degree of doctor of physical and mathematical sciences.

The theoretical works of V D Shafranov many times confirmed the truth of the saying that there is nothing more practical than a good theory. For example, he demonstrated, jointly with L A Artsimovich, the advantages of a tokamak with a D-shaped plasma cross section. Naturally, new findings added by V D Shafranov to plasma physics gave birth to a number of terms and notions which entered this discipline under his name, for instance, the 'Kruskal – Shafranov criterion', the 'Grad – Shafranov equation', the 'Shafranov shift', etc. Suffice it to mention that the 'Shafranov shift' is the first thing which an experimenter comes to know as soon as he starts working with tokamaks.

The tokamak facility justified the hopes put in it and brought world-wide fame to Russian science.

Certainly, progress in the fusion programme was not as fast and easy as all that, and it took much more time to attain the goal than the researchers had been prepared to spend when they initiated the project. However, it is quite clear now that it is experimental tokamak research that has confirmed the feasibility of controlled thermonuclear synthesis. Efforts currently undertaken to ensure further progress largely address engineering issues and have the construction of an experimental fusion reactor as the ultimate object. It is at this stage that the work begins to be hindered by the physical limitations of tokamaks, viz. low plasma pressure as compared with the confining magnetic field pressure (parameter $\beta \ll 1$), disruption instability, and nonstationarity.

Being among the first to consider tokamaks, V D Shafranov is at the same time an acknowledged proponent of the modern theory of 'alternative' systems for plasma confinement. He is one of the few who accepted the challenge of time, to answer the question whether the theory of magnetic plasma confinement is able to offer a qualitative improvement of magnetic trap properties and thus ensure controlled fusion. This is especially true in regard to the stellarators. V D Shafranov and his disciples actively develop new principles for the optimization of magnetic configurations in these fusion facilities based on quasi- and pseudosymmetric approaches. Recent experiments on stellarators have demonstrated the possibility, in principle, to attain plasma parameters similar to those available with tokamaks, under steady-state conditions and without disruption. However, V D Shafranov never stops at what has been accomplished. Jointly with B B Kadomtsev, V M Glagolev, and B A Trubnikov, he proposed a hybrid 'Dracon' type trap in which the advantages of closed and open systems are combined. This work is currently being expanded to the development of a novel magnetic configuration in which positive features of 'Dracon' are integrated with poloidal pseudosymmetry. Such a system is expected to ensure a significantly higher value of the β parameter. The life-long scientific career of V D Shafranov serves as illustration that high-temperature plasma physics is an inexhaustible source of new ideas which exert considerable influence on other sciences and technical progress at large. For the considerable contribution to the plasma magnetic confinement theory V D Shafranov was honoured by the 1971 State and 1984 Lenin Prizes of the USSR.

V D Shafranov created a powerful scientific school of theorists working in the field of magnetic plasma confinement, which is recognized in this country and abroad. Vitaliĭ Dmitrievich is a bright successor of M A Leontovich, and it is only natural that since April 1981 he has been at the head of the Department of Plasma Theory at the Institute of Nuclear Fusion, Russian Research Centre 'Kurchatov Institute'. In 1981, V D Shafranov was elected a Corresponding Member of the USSR Academy of Sciences. In 1997, he became a full Member of the Academy.

The selfless labor of V D Shafranov as an editor and organizer of scientific publications also earned him immense prestige. Under his guidance as the editor-in-chief (since 1983), the journal *Fizika Plazmy* (*Plasma Physics*) became one of the leading editions representing physical disciplines. Twelve volumes of *Plasma Physics* edited by V D Shafranov and published by VINITI Publ., Moscow in the established series of 'Itogi Nauki i Tekhniki' (Recent Progress in Science and Technology) was a resounding success. In 1999, V D Shafranov became a member of the editorial board of *Uspekhi Fizicheskikh Nauk*. Also, he is editor-in-chief of a reputed international series currently published in English under the heading of *Reviews of Plasma Physics* by Kluwer Academic/Plenum Publishers.

V D Shafranov is a modest and wise man showing original judgment and sound appraisal not only in science but also in day-to-day life. These are manifestations of his inborn leaning towards a critical view of things which he often treats with a touch of humor. There seem to be a few men of wisdom as warm-hearted and open to contact as Vitaliĭ Dmitrievich Shafranov. These qualities of his remain unaffected by the standing of a person whom he happens to deal with, political volte-faces or flattery. But above all are his impartiality and fairness. No wonder, V D Shafranov chairs many commissions and juries as a recognized guarantor of objectivity and justice. That is why his judgments are held in such high esteem and sometimes feared for their power to lay the truth bare.

V D Shafranov is a versatile person. His mature emotional attitude to life not infrequently manifests itself in poetry. Taken together, his extempore rhymed comments on dynamic events in CF provide a vivid description of the long history of this field of physics. Plasma science is the life-work of V D Shafranov. But his improvised poetical compositions are so bright, fresh, and ingenuous, meet with such a warm response from his listeners that they ought to be published for a broader audience they deserve. Indeed, such a book would be a real treat to many as the poetical history of plasma physics.

We cordially wish Vitaliĭ Dmitrievich good health, welfare, and new impressive achievements in his many endeavours.

E P Velikhov, V I Il'gisonis, V S Imshennik,
L M Kovrizhnykh, V I Kogan, S V Mirnov,
K A Razumova, A A Skovoroda, V P Smirnov,
Yu N Smirnov, V S Strelkov, B A Trubnikov