

Soviet Low-Temperature Physics

Research in the USSR is strong and well supported. Laboratories at Kharkov, Tbilisi and Leningrad pursue programs in many cryogenic subjects including Josephson tunneling, film flow rates, thermoelectricity, fourth sound, and liquefied and solidified gases.

by Edward F. Hammel

THE SOVIET ACADEMIES of science put great emphasis on low-temperature physics and strongly support a vigorous program of both basic and applied research in this field. For example, the new Kharkov laboratory is undoubtedly the largest in the world devoted exclusively to low-temperature investigations. These were some of the impressions that some of my low-temperature colleagues and I gathered when, after the Tenth International Conference on Low Temperature Physics, we toured laboratories in Kharkov, Tbilisi and Leningrad.

Kharkov Low-Temperature Institute

Kharkov is a city of approximately 1.5 million people and one of the centers of heavy industry in the USSR. It is also one of the outstanding Soviet scientific research centers.

In 1932 the first helium liquefier in the Soviet Union was constructed in Kharkov by L. W. Schubnikov and his colleagues, and with the helium from that liquefier the first Soviet research at liquid-helium temperatures was carried out at the Kharkov Physico-Technical Institute. During the late 1930's

Kharkov was the scene of much outstanding research in liquid helium, superconductivity and low-temperature solid-state physics. Many who assisted in these pioneering experiments are still active in low-temperature research today. B. N. Eselson is deputy director of the Physico-Technical Institute of Low Temperatures in Kharkov; B. G. Lazarev, who collaborated with Schubnikov on the first direct measurement of the proton magnetic moment, is head of the low-temperature physics work at the original Kharkov Physico-Technical Institute; I. K. Kikoin is at the Kurchatov Atomic Energy Institute, Moscow; S. S. Shalyt is at the Institute of Semiconductors, Leningrad; O. G. Trapeznikova (Schubnikov's widow) is at the Leningrad State University; and N. E. Alekseevski is at the Institute for Physical Problems, Moscow.

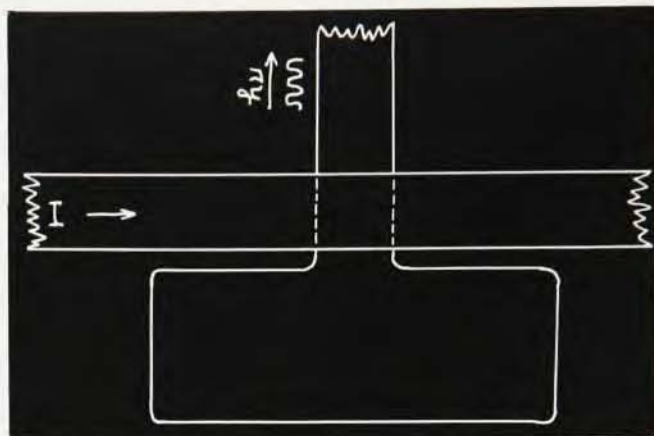
The Physico-Technical Institute of Low Temperatures of the Ukrainian Academy of Sciences was established about six years ago in a large new building on the outskirts of Kharkov. Its director, B. I. Verkin, told us that about 2000 scientists, engineers and

technicians are employed there; approximately 400 hold scientific or engineering degrees. Machine shop personnel, glass blowers, electronic technicians, et al, number 400-500. The remaining technicians assist with the experiments. Since the institute was so recently established, the average age of the scientific staff is only about 27. Many of the senior staff of the institute were originally at the Physico-Technical Institute in the center of Kharkov.

The low-temperature institute and its library serve as the main Soviet review center for all of the published literature on low-temperature physics. Current title lists are prepared and distributed periodically to other low-temperature laboratories in the USSR, and the library staff translates the more important articles.

Basic to any research program in low-temperature physics is of course the ready and easy availability of sufficient quantities of liquefied gases. At the institute there is a conventional liquid-nitrogen plant of 160-170 liters/hr capacity. Should larger amounts of liquid nitrogen be required trailers

SANDWICH
of Sn-SnO₂-Sn
used by Yanson
and Dmitrenko
to make a high
transfer efficiency
Josephson
junction. —FIG. 1



that hold several thousands liters are available for transporting it from a nearby industrial gas-liquefaction center. Normal hydrogen is liquefied at a rate of 50 liters/hr in one liquefier and 30 liters/hr in a second, and a third smaller liquefier is also available for producing liquid parahydrogen. Two liquefiers produce liquid helium, one with a capacity of 17 liters/hr and the other 22 liters/hr. Both operate on the Joule-Thomson principle with liquid hydrogen precooling.

Mechanical properties. Near the liquefiers was a laboratory in which the mechanical properties of metals and alloys, both as single crystals and in the polycrystalline state, were being investigated as a function of temperature. The laboratory has several tensile testing machines and associated cryostats in which different samples can be examined. Stress-strain data illustrating the typical serrated behavior (discontinuous load drops arising from thermal instability of the lattice) associated with metal deformation at liquid-helium temperature were presented and discussed for several metals and alloys.

Josephson tunneling. Shortly after the publication of B. D. Josephson's

paper on tunneling, I. K. Yanson and I. M. Dmitrenko¹ of Kharkov began investigating the step structure of the characteristic I - V curves and the dependence of I_c upon magnetic field. By improving the quality of their films (Sn-SnO₂-Sn) and using a very sensitive (10^{-16} watts) microwave receiver they observed directly for the first time the radiation emitted from a Josephson tunneling junction. They also studied the variation of the spectrum and line width of this radiation as functions of magnetic field and other parameters. With some recently developed tunnel structures such as the one shown in figure 1 they have observed as much as 3×10^{-10} watts in the X band with 2% of the input power as Josephson radiation.²

Yanson and Dmitrenko's excellent work on Josephson tunneling junctions was made possible in part by the carefully controlled conditions under which the junctions were formed. Fortunately much of the necessary background and technique was already available at the institute from the work of Yu. F. Komnik, I. O. Kulik and other members of a small group who have been investigating properties of thin metallic films for several years. As one example of this work we were shown in another laboratory measurements of the resistance ratio $R(T)/R(300^\circ\text{K})$ as a function of the film thickness d for thin bismuth films. Resonances in this ratio should occur with increasing d whenever the product of the Fermi wave vector k_f and d equals an integer. For most materials k_f is so large that the change in film thickness per cycle is impossibly small. For bismuth however k_f is

reduced sufficiently to permit observation of such effects provided the films being compared are identical except for thickness. At Kharkov, techniques have now been developed to meet such exacting standards. (Similar work has also been carried out at the Radio Engineering and Electronics Institute, USSR Academy of Sciences.^{3,4})

Liquid helium and He³-He⁴ mixtures. Besides work on superconductivity and solid-state physics the institute has done much fundamental research on both isotopes of helium and their mixtures.

Special facilities available to this group include a distillation unit for separating He³-He⁴ mixtures, a small He⁴ cryostat capable of reaching temperatures of about 0.75°K and two He³ cryostats. The group is systematically investigating several important properties of He II as a function of He³ concentration. They have studied solutions with He³ concentrations up to about 30%.

Film flow rates. In 1963 Eselson, Yu. Z. Kovdrya and B. G. Lazarev,⁵ noting that serious discrepancies in He II film flow rates had been reported, devised a new "time-of-flight" technique to measure this quantity. Two glass tubes differing in length by a factor of three (the longer one was in the form of a helix) were connected together at their lower ends; at the top of each tube was a thermometer. The assembly was suspended in the vapor above a bath of He II and after reaching temperature equilibrium (approximately 0.05°K above the bath temperature) it was lowered until its lower end touched the liquid surface. The film was then assumed to travel up the two rods and upon reaching the thermometers an abrupt drop in temperature was observed. From the difference in arrival times Eselson and his collaborators could calculate the film flow velocity directly. This same technique has now been extended to He³-He⁴ mixtures. One surprising result reported in the original paper was the observation of film flow velocities three times faster than other investigators had found. Eselson and his colleagues assume that in their experiment dissipative processes do not have time to develop.

Since it is indeed true that conventional flow-rate measurements yield

The author has been at Los Alamos Scientific Laboratory since he earned his PhD from Princeton University in 1944. He heads the low-temperature physics, chemistry and cryogenic engineering group there.



only the product $v_e d$, film velocity is usually inferred from measurements of static film thickness. Hence the direct velocity measurements of Eselson and his collaborators do not contradict previously published results if one can establish that the thickness of the flowing film is significantly less than that of the stationary film. The evidence available to date suggests that the moving film is actually thinner than the stationary one, but the difference appears to be smaller than that necessary to account for Eselson's results.

Fourth sound. Eselson and his colleagues are also investigating propagation of fourth sound in He II and He³-He⁴ mixtures. Of the several different types of wave motion that can occur in superfluid helium, fourth sound is characterized by "clamped" normal fluid and motion of the superfluid such that first-order changes occur in both density and temperature. To establish fourth sound one transmits a pressure pulse through helium confined in narrow channels or capillaries. In 1964, D. G. Sanikidze and D. M. Chernikova⁶ considered theoretically the properties of fourth sound in He³-He⁴ solutions and obtained the following expression for its velocity in solutions:

$$v_{IV}^2 \approx \frac{\rho_s}{\rho} \left(1 + 2 \frac{x}{\rho} \frac{\partial \rho}{\partial c} \right) v_I^2 + (\rho_n/\rho) v_{II}^2$$

X is the He³ concentration, ρ is the density of the mixture and v_I and v_{II} are the velocities of first and second sound in the mixture. Since v_I (mixture) $< v_I$ (pure He⁴) and since $\partial \rho / \partial c$ is negative, the velocity of fourth sound should decrease with increasing He³ concentration. Eselson, N. E. Dyumin, E. Ya. Rudavsky and I. A. Serbin⁷ have experimentally confirmed the Sanikidze and Chernikova prediction and simultaneously shown that ρ_s/ρ has the same value in narrow channels (about 0.5 micron) as in bulk He³-He⁴ mixtures.⁸

Normal fluid density. In discussing the theory of He³-He⁴ mixtures in 1948, L. D. Landau and I. Pomeranchuk⁹ pointed out that "impurity" energy levels, in addition to those associated with phonons and rotons in pure He⁴, must exist in such mixtures. The energy spectrum of these He³ atoms could not be uniquely estab-

lished theoretically, however. Subsequently Pomeranchuk¹⁰ showed that the two possible expressions for $E(p)$, namely

$$E(p) = E_0 + (p - p_0)^2/2m_3^*$$

$$E(p) = E_0 + p^2/2m_3^*$$

led to different equations for the dependence of the normal fluid density upon concentration, one being temperature dependent and the other not. The determination of ρ_n as a function of concentration and temperature was therefore a matter of considerable interest, and several investigations of this quantity were undertaken, some by means of second-sound measurements, others by direct measurement of ρ_n with a torsion balance. The second-sound measurements were completed first and clearly established that in the lowest energy state the momentum of impurity atoms is zero. The torsion-balance measurements, published more or less simultaneously by J. R. Pellam,¹¹ J. G. Dash and R. D. Taylor,¹² and N. G. Berezniak and Eselson,¹³ not only confirmed the second-sound results but also found that at low enough temperatures the effective mass m_3^* of a He³ atom in dilute He³-He⁴ solutions is about 2.7 m_3 where m_3 is the atomic mass of He³. Although the dependence of the normal fluid density upon He³ concentration was thus established as

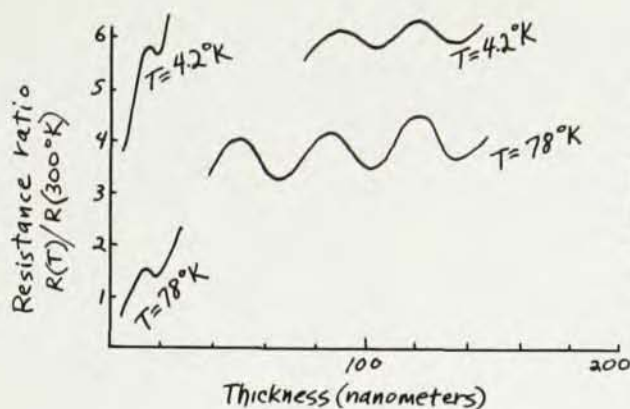
$$\rho_n = \rho_{n,4} + \frac{m_3^*}{m_4} \rho X \quad (1)$$

early work upon which this equation is based was limited to He³ concentrations less than about 10%, primarily because large vapor volumes are nec-

essary in experiments such as these and accurate determinations of vapor pressure as a function of liquid concentration had not been made for solutions with high He³ concentrations; thus the He³ concentration at which deviations from this simple formula set in was not known. This situation has now been remedied; V. I. Grigoriev, Eselson, V. P. Malkhanov and V. I. Sobolev¹⁴ have measured $\rho_n(X, T)$ for $0 < X < 0.27$ and $1.4 < T < T_\lambda$. Equation (1) has been verified for He³ concentrations up to about 0.2 and a revised value of $m_3^* = 2.35 m_3$ has also been obtained.

Liquefied and solidified gases. A comprehensive program is under way to measure physical properties such as specific heat, thermal conductivity, thermal expansion, viscosity, ultrasound velocity and absorption and critical-point phenomena (such as light scattering), in a large number of liquefied gases and their mixtures. From the data obtained together with that available from previously published work, V. G. Manzhelii¹⁵ and his collaborators are trying to correlate these properties with the molecular structure of the gases concerned.

D. N. Bolshutkin and his group have developed a number of ingenious techniques for studying mechanical properties of solidified gases. Until recently these properties had been investigated only with metal and dielectric crystals. Now the motion of dislocations, hardness, plasticity, elastic moduli, etc., for molecular crystals, in which the intermolecular attraction is predominantly the van der Waals force, are being investigated. As an example of the degree of sophistica-



RESISTANCE RATIO vs. thickness for thin bismuth films. Resonances occur when product of thickness and Fermi wave vector is an integer. —FIG. 2

tion to which these techniques have been carried, it has been shown that the static modulus of elasticity for solid hydrogen increases after nine stress reliefs from 64 to 2900 kg/cm²! Techniques have also been developed for producing single crystals of these solids (we were shown a single crystal of ammonia approximately 2 cm in diameter by 5 cm in length). The microstructure of polycrystalline specimens of solidified gases has also been observed optically.

Tbilisi Institute of Physics

The Institute of Physics of the Georgian Academy of Sciences, of which E. L. Andronikashvili is director, is not far from the center of Tbilisi. It was built about 15 years ago. Its staff now numbers about 650 of whom 200 are experimental physicists, 36 are theoreticians and about a dozen are postdoctoral fellows. The particular interests of the institute are superfluid helium, superconductivity, solid-state physics (particularly low-temperature radiation physics of solids), radiation chemistry, cosmic ray and high-energy particle research and low-temperature calorimetry of biological objects. (The calorimeter for biological studies controls the temperature to plus or minus a few microdegrees at room temperature and has been used to study phase transitions in proteins down to -120°C .)

Liquid helium. Andronikashvili's own experimental contributions to superfluid physics began in Moscow in 1946 when he demonstrated that two independent velocity fields exist simultaneously in liquid He II. This was the classic oscillating-disk experiment which seemed to confirm Landau's basic prediction that the superfluid would not participate in any kind of rotational flow imposed upon the liquid, that is for the superfluid curl $v_s = 0$. Both D. V. Osborne¹⁶ and Andronikashvili¹⁷ subsequently showed that when bulk liquid helium II is rotated the entire fluid rotates as a solid body, that is it has a parabolic meniscus consistent with curl $v_s = 2\omega$, and this paradox was not fully resolved until Richard Feynman and Lars Onsager developed the vortex-line theory for He II.

Upon returning to Tbilisi from Moscow, Andronikashvili's interest in the

hydrodynamics of rotating helium continued; since then a wealth of information on this important aspect of superfluid behavior has originated from Tbilisi. Since Andronikashvili and Yu. G. Mamaladze have recently published an extensive review article on the quantization of macroscopic motions and hydrodynamics of rotating He II¹⁸, it would be superfluous to comment further on it here. I should however mention the very recent work by Andronikashvili and J. S. Tsakadze¹⁹ on the He I-He II phase transition. Using a sensitive rotating pycnometer they found when the fluid is rotating that in crossing the lambda line from above the density of the liquid *increased* discontinuously by about 0.023%. Such behavior is of course characteristic of a first- rather than a second-order transition. It is well known, however, that many of the other properties of the superfluid state such as fountain pressure and film flow are unchanged in rotating helium; hence this apparent first-order transition at T_λ in the rotating liquid is tentatively assumed to be superimposed on the usual second-order transition.²⁰

In addition to the experimental research on liquid helium, Mamaladze and his colleagues have been examining theoretically the liquid-helium analog of the Josephson effect in superconductors. In helium, the coherence length is so short (about 0.1 nanometer) that no physical tunneling medium (analogous to the oxide layer in superconducting tunneling experiments) is available. On the other hand, as Philip Anderson²¹ has shown, the Josephson frequency equation and the associated concept of phase slippage are also quite relevant to liquid helium. The problem therefore is to develop suitable substitute weak links such as narrow channels, thin film, micropores, etc. The recent theoretical work by Mamaladze and O. D. Cheishvili²² has therefore been most helpful to experimentalists interested in investigating this exciting new aspect of quantum fluid behavior.

Superconductivity. Research in superconductivity was begun at Tbilisi quite recently, probably in recognition of recent overwhelming evidence²³ that superfluidity and superconductivity are complementary manifestations

of quantum fluid behavior. Investigations of either of these systems contribute to the understanding of the other; consequently it no longer makes much sense to specialize in superfluidity to the exclusion of superconductivity or vice versa.

Solid-state research. Although a considerable amount of solid-state research is being carried out at the institute, there was insufficient time for us to see more than a very small sample of the work in progress. Of particular interest nevertheless was a comprehensive program in which the effect of various types of radiation (for example, x ray, ultraviolet, gamma ray, neutron) on the motion of dislocations in alkali halides was being investigated.

Tbilisi State University

Supplementing the liquid-helium studies at the Institute of Physics is a low-temperature research program at Tbilisi State University in which several other aspects of the rotating-helium problem are being investigated. In this laboratory several years ago G. A. Gamtsemlidze demonstrated that no tangential velocity discontinuity existed in the superfluid component of helium near a wall,²⁴ and this result has been important in establishing the superfluid boundary conditions at a solid surface in the Ginzburg-Pitaevskii theory of liquid helium. Recently Gamtsemlidze's group, using an ingenious doubly rotating system, determined the slippage coefficient of vortices with respect to a solid surface.²⁵

Ioffe Physico-Technical Institute

The Ioffe Physico-Technical Institute of the USSR Academy of Sciences in Leningrad, originally the Leningrad Physico-Technical Institute, was established in 1918 by A. F. Ioffe. In contrast to the more specialized Soviet scientific centers organized in recent years, such as the I. V. Kurchatov Atomic Energy Institute in Moscow and the Semiconductor Institute in Leningrad, the interests of Ioffe's institute were from the beginning encouraged to be quite general although admittedly there was (and still is) considerable emphasis on the physics of the solid state. Ioffe's laboratory was also the prototype for many other Physico-Technical Institutes estab-

lished subsequently in other large cities in the USSR, such as Kharkov, Dnepropetrovsk and Tomsk.

While John Dewey was urging the philosophy of "learning by doing" upon American educators, Ioffe was applying this same concept to the graduate training of physicists in Leningrad. Having established a fine research institute staffed with many scientists who were later to become eminent in their own right, Ioffe recognized the educational value of using both facilities and staff for a sort of on-the-job training program. He therefore sought and obtained approval from the authorities not only to carry forward the excellent research program of the institute, but also to train physics students and award advanced degrees.

Ioffe remained director of the Physico-Technical Institute until 1951. In 1954 he became director of the newly established Semiconductor Institute of the USSR Academy of Sciences in Leningrad, and he held this post until his death in 1960. The present director of the Ioffe Physico-Technical Institute is B. P. Konstantinov, who is also vice president of the USSR Academy of Sciences. Institute activities include semiconductor and solid-state physics, spectroscopy, low-temperature physics, atomic and nuclear physics, and gaseous electronics or plasma physics. Undoubtedly there is much other work in progress at the institute, some of it probably classified since entry to the laboratory appeared to be by way of a security guard station.

In a new facility outside the city a staff of about 1500 (half of whom are scientists and engineers) carry out a part of the institute's work in solid-state and nuclear physics. The institute's reactor (flux 2×10^{14}), is there, too, and it is being used to study, among other things, the effect of radiation damage on semiconductors and other solids. In Leningrad, although the original laboratory building is undergoing a major remodeling, research is continuing in all of the areas mentioned above. Specifically in the Solid State and Semiconductor Physics group the physical and chemical properties of semiconductors (including 3-4-component semiconductors) and the mechanical properties of



SPIRITED DISCUSSION in the Petrodvorets, Leningrad between C. J. Gorter, V. P. Peshkov and R. Hilsch, who toured Soviet laboratories.

crystals and polymers are being investigated. Another group, headed by S. M. Ryvkin, is studying nonequilibrium processes in semiconductors and using photoconductivity to study carrier lifetimes and relaxation times. Work on lasers has also been carried out at the Physico-Technical Institute, including development of the gallium arsenide laser.

In gaseous electronics, various plasma confinement devices are being built. Concurrently new plasma diagnostic techniques are being investigated, including mass-spectrographic analysis of the collision products of ions and electrons with atoms.

The spectroscopic studies, directed by E. F. Gross, include investigations of Raman effect, exciton and phonon distribution spectra. Also in this group B. P. Zakharchenya is studying the Zeeman effect for rare-earth impurities in various crystals.

Superconductivity and antiferromagnetism are being investigated by a low-temperature physics group headed by A. V. Kogan. This group is also responsible for supplying liquid helium and other cryogenic liquids to other investigators in the laboratory. The helium liquefaction plant has a capacity of about 40 liters/day.

Superconductivity. We visited first a laboratory in which the kinetics of the superconducting transition were being studied. Using thin (0.10-0.17-

micron) films of tin and microsecond pulses of 10^7 A/cm² current density, A. P. Smirnov and his collaborators²⁶ have shown that the transition from superconducting to normal is always initiated at the edges of the superconducting strip. By observing those regions of the specimen where the surrounding He II boils, they have demonstrated that the critical current, its temperature dependence and other details of the superconducting normal transition depend critically on the way in which the Joule heat production in the normal regions is transferred to both the substrate and the liquid helium.

Magnetic studies. Kogan himself has been investigating recently the variation of the effective internal magnetic field at various nonmagnetic impurity nuclei in transition metals such as iron.²⁷ To obtain H_{eff} one measures the anisotropy of gamma rays emitted from radioactive nuclei of the impurity atoms dissolved in the iron and oriented at very low temperatures.²⁸ In addition to the well-known dependence of H_{eff} upon atomic number, it has been shown that the internal field is also dependent on the "size" of the impurity ion; specifically H_{eff} is small when d_{imp} is small and vice versa.

Leningrad Semiconductor Institute

The Semiconductor Institute of the USSR Academy of Sciences, while



BANQUET TALK between E. Kanda, E. F. Hammel, V. P. Peshkov and B. N. Eselson. Eselson proposed a toast "To liquid helium, the study of which has given us all so much enjoyment." At another banquet one of the visitors toasted, "To the women scientists of the Soviet Union: we knew before we came to your country that you were good physicists, but to find that you are also *beautiful* physicists has been a very special pleasure!"

new laboratory facilities are under construction, occupies two former embassies and the former town house of the tsar's uncle. G. A. Smolensky, director of the institute, told us that research is mainly in thermoelectricity, nuclear-magnetic-resonance and electron-spin-resonance investigations of crystals, magnetic and electric ordering in crystals, and semiconductor theory. In addition, the institute has recently been granted by the Soviet Commission on Higher Education the authority to confer both the candidate's and doctor's degrees.

Ioffe's special interest in practical applications of thermoelectricity led to development of a variety of thermoelectric coolers utilizing semiconductors. In recent years improvements have been made both in the efficiency and ultimate cooling capacity of the original units, and in addition so many new applications have been found that at present over 100 different types of thermoelectric coolers are being produced. Some of these (using three stages) can maintain temperatures

100°C below ambient. They are being used for cooling radiation receiving devices such as photomultipliers and photoresistors, and in the chemical industry they are routinely employed for infrared analysis of liquids (here the cooling of the photocathode reduces the dark current by a factor of 1000). In the laboratories and in large nuclear-physics facilities thermoelectric coolers have been used successfully and with negligible maintenance problems to refrigerate cold traps in large vacuum installations for over five years.

Some of the most interesting practical applications of thermoelectricity have been made in biology and medicine. Microcoolers have been developed for cooling microscope stages to as low as -40°C and for varying the temperature in a controlled fashion while making biological observations. They are also used to quick freeze specimens prior to sectioning with the microtome. Another thermoelectric device is being used in dermatology for local cooling of the skin, and in oph-

thalmology these devices have been used very effectively for cataract operations. Finally they are being used to study various kinds of biological reactions.

S. S. Shalyt, who is in charge of the low-temperature laboratory at the Semiconductor Institute, has recently observed oscillations of the magnetoresistance of tellurium²⁹ similar to those previously reported in n-type indium antimonide. Singularities such as these, which occur in nondegenerate semiconductors, may be evidence of magneto-phonon resonance resulting from the resonant scattering of the carriers by optical phonons in strong magnetic fields (a phenomenon first predicted by V. L. Gurevich and Yu. A. Firsov³⁰).

For a degenerate semiconductor, quantum oscillations of the magnetoresistance, thermoelectric power and Hall coefficient should occur and these have now also been observed in n-type indium arsenide at liquid-helium temperatures.³¹

M. I. Kornfeld's group has distorted the lattice structure of alkali halide crystals by introducing substitutional point defects by diffusion techniques. Using NMR the group found that the shape of the resonance curve is significantly altered due to perturbations introduced by the impurity atoms. The number of lattice sites affected per impurity atom can thus be estimated and this number correlated with other physical properties of the specimen such as its thermal conductivity.

Smolensky, in addition to his administrative duties, is investigating the weak ferromagnetic properties of certain perovskite structures. Specifically the temperature dependence of the magnetic susceptibility along different crystallographic axes has been determined³² for YCrO_3 , NaNiF_3 and several other similar perovskites and, using NMR techniques, the spin density distributions have also been measured in the paramagnetic region.³³

Ways of research

In the experimental work we saw, it was obvious that a nice distinction is drawn between what is necessary to do a given piece of research and what is desirable for convenience or comfort or ease. The former is usually provided; the latter often is not. Another

noticeable difference between research in the USSR and that in the US is that we tend to rely more on assistance from machines; in the USSR one is conscious of a much higher ratio of trained technician and assistant support for the principal investigator. One can argue of course about which is the better way, but from a practical standpoint any research scientist would probably agree the obvious desideratum is to have both! (Perhaps the millenium will arrive for each of us at the same time.)

The opportunity to talk with colleagues from abroad and to discuss with them the fine points of a given measurement or calculation is always one of the most valuable consequences of attending meetings or visiting laboratories. This exchange of ideas at the working level is not only an excellent method of encouraging good science to become better science, but with increasing specialization and the proliferation of journal articles it soon may well be the only way! We are therefore grateful to our Soviet colleagues for the opportunity to visit with them during and after LT-10, and we hope that the benefits arising from these contacts will help to insure that no impedimenta are placed by anyone in the way of increased coöperation in the future.

* * *

The author gratefully acknowledges the comments and suggestions sent him by the members of our party. The other members of our group, all invited by the USSR Academy of Sciences, were C. J. Gorter (recipient of the 1966 Fritz London Award), O. V. Lounasmaa (chairman of the Low-Temperature Calorimetry Conference held in Otaniemi, Finland the week before LT-10) and the following members of the IUPAP Commission on Low Temperature Physics: John Bardeen, University of Illinois; E. Kanda, Research Institute for Iron, Steel and Other Metals, Tohoku University, Sendai, Japan; R. S. Safrata, Nuclear Research Institute, Rez, Czechoslovakia; R. Hilsch, University of Göttingen; J. van den Handel, Kamerlingh Onnes Laboratory, Leiden, Holland; and V. P. Peshkov, Institute for Physical Problems, Moscow. An expanded version of this article, including a description of the social aspects of our trip, is available as AEC document LA-DC-8576.

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