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SOVIET EQUATION OF STATE RESEARCH IN 1970-1975

by

William H. Weihofen

ASBTRACT

Equation of state (EOS) research performed in the Soviet Union as reported in the open literature from 1970 to 1975 is analyzed. The work is discussed by institution and group, and attention is given to the intensity and type of research as well as the materials of interest. The appendixes list the substances whose EOS have been studied, the institutions where the research was done, and the authors of the research papers, all referenced to the extensive bibliography.

I. The Scope of This Work.

Research on equations of state (EOS) in the Soviet Union has been increasing in breadth and sophistication. This report does not attempt to trace this growth or fix its direction, but rather to present the most complete picture possible of recent Soviet EOS work. Some of the areas of active interest may be inferred from the quantity and quality of effort evidenced by published research, especially in conjunction with previous similar studies.[1] For this purpose, the primary goal of this study has been to gather and sort all the available literature on EOS work published from 1970 to 1975. Owing to the delays intrinsic to publication and translation, this portrayal of Soviet research can be assumed to be out of date by at least two years.

The institutions ostensibly carrying on EOS work during this period are discussed individually in Section II. The order of discussion is geographical; institutions in Moscow and its environs (generally the most important) are considered first, then those toward the Ural Mountains and farther east, and finally the institutions to the west and south. Among the facts noted are the various experimental and theoretical facilities in evidence, the size of the research staffs, and the apparent research objectives of each. Also included are the materials whose EOS seem to be of interest, both as general categories and specific substances, and the types of research being conducted on each. Appendix A is a complete list of references on the materials whose EOS are treated. They are listed by category: solids, explosives, liquids, gases and plasmas. Appendix B is a list of institutions where the EOS work has been done, in the order discussed in the text (roughly the order of importance). Also given are the institutional acronyms used in Appendix C. An alphabetical list of all authors appearing in the bibliography is given in Appendix C, with their institutional affiliation (where known) and references to their papers in the bibliography. The bibliography covers the Soviet EOS research published from 1970 to 1975, and is arranged by originating institution, chronologically, in the order of discussion in Section II. Volume and page numbers are always those in the English translations of the original Russian journals. The date given, however, is always the year in which the original publication appeared.

II. EOS Research by Soviet Institutions.

The Institute of Chemical Physics[2-55] is the Soviet organization most extensively engaged in EOS work. The research there is almost exclusively on dynamic compressibilities, involving explosions and shock waves, although theoretical thermodynamic calculations, with or without a computer, are used to support the experimental work. The techniques and equipment most often used are (1) spherical explosive charges in a medium, (2) detonation wave impingement on a contained or semicontained sample, (3) double compression of a sample by two simultaneous detonation waves, and (4) "flying plate" experiments, in which a metal plate, usually steel or aluminum, is accelerated to velocities of up to 15 km/s by a "gun" and stopped by the material to be investigated, with or without a "screen" or shield of some other material in front of or behind the sample (the reflected and unloading waves yield additional data if the EOS of the "screen" is known). Method (2) yields pressures of up to 400 kbar; method (3), up to 800 kbar; and method (4), up to 51 Mbar. Usually the shock wave velocities are measured by electrical contacts placed in the sample and screen, but sometimes more direct measurements are made by means of pressure sensors,[55] optical pyrometry,[30] or high-speed x-ray photography.[14,24] In addition, to shock Hugoniots and expansion isentropes of basic materials such as earth, rocks, and minerals, as well as of metals and very hard substances, there is great interest in the details of explosion processes and in the EOS of explosives of all kinds. Among the goals of the Institute of Chemical Physics[8] are investigations of mixtures and new classes of organic and inorganic compounds, especially of formation of new high-pressure phases such as the "metallization" of dielectrics; ingenious application of strong shock waves to study the detailed phenomenology of shock processes, including the resulting expansion (unloading); and experimental or theoretical interpolation of the EOS of all materials from the presently accessible experimental region (pressures of a few megabars) to the high-pressure Thomas-Fermi or Thomas-Fermi-Dirac limit (pressures of a few hundred megabars). Within the Institute are at least a half-dozen major groups that interact with one another. L. V. Al'tshuler seems to have a hand in most of the major areas of research, notably those involving explosives or the "flying plate" apparatus; he is probably the senior active member of the Institute. The group headed by A. A. Bakanova has done extensive research on the electronic component of the EOS. Long involved in the shock compression and phase transformations of metals and alloys, she has recently turned her attention to water.[53] A. N. Dremin is one of the foremost experts on the theoretical and practical features of shock waves; his group has done extensive work with explosives and refractory compounds. V. E. Fortov has worked with Dremin and is a rising young star at the Institute. He has a strong theoretical background in EOS research and has been involved in experimental work with a wide variety of substances, including plasmas. Recently his talents have been engaged in studying the unloading aspects of shock waves, a topic of great current interest. One of the more experienced experimental groups, headed by S. B. Kormer, works on hydrogen at high pressures; it does not publish much in the open literature. K. K. Krupnikov and N. M. Kuznetsov each have made thermodynamic calculations, with the aid of a computer, of explosion process details, including EOS considerations of the media undergoing phase transitions and of the explosion products. Among the numerous experimentalists, at least three others are worthy of mention. M. N. Pavlovskii has done a lot of work on the shock compression of hard substances, refractory materials, and minerals. He has sometimes worked with the group headed by R. F. Trunin, who has been more active than anyone else in investigating the EOS of minerals at very high pressures. Finally, I. M.

Voskoboinikov has done sophisticated research on the physical chemistry of liquid explosive detonation and explosion products, elucidating his data on the basis of model molecular crystal EOS.

Closely associated with the Institute of Chemical Physics is the All-Union Scientific-Research Institute of Opticophysical Measurements.[56-58] The EOS work done there is theoretical, primarily concerning metals and minerals at high pressures (megabar regions and above). Sometimes a computer is used. The most experienced EOS researcher there seems to be G. M. Gandel'man.

The O. Yu. Shmidt Institute of Earth Physics[59-82] also has research interests in common with the Institute of Chemical Physics, and probably uses their apparatus for some dynamic high-pressure experiments, in particular I. V. Belinskii and B. D. Khristoforov's work on porous NaCl. The Institute of Earth Physics also operates its own apparatus for measuring both the dynamic and static compressibilities of rock and minerals. The former system measures the shock waves induced in a sample encapsulated in lead, and the latter is a displacement piezometer for measuring isothermal compressibilities. The experimental group is headed by M. P. Volarovich, and it occasionally collaborates with geological groups from other regions of the Soviet Union, such as the Institute of Geology of the Kazakh S.S.R.[59] Much of the Institute of Earth Physics' research is theoretical. V. A. Kalinin and V. L. Pan'kov have worked intensively on establishing the EOS of solids, especially rocks, through understanding their behavior under dynamic loading, or shock. Their interests are ostensibly relevant to geophysical processes in various layers in the Earth. The work of V. N. Zharkov and V. P. Trubitsyn, on the other hand, could be considered astrogeophysics, as it concerns those aspects of EOS pertinent to planet and star formation. The pressures of greatest interest at the Institute of Earth Physics are from about 1 to 100 Mbar.

The Institute of High Temperatures[83-101] has been working extensively on plasma theory and production; consequently, the EOS of metal vapor has occupied their attention. Cesium, whose low ionization potential makes it a prime candidate for plasma production, has been the object of much theoretical and experimental research. The apparatus used generally is a tungsten chamber in which cesium, mercury, or other metals are heated as high as 2500°C and temperature, pressure, and density are measured simultaneously, the last from the intensity of γ-ray emission from a radioactive isotope such as Cs^{134}. About ten men are engaged in this work, perhaps the most prominent being Yu. S. Korshunov.

Another dozen researchers, most notably G. E. Norman, provide strong theoretical support. This includes construction of sophisticated pseudopotential models of a many-component plasma and statistical mechanical calculations, sometimes using a computer, in attempts to understand the thermodynamic behavior of metal vapors in general and plasmas in particular.

At the Moscow Energy (or Power) Institute,[102-119] there seems to be an ongoing program to improve the EOS of industrially important substances such as CO_2, steam, air, and heavy water. Most of the effort is theoretical, consisting either of constructing an EOS from a virial or cluster expansion or of combining different kinds of experimental data to form a semiphenomenological EOS. A. M. Semenov is active in using cluster expansions to consider the thermodynamics of dissociated and reacting gases, and groups under V. V. Altunin and V. N. Zubarev construct semiphenomenological EOS. In addition, there are at least two experimental setups at the Moscow Energy Institute. One is a piezometer with a piston pressure gauge and thermostat used to measure isotherms of compressed fluids up to 1 kbar. The other is refractometry equipment for measuring the refractive index and hence the second virial coefficient in the virial expansion of the compressed gas EOS.

The I.V. Kurchatov Institute of Atomic Energy [120-129] shows great interest in the EOS of the group VI element hexaflourides, especially UF_6. V. V. Malyshev has run series of experiments using a constant-volume piezometer to measure the isochores of these gases to 250 bars. V. A. Dmitrievskii et al. have run shock tube experiments to measure the specific heats from the shock wave velocities. There is also some theoretical research, notably by E. G. Brovman, Yu. Kagan, and A. Kholas, on the thermodynamic behavior of metals (including the question of hydrogen metallization), based on an electron-ion pseudopotential model.

One of the best established facilities for basic EOS research is the Institute of High Pressure Physics,[130-137] under the direction of L. F. Vereshchagin. This institute has at least four sets of high-pressure experimental apparatus: two piezometers with pressure ranges to 10 and 20 kbar, and two quasihydrostatic presses, one with operating pressures above 100 kbar, and a new one that operates in the 1-Mbar region. With the large presses, the favorite experimental technique involves use of a high-pressure x-ray camera to obtain diffraction patterns of the sample under pressure, from which the volume compressibilites as well as phase changes can be determined. F. F. Voronov is in charge of the piezometric experiments. He uses an ultrasonic impulse (about 5 MHz) whose longitudinal and transverse velocities in the sample are measured by strain gauges to derive the material's density and elastic moduli (e.g., compressibility). Additional work on determination of the Grüneisen parameter has been done by measuring the Mössbauer effect in some metals.[136] The topic most recently absorbing Vereschschagin's attention is the dielectric-metal transition. He has been using his megabar press to try to metallize everything from water to diamond; the results are questionable. Although little purely theoretical research is done at the Institute of High Pressure Physics, it is closely associated with the Institute of Metallography and Metal Physics of the Bardin Central Research Institute of Ferrous Metallurgy, where a two-level, two-compressibility model has been used to derive the high-pressure compressibility of diamond.[138]

The primary concern at the N. E. Zhukovskii Central Aerohydrodynamics Institute[139-148] is dense gases with industrial applications, primarily nitrogen but also methane and the noble gases. The work done there is all theoretical; it attempts to fit data on compressibilities, specific heats, etc. with virial coefficients derived from a Lennard-Jones potential and rigid sphere molecular models. Agreement with experiment is generally within a few percent up to pressures of 10 kbar or so and temperatures of several hundred degrees centigrade. Prominent at the Central Aerohydrodynamics Institute are M. A. Plotnikov, R. M. Sevast'yanov and S. D. Gavrilov. The last has become associated with the experimental group headed by D. S. Tsiklis at the State Scientific-Research and Planning Institute of the Industry of Nitrogen and Products of Organic Synthesis,[149,150] where a piezometer is used to measure PVT relations of gases at high pressures and temperatures.

Liquefied gases, especially the noble gases, are the objects of both theoretical research, such as V. A. Abovskii's quantum cell model, and V. A. Rabinovich's experiments with a constant volume piezometer, at the All-Union Scientific-Research Institute of Physicotechnical and Radiological Measurements.[151-157] Work also has been done there on understanding the EOS near the critical point.

While at the Moscow Physical-Technical Institute,[158-163] V. E. Fortov did extensive research on the EOS of nonideal plasmas, particularly cesium, using shock-tube experiments and sophisticated thermodynamic theory. In 1972 or 1973 he became a member of the Institute of Chemical Physics.

Moscow State University (MSU) supports diverse EOS work.[164-169] L. L. Pitaevskaya studies compressed gases by use of piezometer data fitted to a virial expansion. S. S. Grigorian of the Scientific-Research Institute of Mechanics at

MSU works on the effects of explosions in rock, using several kinds of EOS to derive features of the rock behavior. Others are working to understand crystals and "liquid crystals."

At the L. D. Landau Institute of Theoretical Physics[170-172] there has been recent interest in formulating the EOS near a critical point by means of an order parameter to express the thermodynamic functions as rapidly converging series. A leader in this effort has been A. A. Migdal; a co-worker is G. M. Avdeeva from Gor'kii State University.[173]

There are a few other noteworthy contributions to EOS research from Institutes in the Moscow area. At the Lebedev Institute, D. A. Kirzhnits[174] has considered the behavior of matter at very high pressures, above the Thomas-Fermi region, from several hundred megabars to astronomical pressures. N. N. Kalitkin and L. V. Kuz'mina,[175] working at the Institute of Applied Mathematics, have developed a quantum statistical model that seems to describe matter from the atomic level better than the Thomas-Fermi model does. It is the basis of much recent research, requiring the use of a computer to solve the requisite integrodifferential equations numerically. The Moscow Institute of Crystallography has a variable-volume piezometer by means of which sodium compressibility has been measured below, on, and above the fusion curve.[176,177] At the Institute of Electrochemistry, some theoretical work has been done on solid electrolytes.[178] Finally, the EOS of liquid parahydrogen has received attention at the Joint Institute for Nuclear Research in Dubna.[179]

In the Ural Mountain region, several installations are engaged in EOS work. The best known is the Institute of Metal Physics in Sverdlovsk, where K. L. Rodionov et al. operate a high-pressure chamber with an x-ray diffractometer to measure compressibilities at up to 10-kbar pressures. There is also considerable fitting of data to EOS forms for a broad range of solids, including frozen inert gases.[180-182] At the Urals Polytechnic Institute there is an active interest in the EOS of liquids in the metastable region,[183,184] which is shared at the Urals Scientific Center, along with an interest in liquid metals.[185,186] A variable-volume piezometer is used for PVT measurements. There is also an experimental group at Chelyabinsk that has done dynamic high-pressure research on porous metals;[187] they might be associated with the Institute of Chemical Physics.

At the Institute of Inorganic Chemistry in Novosibirsk the EOS of gases near the critical point are obtained with the aid of a variable-volume piezometer.[188,189] Other unspecified institutes are formulating interpolated or semiempirical EOS of metals[190] and nitrogen.[191,192]

V. A. Zhdanov and his co-workers at Tomsk State University have been very active in EOS formulation from fundamental theory.[193-201] Their work falls into two categories: (1) deriving tensor EOS (for the stress-energy tensor components) of metal crystal structures in order to understand the anisotropic features of their behavior, and (2) using a quantum theoretical statistical approximation to improve upon the Thomas-Fermi-Dirac model as a basis for the EOS of ionic crystals, particularly alkali halides. Comparison with experiments on compressibilities reveals only moderate agreement.

At the Institute of Geocryology in Yakutsk some work has been done on the thermodynamics of metals and minerals near the fusion curves at high pressures.[202]

Whereas the EOS research done east of Moscow is concerned primarily with solids, the work to the west and south is oriented toward gases and liquids. Leningrad State University sees occasional theoretical work.[203] Also in Leningrad is a rather diffident although active group, including S. V. Bobrovskii, V. M. Gogolev and B. V. Zamyshlyaev,[204,205] which formulates EOS to very high pressures. It has been conjectured that they are associated with the Soviet nuclear testing program.

Multiply ionized gases are the subject of theoretical research at the Physics Institute of the Belorussian State University in Minsk.[206]

In Kiev two institutions perform EOS work. At Kiev State University some statistical mechanical calculations have been done for a two-phase model of an excited gas.[207] Also a system of optical and microfloat techniques has been developed for measuring the index of refraction, densities, and compressibilities of alkanes near the critical point.[208,209] The Institute of Strength Problems is concerned with the behavior of steels such as the EOS time dependence under various conditions.[210] The Physical-Technical Institute of Low Temperature in Khar'kov has apparatus for measuring ultrasonic wave velocities in solids; by this means, the compressibility and Grüneisen constant of solid neon have been derived.[211]

In the industrial port of Odessa there seems to be a great interest in gases, presumably for industrial purposes. The research is apparently entirely theoretical; the Odessa Institute of Marine Engineers uses data from other sources to get the effective temperature dependence of virial coefficients,[212-216] whereas the Odessa Engineering Institute of the Refrigeration Industry is engaged in more esoteric considerations involving the virial series and its relation to intermolecular potentials.[217-219]

At the M. D. Millionshchikov Petroleum Institute in Groznyy there are at least two spherical discharge piezometers that have been used to measure the specific volume of water along several isotherms.[220] Further south, in Baku, a computer is used to fit experimental data on liquid carbon dioxide and alkanes to an empirical EOS at the Azerbaidzhan Institute of Petroleum and Chemistry,[221,222] and at the Institute of Physics the isothermal compressibilities have been derived from measurements of the linear expansion coefficients of indium chalcogenides.[223]

The place of origin of a number of papers on EOS research remains unidentified.[224-235] The Institute of Chemical Physics is almost certainly responsible for most of them, except for the two on gases,[227-233] perhaps produced at the Central Aerohydrodynamics Institute; the paper on Mars,[232] probably from the O. Yu. Shmidt Institute of Earth Physics; and the two highly theoretical papers.[234,235] The other papers reflect a heavy emphasis on explosives and shock Hugoniots of complex substances, such as plastics, that characterize the research interests of the Institute of Chemical Physics.

In summary, Soviet EOS work largely seems to have passed out of the "hit-it-and-see-what-it-does" stage and is digging deeply into the underlying atomic and subatomic physics to gain fundamental understanding of the observed macroscopic behavior of matter. The consequences of detailed theoretical and semiphenomenological models, especially of complex and compound materials, have been pursued largely by the ICP, whose output seems to be geared primarily to military applications. The consequences for minerals are studied by the IEP, whose main concern is in geophysics, although applications to civil defense are evident. High pressures, from 1 to 100 Mbar, are of particular interest. Similar applications are visible in the work on compound explosives and their effects on rocks, done at the ICP and Institute of Mechanics at MSU. The theory of matter near a phase transition is another active area of research, not only at the Landau ITP, but also in Kiev and Novosibirsk. This work's range of potential applications is very broad, from solid state to plasma confinement to industrial chemistry, as both physical and electromagnetic phase transitions are embraced by the same theory. There is also a lot of research on the theory and practice of nonideal plasma confinement. The apparent purpose is future energy production; however, there may be military goals, in view of the fact that some of the best workers in this field are now at the ICP. Much EOS work is devoted to fluids with routine industrial applications, as is reflected in efforts to refine data on the behavior of water, carbon dioxide, air, and inert gases. However, this work lacks the theoretical sophistication and experimental intensity of the research on solids.

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APPENDIX A

REFERENCES THAT COVER EOS WORK ON VARIOUS SUBSTANCES

General 96,174
Solids 31,40,56,66,69,77,96,134,163,174,175,180,205,225
Near critical pts. 62,96,173,202
Metals 122,185,190,195,234,235
porous 49,187

Al 12,22,50,56,180,190,195
porous 49

Sb 180

As 180

Ba 180

Be 180

Bi 180

Cd 23,135,180

Ca 56,180

C 10,138,180

Cs 84,86,88,89,94,95,100

Co 180

Hg 84,89,93,100,103

Mo 28,180,194
porous 49

Ni 50,56,180,190,195,232
porous 187

Nb 28,56,180

P 180

K 56,120,180

Pr 180

Re 28

Rh 180

Ru 180

APPENDIX B

INSTITUTES

	Acronym
Institute of Chemical Physics, Moscow (Chernogolovka)	ICP
All-Union Scientific-Research Institute of Optophysical Measurements, Moscow	IOM
Institute of Earth Physics (O. Yu. Shmidt), Moscow	IEP
Institute of Geology, Kazakh	IG,K
Institute of High Temperatures, Moscow	IHT
Moscow Energy (or Power) Institute	MEI
Institute of Atomic Energy (I. V. Kurchatov), Moscow	IAE
Institute of High Pressure Physics, Moscow (Podolsk)	IHPP

Institute of Metallography and Metal Physics of the Bardin Central Research Institute of Ferrous Metallurgy, Moscow	IM&MP
Central Aerohydrodynamics Institute (N. E. Zhukovskii), Moscow	CAI
State Scientific-Research and Planning Institute of the Industry of Nitrogen and Products of Organic Synthesis, Moscow	IIN&POS
All-Union Scientific-Research Institute of Physical and Radiological Measurements, Moscow	IP&RM
Moscow Physical-Technical Institute	MP-TI
Moscow State University (M. V. Lomonosov)	MSU
Scientific-Research Institute of Mechanics	IM
Institute of Theoretical Physics (L. D. Landau), Moscow	ITP
Gor'kii State University, Gor'kii	GSU
Institute of Physics (P. N. Lebedev), Moscow	LI
Institute of Applied Mathematics, Moscow	IAM
Institute of Crystallography, Moscow	MIC
Institute of Electrochemistry, Moscow	IE
Joint Institute for Nuclear Research, Dubna	JINR
Institute of Metal Physics, Sverdlovsk	IMP
Urals Polytechnic Institute (S. M. Kirov), Sverdlovsk	UPI
Ural Scientific Center, Sverdlovsk	USC
Institute of Chemistry	
Physical-Technical Power Engineering Problems Section	
Chelyabinsk group	
Institute of Inorganic Chemistry, Novosibirsk	IIC
Novosibirsk group	
Tomsk State University (V. V. Kuibyshev), Tomsk	TSU
Research Institute of Applied Mathematics and Mechanics	
Siberian Physical-Technical Institute (V. D. Kuznetsov)	
Institute of Geocryology, Yakutsk	IG,Y
Leningrad State University (A. A. Zhdanov)	LSU
Leningrad group	
Physics Institute, Belorussian State University (V. I. Lenin), Minsk	PI
Kiev State University, Kiev	KSU
Institute of Strength Problems, Kiev	ISP
Physical-Technical Institute of Low Temperature, Khar'kov	P-TILT
Odessa Institute of Marine Engineers	OIME
Odessa Engineering Institute of the Refrigeration Industry	OEIRI
Petroleum Institute (M. D. Millionshchikov), Groznyy	PI,G
Azerbaidzhan Institute of Petroleum and Chemistry (M. Azizbekov), Baku	AIP&C
Institute of Physics, Acad. Sci. Azerbaidzhan S.S.R., Baku	IP,ASSR

APPENDIX C

AUTHORS

	Papers	Institution
Abovskii, V. A.	151,153,154	IP&RM
Adadurov, G. A.	9	ICP
Afanasenkov, A. N.	30,37	ICP
Afanas'yev, N. S.	79	IEP
Aleksandrov, A. A.	113	MEI

Alekseev, V. A.	84,88	IHT
Alekseev, Yu. F.	17	ICP
Alekseev, Yu. L.	187	Chelyabinsk
Aliev, N. G.	223	IP,ASSR
Al'tshuler, L. V.	2,8,15,17,18,25,33,39,57,58	ICP
Altunin, V. V.	105,106,111,112	MEI
Anan'in, A. V.	38,46,47	ICP
Andreev, S. G.	225,226	Moscow
Anisichkin, V. F.	191	Novosibirsk
Anisimov, M. A.	157	IP&RM
Antanovich, A. A.	140	CAI
Aptekar', I. I.	138	IM&MP
Artym, R. I.	117	MEI
Artyukhovskaya, L. M.	208,209	KSU
Asinovskii, E. I.	86,95,100	IHT
Avdeeva, G. M.	171,173	GSU
Avdonin, O. S.	4	ICP
Averin, A. N.	63	IEP
Baidakov, V. G.	186	USC
Bakanova, A. A.	5,28,49,53	ICP
Bakhrakh, S. M.	14	ICP
Balabanov, A. V.	2,14	ICP
Balashov, D. B.	61	IEP
Baskakov, V. Ya.	167	MSU
Batalov, V. A.	2	ICP
Bavina, T. V.	52	ICP
Belinskii, I. V.	60,63	IEP
Berestov, A. T.	156,157	IP&RM
Berezhkovskii, A. M.	26	ICP
Berezin, V. M.	152,155	IP&RM
Bezuglyi, P. A.	211	P-TILT
Bilevich, A. V.	164	MSU
Bobrovskii, S. V.	205	Leningrad
Bogachev, G. A.	231	Moscow
Bogomolov, V. M.	7	ICP
Boiko, M. M.	225	Moscow
Bondarenko, V. F.	112	MEI
Brazhnik, M. I. (died 1971)	18	ICP
Breusov, O. N.	9,38,46,47,52	ICP
Brovman, E. G.	120,122,125	IAE
Bugayeva, V. A.	45	ICP
Chelovskii, A. V.	146	CAI
Chernyavskaya, R. A.	139,146	CAI
Chukanov, V. N.	184	UPI
Dmitriev, N. A.	235	?
Dmitrievskii, V. A.	123	IAE
Dremin, A. N.	4,9,32,38,46,47,48,51,52	ICP
Drobyshev, V. N.	9	ICP
Dudoladov, I. P.	28,49	ICP
Duman, E. L.	128	IAE
D'yachkov, E. I.	179	JINR
Dynin, E. A.	11	ICP
Egorov, A. N.	150	IIN&POS
Ermakov, G. V.	183	UPI
Evterev, L. S.	169	MSU (IM)
Fedulov, V. I.	123	IAE

Fekhretdinov, F. A.	46,47	ICP
Filinov, V. S.	94,97,98,101	IHT
Fokin, L. R.	90,96	IHT
Fomichev, S. V.	172	ITP
Fortov, V. E.	20,21,32,35,36,48,50,51,158-163	ICP
Frolov, A. P.	182	IMP
Fryazinov, I. V.	26	ICP
Gadetskii, O. G.	105,106	MEI
Gandel'man, G. M.	56	IOM
Gavrilov, S. D.	145,148,150	CAI,IIN&POS
Gerashchenko, N. A.	2	ICP
German, V. N.	5	ICP
Giterman, M. Sh.	156	IP&RM
Gleizer, A. I.	99	IHT
Godunov, S. K.	190	Novosibirsk
Gogolev, V. M.	205	Leningrad
Gogulya, M. F.	37	ICP
Golovskii, E. A.	213	OIME
Goncharova, V. A.	132,133	IHPP
Grigor'ev, B. A.	220	PI,G
Grigor'ev, F. V.	24,54	ICP
Grigor'ev, S. B.	132	IHPP
Grigorian, S. S.	166,169	MSU (IM)
Gryaznov, V. K.	35	ICP
Gurevich, Yu. Ya.	178	IE
Iosilevskii, I. L.	35	ICP
Itskevich, E. S.	135	IHPP
Ivanov, V. A.	176	MIC
Ivanova, V. B.	46,47	ICP
Kabalkina, S. S.	130,131,137	IHPP
Kagan, Yu.	120,122,125	IAE
Kalashnikov, N. G.	27,34,43,55	ICP
Kalinin, V. A.	64,66,67,69,70,73,74,78,80,81,82	IEP
Kalitkin, N. N.	175	IAM
Kamenetskaya, D. S.	138	IM&MP
Kashirskii, A. V.	229	Moscow
Katkov, A. I.	37	ICP
Kaverin, A. M.	186	USC
Kerimov, I. G.	223	IP,ASSR
Kessel'man, P. M.	218	OEIRI
Khasanshin, T. S.	113	MEI
Khokhlachev, S. B.	172	ITP
Kholas, A.	120,122,125	IAE
Kholodov, E. P.	108,110	MEI
Khomkin, A. L.	92	IHT
Khrapak, A. G.	93	IHT
Khristoforov, B. D.	60,63	IEP
Kirillin, A. V.	95	IHT
Kirzhnits, D. A.	174	LI
Kiselevskii, V. N.	210	ISP
Kondrat'ev, V. V.	181	IMP
Kononenko, V. I.	185	USC (IC)
Konusov, V. F.	193,194,195,197,198	TSU
Kormer, S. B.	24,54	ICP
Korotkina, M. R.	168	MSU
Korshunov, Yu. S.	86,89,95,100	IHT