Meetings and Conferences

FIFTH ALL-UNION CONFERENCE ON LOW-TEMPERATURE PHYSICS

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RECENT years have seen the vigorous development of research in the field of low temperature physics. New institutes and laboratories continue to enter into this work, and the number of scientific publications is growing. This is due both to the great successes of theoretical research in this field — here one must set foremost the systematic microscopic theory of superconductivity established in 1957 — and to the prospects revealed for important practical applications of low temperature physics. In this connection the significance of the All-Union Conferences, organized annually by the Academy of Sciences with the object of coordinating research on the problem of low temperature physics, carried out in the U.S.S.R., continues to increase.

The Fifth All-Union Conference on Low Temperature Physics took place in Tbilisi from October 27 to November 1, 1958. The conference was conducted jointly by the Physico-Mathematical Sciences Division of the Academy of Sciences, U.S.S.R., the Academy of Sciences of the Georgian S.S.R., and the Stalin Tbilisi State University. Some 300 specialists from Tbilisi, Moscow, Khar'kov, Kiev, Leningrad, Sverdlovsk, and other cities participated in the work of the conference. Approximately 50 papers were presented. The work of the conference embraced all of the basic branches of low temperature physics; separate sessions were devoted to liquid helium, superconductivity, galvanomagnetic phenomena, and magnetism. Fundamental emphasis, as in previous conferences, was placed upon discussion. The majority of the papers were discussed in most lively fashion. In addition to the plenary sessions of the conference, several symposia were organized, in which participated persons especially interested in one or another specific problem. All those participating in this conference remarked upon its excellent organization. Each of them was presented with the opportunity of becoming closely acquainted with the university's cryogenic laboratory, with the branches and laboratories of the Physics Institute of the Academy of Sciences of the Georgian S.S.R., and with the curiosities of Tbilisi — one of the oldest and most colorful cities of our country. In addition to the Soviet physicists, a number of young scientists from China, at present working in scientific establishments in the Soviet Union, also took an active part in the work of the conference.

I. LIQUID HELIUM

Seven papers were read which dealt with the problem of superfluidity and the properties of liquid helium. Several fundamentally new results have been obtained in the field of liquid helium within the last two or three years. The most interesting of these relate to the properties of superfluid helium (helium II) under rotation. The great role of the local disturbances of superfluidity in rotating helium II, and in the flow of helium II at high ("super-critical") velocities, has been clarified. These disturbances take the form of vortex lines, with the circular velocity of motion of the superfluid component a multiple of h/m (where h is Planck's constant and m is the mass of the helium atom), as predicted by Onsager and Feynman. The vortex lines, interacting with roton and phonon excitations, give rise to a dissipation of mechanical energy in the moving helium II, which is manifested, for example, in the strong attenuation of second sound in rotating helium. Vinen, at Cambridge, has recently shown experimentally that the minimal magnitude for the circulation in superfluid helium II about a vortex line is in fact equal to h/m; by this same experimental method the existence of a quantum effect of a new type — quantization of the macroscopic rotational motion of a fluid — has been established.

The papers presented by the "hosts" of the conference — the staff of the low temperature laboratory at Tbilisi State University — were devoted to investigations of rotating helium II. The director of the laboratory **É. L. Andronikashvili**, and his colleagues, **D. S. Tsakadze**, **Yu. G. Mamaladze** and **S. G. Matinyan**, have investigated the damping of the rotational oscillations of a single disk, oscillating in rotating helium II, as a function of the rotational velocity. It has been found that at low velocities the rotation does not affect the damping of the disk. When the rotational velocity is increased to values exceeding a certain critical figure, the damping decrement begins to increase rapidly, then reaches a maximum, and for higher rotational velocities decreases once again. An explanation has been proposed for this phenomenon on the basis of ideas regarding the vortex lines. These same authors have noted a periodic dependence of the damping upon the height of the liquid helium level above the disk; i.e., upon the lengths of the vortex lines. **G. A. Gamtsemlidze** has investigated the effect of the state of the surface of the disk upon the critical velocity and upon the damping of its oscillations in the super-critical region. The critical velocity has been found to decrease extremely rapidly as the roughness of the surface increases. This leads to the supposition that the values obtained by various experimenters for the critical velocity are evidently seriously underestimated.

V. P. Peshkov (Inst. Phys. Prob. Acad. Sci. U.S.S.R.) described further investigations of the boundary which he has found to appear between superfluid and non-superfluid helium in the presence of a thermal current. This boundary is characterized by a substantial jump in the density (~ 1%) and in temperature (up to 0.3°K). The author reported results of studies of the effects of the dimensions of the apparatus and its inclination upon the phenomenon. Motion pictures were presented illustrating the displacement of the boundary as the magnitude of the thermal current was varied. The author expressed his ideas regarding the nature of the phenomenon.

The work of **Kuang Wei-yen** and **K. N. Zinov'eva** and **V. P. Peshkov** made use of ultra-low temperatures (down to ~ 0.5°K), obtained by the method of pumping out He. vapor, developed at the Institute of Physics Problems. Using ordinary helium (He^4), as is well-known, one can readily reach only temperatures above 1°K. The production of sufficient quantities of He^3, therefore, as a by-product, for example, of controlled thermonuclear reactions, would make available for general scientific study the extremely important temperature region below 1°K. The number of laboratories in the world now making use of this possibility is very small. Kwang Wei-yen has investigated the phenomenon discovered by P. L. Kapitsa in 1941, of a thermal discontinuity at the boundary between a solid body (in the present case, copper) and helium II, over the broad temperature interval between 0.57 and 2.07°K. He has established that the theoretically-predicted T^3 law for the thermal resistance is not fulfilled: the resistance varies with temperature as T^n, where $n = 2.6 \pm 0.1$. V. P. Peshkov attributes this disparity to the influence of the electronic component of the thermal conductivity and specific heat of the metal: from his point of view the T^3 law should hold rigorously only for dielectrics. It has also been found by Kuang Wei-yen that only relatively high pressures affect the magnitude of the discontinuity; this has led him to the conclusion that a thin layer of helium II adjacent to the surface of the copper is subjected to a certain effective pressure (~ 15 atmos). K. N. Zinov'eva and V. P. Peshkov have improved the phase separation diagrams for solutions of He^3 (20 – 89%) in liquid He^4, and have determined the λ-transition curve. It has been found that the λ line meets the separation curve at 0.67°K (82% He^3); at higher temperatures both phases of the separated solution are superfluid.

Two papers were heard on the theory of liquid helium. **V. L. Ginzburg** (Phys. Inst. Acad. Sci.) described the phenomenological theory of helium II in the vicinity of the λ-point, taking quantum effects into account, constructed by him and **L. P. Pitaevskiĭ**. In this theory it is assumed that the density of the superfluid component falls to zero at the boundary of a solid body (this follows from the absence of any "dry friction" effect between helium and a solid wall), and only at some distance from it determined by a characteristic length, it assumes the value appropriate for helium II in an infinite volume. Expressions are obtained for this characteristic length, as well as for the surface energy of the boundary between helium II and a solid wall indicated by the theory. This energy should be manifest in an anomalous specific heat for helium II in thin layers, and also (as was pointed out in the discussion) in the appearance of a sharply varying increment, in the vicinity of the λ point, to the Van der Waals attraction between two adjacent solid surfaces. The authors have also reached certain conclusions concerning vortex lines in helium II. **B. T. Geĭlikman** (IAE, Acad. Sci. U.S.S.R.) described in a short communication his work on the theory of the phase transition in liquid He^4. **I. M. Lifshitz** and **D. G. Sanikidze** (Khar'kov Physico-Technical Inst. Acad. Sci. Ukr. S.S.R.) have considered the melting of solid He^3 on the basis of Landau's theory of a Fermi liquid, and have found that the melting pressure, taken as a function of temperature, has a minimum ($P_0 = 30$ atmos) for a temperature near 0.5°K (the Pomeranchuk effect). They have also considered a number of problems relating to the equilibrium diagram for the liquid and solid phases in the system He^3-He^4.

Summarizing the discussion, **P. L. Kapitsa** emphasized that the rotation of helium II and the critical velocities remain as the fundamental problems of low temperature physics.

II. SUPERCONDUCTIVITY

Thirteen papers were presented on the subject of superconductivity; of these, two were devoted to experimental work, and the rest were theoretical.

The phenomenon of superconductivity, discovered by Kamerlingh-Onnes as long ago as 1911, found no explanation for decades. It has only quite recently been established that this phenomenon does not stand isolated, but may be systematically deduced from the modern theory of metals.

In the new theory superconductivity is associated with the "Cooper phenomenon," the pairing-up of electrons at low temperatures. These pairs behave as charged particles of integral (rather than half-integral) spin; a system of such particles, as was known from the theory of liquid helium, possesses superfluidity below its "condensation temperature." It may thus be said that superconductivity represents superfluidity in an electron fluid. Each superconductor is characterized by a binding energy for an electron pair at absolute zero (this energy is proportional to the critical temperature), as well as by a "correlation distance" characterizing the "size" of the pair.*

These papers have led to the appearance of a large number of new publications in which the theory of superconductivity has been further developed. It is evident that within the next few years one may expect physical investigations in the superconducting region to develop from "ends in themselves" into a means of studying the electronic structure of metals and alloys (in particular, it may be remarked that the velocity of the electrons at the Fermi surface is obtained directly from the critical temperature). At the same time it is necessary to emphasize that in its present form the microscopic theory of superconductivity is as yet relatively crude. It is, so to speak, a theory for an ideal superconductor, not taking into account the crystalline lattice possessed by a real metal, with its anisotropies, symmetry properties, etc. The theory cannot as yet explain the appearance or nonappearance of superconductivity for this or that specific element, alloy or compound; nor is it in a condition to answer the question of whether or not superconductivity is possible at significantly higher temperatures than the "limit" reached at present (18°K).

The papers by **Yu. V. Sharvin** and **V. F. Gantmakher** (Inst. Phys. Prob.) and by **N. V. Zavaritskiĭ** (Inst. Phys. Prob.) were devoted to experimental studies of superconductivity. The former authors have investigated the structure of the intermediate state in monocrystals of pure tin, observing the patterns formed by ferromagnetic powder deposited upon the plane surface of the sample. A convincing demonstration was obtained of the anisotropy in the magnitude of the surface energy at the superconducting-normal phase interface. This anisotropy is manifested in the fact that at low temperatures the nodules of the superconducting phase, elongated in form, lie predominantly along specific crystallographic directions (along the tetragonal axis, for example, when this lies in the surface under study). The anisotropy disappears near the critical temperature.

N. V. Zavaritskiĭ has made measurements of the thermal conductivity of variously oriented cylindrical samples of gallium at temperatures between 0.1 and 4.2°K. From the results obtained the author calculated that the width of the energy gap (at absolute zero) can vary by a factor of 1.5 to 2 for various crystalline orientations.

A. A. Abrikosov, L. P. Gor'kov and **I. M. Khalatnikov** (Inst. Phys. Prob.) have investigated theoretically the behavior of a superconductor in a high-frequency field. The Meissner effect (nonpenetration of a magnetic field into the superconductor) requires a linear relation between the current density and the vector potential of the field. In the microscopic theory this relation holds, but has a non-local character: the value of the current at a given point is determined by the value of the vector potential, not at that point alone, but over a certain region. The coefficients entering into this expression were considered by Bardeen et al. to be independent of frequency. The present authors have obtained the corresponding generalized relations for the case of a fluctuating current, and have found that the current-vector potential relation is altered in character and depends fundamentally upon frequency. Expressions for the surface impedance of the superconductor have been derived both for the case of absolute zero and for finite temperatures. These expressions have been particularized for Pippard superconductors (with large electron pair "sizes") for various limiting conditions. The calculated results agree well with the data of M. S. Khaikin for cadmium. A. A. Abrikosov and L. P. Gor'kov have developed, also on

*A brief survey of the microscopic theory of superconductivity may be found in the Vestnik of the Academy of Sciences, U.S.S.R., and a more detailed treatment in Uspekhi Fizicheskikh Nauk.

the basis of the microscopic theory, the electrodynamics of an "impure" superconductor (alloy) in which the electron mean free path is extremely short. Expressions have been found for the penetration depth of the magnetic field into a superconducting alloy, both at absolute zero and at temperatures different from zero. **V. L. Ginzburg** and **G. F. Zharkov** (Phys. Inst. Acad. Sci.) expressed a number of ideas concerning the microscopic theory and problems still under computation. In particular, it was noted that no results have as yet been obtained in the theory for the case of strong magnetic fields (comparable to the critical field). The problem of the limits of applicability of the Ginzburg-Landau phenomenological theory of superconductivity was also considered. The authors communicated results of calculations of the susceptibility in critical fields for thin superconducting films. **V. L. Ginzburg** noted an interesting consequence of the hypothesis regarding the role of fluctuations at phase transitions of the second order. The magnitude of the fluctuations in the thermodynamic potential is proportional to the mass m of the particles. In the case of transitions in the electronic system (superconducting transition, ferromagnetic Curie point), when m is equal or close to the mass of the electron, the fluctuations are strongly suppressed relative to the case of liquid helium (m the atomic mass). Phenomena associated with these fluctuations, such as the λ-shaped rise in the specific heat, should therefore in principle be observed in both cases, but in the case of the superconductor they may be expected only within an extremely narrow region ($\sim 10^{-4}$ to 10^{-5} degree) about the critical temperature.

I. M. Lifshitz (Kar'kov Phys. Tech. Inst.) showed that from the present theory of superconductivity, taking into account the anisotropy of the metal, there follows in principle the possibility that superconductors may exist which possess superconductivity only over a limited temperature interval (and not for all temperatures below the critical value). **B. T. Geĭlikman** and **V. É. Kresin** (IAE) have investigated, on the basis of the microscopic theory, the electron and phonon thermal conductivities of superconductors at temperatures not especially close to absolute zero. The results of calculation agree satisfactorily with experiment. These same authors also presented a theory of the paramagnetism of superconductors as represented by the displacement of electron magnetic resonance lines. A paper by **M. V. Buĭkov** and **L. É. Gurevich** (Physico-Technical Inst. Acad. Sci. U.S.S.R.) dealing with the surface energy at the superconducting-normal phase boundary was also read.

A number of papers were presented at the conference by representatives of the school of N. N. Bogolyubov. **D. N. Zubarev** and **Yu. A. Tserkovnikov** (Mathematics Inst. Acad. Sci. U.S.S.R.) have investigated the thermodynamics of the superconducting state on the Fröhlich model. Expressions were found for the thermodynamic functions of the superconductor and for the jump in the specific heat at the transition through the critical temperature. On the basis of a method proposed by N. N. Bogolyubov, **V. V. Tolmachev** (Math. Inst. Acad. Sci.) has studied the problem of collective excitations in a superconductor. For large values of momentum these excitations go over into the ordinary plasma excitations. This work supplements the ordinary microscopic theory, making possible an explanation of the gauge invariance of the Meissner effect. **D. V. Shirkov** (Joint Institute for Nuclear Research) has carried through a computation of the Coulomb interaction of the electrons in a superconductor, the role of which was left quite unclarified in the theory of Bardeen et al. The Coulomb interactions are repulsive; they therefore hinder the formation of electron pairs, and, as a result, oppose superconductivity. From a qualitative analysis of the results of the calculation, the conclusion is drawn that the role indicated for the Coulomb interaction is in actual fact considerably reduced.

The problem of calculating the Coulomb interaction was also investigated in a paper by **Ch'en Ch'un-hsien** and **Chou Hsi-shin**, devoted to a summation method for divergent curves and its applicability to the theory of superconductivity. This work permitted the accuracy of the qualitative results obtained previously in the well-known monograph by N. N. Bogolyubov, V. V. Tolmachev and D. V. Shirkov to be improved. **Ch'en Ch'un-hsien** also presented a paper on a new variant of the statistical theory of perturbations. The theorem established by the author opens the possibility of applying various methods for investigating a many-particle dynamic system to the determination of the thermodynamic functions of quantum systems. The method proposed has been applied to the theory of an electron gas of high density.

III: GALVANOMAGNETIC PHENOMENA

Ten papers were read on this problem.

The papers by **I. M. Lifshitz** and **V. D. Peschanskiĭ** (Khar'kov Phys. Tech. Inst. and Khar'kov Univ.) and **N. E. Alekseevskiĭ** et al. (Inst. Phys. Prob.) are without doubt to be numbered among the principal features of the entire conference. They were devoted to the theoretical and experimental investigation of the variation of the electrical resistance of metals in a magnetic field at low temperatures. This phenomenon was studied in detail as early as 1926 by P. L. Kapitsa, who investigated the variation of the resistance of polycrystalline samples of several dozen metals in fields of several hundred thousand oersteds' intensity. It was established that this effect, especially at low temperatures, has a very large magnitude, exceeding by several orders that predicted by ordinary electron theory. It was found, moreover, that in strong fields the resistance of the majority of metals increases linearly with the field, while the theory provided for either a quadratic dependence or saturation for extremely large fields. It turned out that these peculiarities of the phenomenon provide theory with a very "tough nut:" for thirty years no success was achieved in finding their explanation. Only the most recent work by I. M. Lifshitz, conclusively confirmed by experiments performed in the laboratory of N. E. Alekseevskiĭ, suggests, finally, the possibility of an explanation for Kapitsa's linear dependence.

I. M. Lifshitz and **V. D. Peschanskiĭ** have demonstrated that the particular form of the Fermi boundary surface for the conduction electrons plays the decisive role with regard to the galvanomagnetic properties of this or that metal. This surface, which in the case of an ideal electron gas takes the form (in momentum space) of a sphere, is deformed in a real metal in accordance with the requirements of symmetry imposed by the crystalline structure, and with other characteristics of the metal. The presence of "open" Fermi surfaces in the metal, for which the electrons have open (unbounded) trajectories in momentum space, has an especially strong influence upon the galvanomagnetic effects. Considering the various possible types of topology for open Fermi surfaces, the authors computed the magnitudes of the galvanomagnetic effects as functions of the field and its crystallographic orientation for various cases. The fundamental result consists of the observation that the very character of the dependence of the resistance upon the magnetic field can vary for one and the same metal, and even for one and the same sample: for some field orientations saturation of the resistance with increasing field may occur quite rapidly, while for others an unlimited increase in resistance is observed, following a quadratic law. Such behavior is characteristic of metals having open Fermi surfaces, and does not occur for metals with closed surfaces. The authors have shown that averaging of the effect over the orientations of the individual crystallites in a polycrystalline sample can lead to a linear growth for the resistance of the sample (Kapitsa's law). Several other possible explanations for the linear law were noted as well. The significance of this work also lies in the fact that from experimentally-determined diagrams showing the dependence of the galvanomagnetic characteristics upon the field orientation one can establish the topology of the Fermi surface. The new work has borne out the fruitfulness of the geometrical approach previously used by I. M. Lifshitz and his coworkers, in studying the effect of the character of the Fermi surface upon other properties of metals.

N. E. Alekseevskiĭ described experiments carried out by himself and **Yu. P. Gaĭdukov**. They have investigated the variation of resistance in a transverse magnetic field at helium temperatures for a whole series of metals: gold, copper, lead, thallium, gallium, sodium, and (N. E. Alekseevskiĭ, together with **T. I. Kostina**) bismuth. The results which they obtained have shown that open Fermi surfaces constitute a very widespread phenomenon. The authors have concluded that for gold, copper, tin, lead, and, probably, thallium and gallium, the Fermi surfaces have open sections, while in the case of bismuth, sodium, indium, and aluminum these surfaces are closed. Especially careful investigations were carried out with a monocrystalline cylindrical sample of extremely pure gold (ratio of resistances at 4.2° K and 300° K: 6×10^{-4}) with its axis oriented close to the crystalline direction of the binary axis. The growth of the resistance in strong transverse magnetic fields was measured for 72 different field orientations relative to a chosen direction in the transverse plane of the sample. Polar diagrams were obtained for the dependence of resistance upon angular orientation for several values of the field. These diagrams have the form of rosettes with symmetrically-distributed minima and maxima. When measurements were made of the resistance as a function of field in the direction of a maximum, a quadratic rise in resistance was observed up to the highest fields; in the direction of a minimum, however, complete saturation was observed in a field of 35,000 oersteds. Averaging of the curves representing this effect over all angles (through 2.5°) gave a curve for which the resistance rose linearly with the field.

E. S. Borovik and **V. G. Volotskaya** (Khar'kov Phys. Tech. Inst.) have studied galvanomagnetic effects at low temperatures in chromium, and also in zirconium. The resistance of chromium increases with field without saturating. The comparatively great magnitude of the effect for the large residual resistance of the sample (1.3% of the room temperature resistance) evidently indicates that in transition metals of the chromium type there exists a numerically small group of electrons having long mean free paths.

A number of additional papers were devoted to problems of low-temperature conductivity and the properties of electrons in metals. **L. S. Kan** and **B. G. Lazarev** (Khar'kov Phys. Tech. Inst.) have investigated the occurrence in gold of a resistance minimum at low temperatures, and have found that annealing of the sample, accompanied by a marked growth of the pellet, causes the minimum to vanish. This demonstrates the influence of the real structure of the metal upon the phenomenon. **Yu. P. Gaĭdukov** (Inst. Phys. Prob.) reported during the discussion that this minimum effect in gold is absent for extremely pure samples (ratio of resistances at 300°K and 4.2°K: 1600), but is observed in samples containing impurities (having values for this ratio on the order of 100). The minimum vanishes as a result of plastic deformation of the sample at helium temperature.

M. Ya. Azbel' (Khar'kov Phys. Tech. Inst.) described the quantum theory which he has developed for the high-frequency resistance of a metal in a constant magnetic field at low temperatures. It turns out that there are superimposed upon the classical dependence of the surface impedance upon field diamagnetic quantum oscillations, the character of which differs accordingly as the field is oblique or strictly parallel to the surface being investigated. For the case of films, a sharp increase in the amplitude of the quantum oscillations should be observed for a value of the field at which the Larmor orbit first fits within the film. The theory indicates the possibility of establishing the form of the Fermi surface from experimental data on the periods of the quantum oscillations and resonant frequencies. **M. I. Kaganov** and **V. M. Tsukernik** (Khar'kov Phys. Tech. Inst.) have investigated theoretically the effect of thermoelectric forces upon the skin effect in various types of conductors. **B. I. Verkin** and **B. N. Aleksandrov** (Khar'kov Phys. Tech. Inst.) have made measurements of the electrical resistance of fine wires of high-purity tin, indium, and cadmium, and have computed the mean free paths for these metals at 4.2°K, which turns out to be of the order of ⅓ to ⅔ mm. **N. B. Brandt** (Moscow State Univ.) and **B. I. Verkin** and **I. M. Dmitrenko** (Khar'kov Phys. Tech. Inst.) have studied the effect of hydrostatic pressure (of the order of 1000 atmos) upon the behavior of metals at low temperatures. The author of the first paper has investigated quantum oscillations in the magnetic susceptibility of bismuth at 1.6 to 4.2°K; he expressed his ideas regarding the variation of the effective mass tensor, the electron concentration, and the Fermi boundary energy of the corresponding group of electrons under isotropic compression. In the second paper the features of the de Haas – van Alphen effect in isotropically-compressed zinc were established. **G. E. Zil'berman** and **A. M. Kosevich** (Khar'kov Phys. Tech. Inst.) proposed a theoretical explanation for the fact that even small relative deformations have an appreciable influence upon the oscillatory effects in metals.

IV. MAGNETISM

On this topic the conference heard 10 papers, among them three on antiferromagnetism and seven on the properties of ferromagnetic materials at low temperatures.

A. S. Borovik-Romanov (Inst. Phys. Prob.) described the research on "weak ferromagnetism" he has carried out with a monocrystalline sample of the antiferromagnetic $MnCO_3$. It was found that the weak ferromagnetic effect has the anisotropy predicted by the thermodynamic theory of Dzyaloshinskiĭ: for any orientation of the external field the ferromagnetic magnetization vector lies in the basal plane. The variation of the spontaneous magnetization of the sublattices with temperature in the neighborhood of the Curie point likewise proceeds in accordance with the thermodynamic theory. The author has carried through a calculation of the dispersion law for an antiferromagnetic with a magnetic structure of the type possessed by $MnCO_3$ on the basis of the spin-wave theory, and has derived expressions for the temperature dependence of the ferromagnetic magnetization and susceptibility in transverse and longitudinal fields. It is found that the relation between the experimentally-observed variations of these quantities with temperature differs sharply from that predicted theoretically, which testifies to the inadequacy of the spin-wave theory. **R. A. Alikhanov** (Inst. Phys. Prob.) spoke during the discussion, describing the neutronographic studies he has made of the magnetic structures of $MnCO_3$ and $FeCO_3$ at low temperatures. He has been able to show that the ferromagnetic moments in $MnCO_3$ do in fact lie in the basal plane, and moreover, in the plane of symmetry — not along the binary axis (as would also be possible from the standpoint of Dzyaloshinskiĭ's theory). In $FeCO_3$ the ferromagnetic moments are directed along the rhombohedral axis. **P. L. Kapitsa** emphasized the great value of this method.

In a paper by **N. M. Kreines** (All-Union Phys. Tech. Inst. for Radio and Electronic Meas.) read by A. S. Borovik-Romanov, the measurements of the magnetic anisotropy of antiferromagnetic monocrystals of $CuSO_4$ and $CoSO_4$ which she has performed at the Institute for Physics Problems were described.

E. A. Turov (Inst. Metal Phys. Acad. Sci. U.S.S.R., Sverdlovsk) discussed his theoretical investigation of a number of the properties (magnetization, susceptibility, specific heat, and resonant frequencies) of antiferromagnetics and weak ferromagnetics. In particular, he has demonstrated the possibility, in principle, of weak ferromagnetism of the "longitudinal type" (with the ferromagnetic axis parallel to the axis of antiferromagnetism) in the case of a difference in the magnitude of the g-factor for the ions of the two sublattices. An interesting discussion was evoked by a talk by **E. A. Turov** during the general discussion (to which a part of the final session was devoted) concerning conflicts between experiment and certain simple theoretical relations growing out of the present theory of spin waves. The participants in the discussion emphasized the necessity of conducting various types of experiments on the same antiferromagnetic substances.

Among the material presented on ferromagnetism, a lively discussion was inspired by the paper of **A. I. Sudovtsov** and **E. E. Semenenko** (Khar'kov Phys. Tech. Inst.). These authors measured the electrical resistance of iron in magnetic fields over a broad range of temperatures, and simultaneously recorded magnetization curves. It was found that at low temperatures (helium temperatures especially, for which the mean free path of the electrons increases strongly) the resistance diminishes appreciably for fields in the technical magnetization range. This diminution is especially great for the case of a longitudinal field: at helium temperature the resistance falls by approximately one third in a field of 10 oersteds. This phenomenon is naturally to be associated with a coarsening of the domain structure of the ferromagnetic and (for a field parallel to the current) with rotation of the magnetic moments into the field direction. The results obtained by the authors indicate the presence of a new mechanism for the scattering of electrons which occurs only in ferromagnetic metals. **N. V. Vol'kenshteĭn**, **G. V. Fedorov**, **É. V. Galoshina**, and **M. I. Turchinskaya** (Inst. Metal Phys.) reported on measurements of magnetization and the Hall effect in polycrystalline samples both of nickel and of the ferromagnetic alloy Ni_3Mn. This was the first report heard at the conference concerning the work at low temperatures (down to and including that of liquid helium) carried out at Sverdlovsk. **E. I. Kondorskiĭ**, **V. Rode**, **U. Gofman**, and **Chang Shou-ch'ung** (Moscow State Univ.) reported measurements of the susceptibility of nickel and its alloys with copper at low temperatures, including the liquid-helium region, performed with the aid of a photoelectric fluxmeter. **T. I. Sanadze** (Tbilisi State Univ.) has observed the paramagnetic resonance spectrum of Tb^{3+} in terbium nitrate at liquid hydrogen temperatures.

Several papers were devoted to the theoretical problems of low-temperature ferromagnetism. **M. I. Kaganov** and **V. M. Tsukernik** (Khar'kov Phys. Tech. Inst.) have considered kinetic phenomena in ferromagnetics at low temperatures, and have computed the relaxation times characterizing the establishment of equilibrium in a system of spin waves, as well as in the interaction of the latter with the lattice oscillations. **A. I. Akhiezer**, **V. Bar'yakhtar**, and **S. Peletminskiĭ** (Khar'kov Phys. Tech. Inst.) have investigated theoretically the relaxation of the magnetic moment in ferromagnetics, and have reached the conclusion that different interaction mechanisms govern the relaxation time in different temperature regions. **Vlasov** (Inst. Met. Phys.) showed that when linearly-polarized pressure (ultrasonic) waves with frequencies of the order of 10^9 cps pass through a ferromagnetic along the direction of the magnetic field, there should be observed a rotation of the plane of polarization of the order of 10^{-3} to 10^{-4} radian cm^{-1} $oersted^{-1}$; at the same time, the originally linear polarization must become elliptical. **M. I. Kaganov** noted that under these geometrical conditions still another phenomenon should be observed: a resonance absorption of ultrasonics when the wave length and the radius of the Larmor orbit for an electron become equal.

V. MISCELLANEOUS PROBLEMS

Among the most interesting papers considered by the conference was that by **I. A. Gindin**, **B. G. Lazarev**, **Ya. D. Starodubov**, and **V. I. Khotkevich** (Khar'kov Phys. Tech. Inst.) on low-temperature polymorphism in metals. As a result of a broadlydesigned study it has been established that polymorphism at low temperatures is a very widespread phenomenon. Polymorphous transformations have been found (in addition to the widely-known transition of white tin into gray) in lithium, sodium, cesium, mercury, bismuth and beryllium. The transition temperatures and volume changes for these metals have been determined. The transformations were detected by means of the variations in volume in the process of low-temperature plastic deformation, and during heating. Observation of the transformations requires a relatively severe degree of deformation, and relatively strong cooling below the transition point (in the case of sodium, for example, deformation at helium temperature was required, although the transition point lies in the vicinity of 73° K). In the alkali metal series a monotonic increase in the transformation temperature was noted with increasing Debye characteristic temperature. It may be presumed that the majority of other metals not having close-packed lattices likewise possess low-temperature modifications. **P. L. Kapitsa** remarked that this phenomenon increases considerably the number of metals which may be studied at low temperatures.

R. F. Bulatova, V. S. Kogan, and **B. G. Lazarev** (Khar'kov Phys. Tech. Inst.) have investigated the crystallization of the system hydrogen - deuterium using the methods of low-temperature roentgenography, thermal analysis, and visual observations. The state diagram for the system in the solid state does not represent a continuous sequence of solutions. At 4.2° a broad region is observed in which the solid mixtures separate out, and the solubility of the isotopes in one another is very limited (~ 15 to 20%). This is in accordance with the marked difference in structure which has been found for solid hydrogen and deuterium, as well as with the conclusions of quantum statistical mechanics regarding the existence of a critical separation temperature for an isotope mixture. The latter effect is a purely quantum one: from the classical standpoint no isotope mixture should decompose into separate phases at low temperatures. In the discussion the question was raised of the possibility of observing this effect in solid mixtures of the helium isotopes.

The "photon wind" phenomenon predicted by Gurevich has evidently been observed in the work of **Kh. I. Amirkhanov, Sh. Kh. Amirkhanova,** and **R. I. Bashirov**, who have studied the thermomagnetic properties of several compounds (of the type $A^{III}B^{V}$ and the type $A^{II}B^{VI}$). This was the first work reported at the conference to be carried out in the liquid hydrogen temperature region at the Dagestan branch of the Academy of Sciences, U.S.S.R.

N. M. Reĭnov and **A. P. Smirnov** (Leningrad Phys. Tech. Inst.) have measured the elastic limit for polycrystals of tin and indium at very low temperatures (below 1° K), observing the transition of the metal from the superconducting into the normal state, due to heating of the sample at the onset of plastic deformation. **N. M. Reĭnov** and **N. I. Krivko** (Len. Phys. Tech. Inst.) have begun experiments to detect the expected diamagnetic resonance of polarons in cuprous oxide.

G. R. Khutsishvili (Tbilisi State Univ. and Phys. Inst. Acad. Sci. Georgian S.S.R.) has investigated theoretically the Overhauser effect in non-metals. **Lomkadze** has studied electron and nuclear (proton) resonance in diphenylpicrylhydrazyl at helium temperature. **B. N. Samoĭlov** described the experiments he has performed on the orientation of Co^{60} and Au^{198} nuclei (in iron) at ultra-low temperatures. The effective field of the electron shell acting upon the nucleus was evaluated from the anisotropy of the gamma radiation. **B. P. Zakharchenya** and **E. F. Gross** (Len. Phys. Tech. Inst.) investigating the structure of the edge of the fundamental band in the absorption spectrum of cuprous oxide placed in a magnetic field at helium temperatures, have observed the effect of magneto-optical oscillations.

Informative talks by **V. P. Peshkov** and **M. P. Malkov** on the foreign scientific mission and a report by **É. V. Shpol'skiĭ** on the work of Referativnyĭ Zhurnal "Fizika" were heard.

The director for problems of low temperature physics, Academician **P. L. Kapitsa** summarized the conference. The President of the Academy of Sciences, Georgian S.S.R., Academician **N. I. Muskhelishvili**, greeted those participating in the conference.

The Sixth All-Union Conference in Low Temperature Physics is scheduled to take place in June-July 1959 in Sverdlovsk.

Translated by S. D. Elliott