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The Fourteenth International Conference on Low Temperature Physics, Helsinki University of Technology Otaniemi, Finland, 14-20 August 1975.

THOMAS A. KITCHENS, JR, BARRY M. KLEIN AND DONALD U. GUBSER, NAVAL RESEARCH LABORATORY, WASHINGTON D. C.

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THOMAS A. KITCHENS, JR., [redacted] BARRY M. KLEIN
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The Fourteenth International Conference on Low Temperature Physics was held in Otaniemi, Finland in mid-August, 1975. Some 530 papers were contributed to this Conference on the subjects of helium, superconductivity, cryogenic techniques and low temperature properties of materials. This report reviews the invited papers and many of the contributed papers of this conference.

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THE FOURTEENTH INTERNATIONAL CONFERENCE ON LOW TEMPERATURE PHYSICS, HELSINKI UNIVERSITY OF TECHNOLOGY, OTANIEMI, FINLAND, 14-20 August 1975

The Fourteenth International Conference on Low Temperature Physics (LT14) was held in Otaniemi, Finland on the campus of Helsinki University of Technology from 14 to 20 August, 1975. The Conference, which is now held on a three-year schedule, was sponsored by the International Union of Pure and Applied Physics (IUPAP) and the International Institute of Refrigeration (IIR), and several Finnish organizations assisted for this particular meeting. The local committee was chaired by Prof. O. V. Lounasmaa, who will be remembered for a most outstanding job of organizing the meeting. All of the contributed papers were published in four volumes and were distributed to the conferees prior to the first session. This greatly facilitated scientific discussions at the Conference. A fifth volume containing the invited sessions and the post-deadline papers will be published in the near future.

The Conference was attended by approximately 820 participants, of whom about 170 were from the USA and about 100 each from West Germany, the United Kingdom and France. About 50 participants were from the Netherlands, Finland and the USSR each. In all, over 30 countries were represented. Seventeen review or plenary papers and about 530 contributed papers were presented. Each morning was devoted to three 50-minute plenary talks, while each afternoon was devoted to contributed papers. The Conference was divided into four groups: 1) Helium studies (Quantum Fluids), 2) Superconductivity, 3) Low temperature properties of solids, and 4) Techniques and special topics, which also title the four published volumes of the proceedings. Under the last category fell a large variety of interesting subjects such as nuclear alignment, weak link phenomena, systems of low dimensionality, and phase transitions.

A large number of excellent papers, covering a wide variety of low temperature phenomena, were submitted for presentation; however, in an attempt to reduce the confusion of many short talks given in multiple parallel sessions, the Very Low Temperature Commission of IUPAP decided to allow only four parallel afternoon sessions and to allocate 20 minutes for each contributed paper. This decision caused about two-thirds of the papers to be read by title only. To compensate for errors in judgement by the Commission and to provide for more informal discussions a large number of "mini-conferences" were held in the evenings after the regular sessions. One evening in particular, there were more parallel sessions of mini-conferences than there were regular sessions during the day! Many interesting scientific presentations and discussions occurred at these informal evening sessions and, for those who were capable of enduring such a long day, they were perhaps more stimulating than the regular sessions. Some of the mini-conferences tended to contain material which had been covered in the regular sessions but this turned out to be advantageous because the participants had a chance to hear what they missed by attending some other parallel session. The Conference was nicely broken after the third day by a Sunday cruise aboard the M/S SVEA CORONA, a newly commissioned ship of the Finnish line. The eight-hour excursion through the archipelago of Finland also allowed for more informal discussions.

The Conference reflected the recent interest generated in quantum liquid studies due to the discovery in 1972 of superfluidity in liquid He^3. Several plenary and contributed papers were devoted to this subject. For his pioneering work in the field of quantum fluids, Professor J. C. Wheatley (University of California at San Diego) received the Fritz London Award. (This award was recently endowed by J. Bardeen with moneys from his second Nobel Prize, for the theory of superconductivity.)

Wheatley gave a very lucid review of his work in showing that pure liquid He^3 obeyed the Landau theory of Fermi liquids and that the dilute He^3 - He^4 solutions were close to an ideal Fermi gas in nature. In each case he presented the material in terms of the technological advances that had made the measurements possible. He discussed the development of Pomeranchuk cooling and the early evidence seen at Cornell of the superfluid properties of high pressure liquid He^3. Wheatley then gave a very clear presentation of the present knowledge of the two magnetic BCS-like superfluid phases of the liquid He^3 and described some of the more outstanding problems in our understanding of these novel superfluid phases. (It will be interesting to see whether the rapid pace of low temperature techniques can continue at the rate it has over the last decade. If so, the state of the art will allow bulk samples to be cooled to temperatures in the order of 100 microdegrees by 1984!)

The emphasis of the Conference was almost equally divided between the four subject categories mentioned above; there were about 135 contributed papers in Helium, Superconductivity, and Low Temperature properties, each, and 115 in the Techniques section.

The remainder of this report will be somewhat subjective, since it represents the authors' opinions and comments concerning the talks given at the Conference. No attempt will be made to designate which contributed papers were orally presented, read by title only, or presented in the mini-conferences, since there were excellent and not-so-excellent contributions in all categories. In some cases, the comments reported here were obtained from discussions with other scientists who attended sessions and mini-conferences not attended by the authors. Certainly, there were excellent and exciting papers that the authors did not hear because of the parallel sessions.

In the following discussion we will denote the papers by the convention used at the Conference, (A.###). A is a letter designating the subject (and volume), that is, H for helium, S for superconductivity, L for low temperature properties of solids, and T for techniques and special topics, and ### is a three-digit integer.

Professor A. J. Leggett (University of Sussex, Brighton, UK) gave a short review of the history of the theory of He^3 and contrasted the values of parameters in the "A" and "B" superfluid phases of He^3 with the known classes of superconductors. He pointed out that the non-zero values of orbital angular momentum make the theory related to anisotropic liquid crystal theory. He discussed the Anderson-Morel state for the "A" phase, and the Balian-Werthamer state for the "B" phase. Leggett went on to speculate on phenomena such as supercurrents associated with spin and orbital waves.

Professor R. C. Richardson (Cornell University, Ithaca), who is spending the year at Oteniemi, reviewed the present experimental knowledge on the "A" and "B" phases of He^3, especially the nuclear magnetic resonance investigations. He also commented on the need for experiments to further elucidate the "textures" (domains) suggested by deGennes.

The last plenary speaker on helium was Professor I. M. Khalatnikov from Moscow. He discussed the very interesting case of superfluid He^3-superfluid He^4 solutions. A very simple calculation lead Khalatnikov to suggest such solutions may exist at temperatures as high as 10^{-4}K. He then calculated some of the hydrodynamic properties of this system. More than a few advances in low temperature technology will be needed before any experimental tests of his predictions are possible.

Of the 135 contributed papers on the properties of the isotopes of helium, 32 were on theoretical and experimental investigations of bulk liquid He^3, 48 on theoretical and experimental investigations of bulk liquid He^4, 14 on the isotopic mixtures, 26 on the properties of films of both isotopes, and 15 on the solid phases. As in the plenary sessions the subject of bulk liquid He^3 was emphasized in the 10 contributed sections devoted to helium.

As one would expect, the observation of not one but two anisotropic and magnetic superfluid states in He^3 has created an enormous interest in the theoretical community. The mini-conferences were a cornucopia of theoretical and experimental results on liquid He^3. C. J. Pethick and coworkers at the University of Illinois and Copenhagen (H.002 and H.003) presented their considerations on the transport properties near the superfluid to normal fluid transition, using a Boltzmann equation approach. A cusp in the viscosity is predicted.

Mr. C. Cross (University of Cambridge) presented his work with P. W. Anderson on orbit waves in the Anderson, Brinkman and Morel (ABM) model of the "A" phase (H.008). These waves are associated with the possible oscillation of the vectorial order parameter which is related to the orbital angular momentum of the He^3 pairing. He found the waves overdamped in the region of stability for the A phase of He^3. H. E. Hall (University of Manchester) presented a phenomenological picture of the superflow and the orbital waves, giving a dispersion relation for them that is consistent with other calculations and experiments (H.009).

W. F. Brinkman and H. Smith (Bell Laboratories, Murray Hill, N.J.) presented their calculations of NMR phase shifts in the A and B phases (H.012). The calculations are in excellent agreement with experiments reported by D. D. Osheroff and L. R. Corruccini also of Bell Labs (H.026) except for some pecularities in the B phase. They also reported on the spin-lattice relaxation times in both the A and B phases (H.029).

Two papers were concerned with sound propagation in superfluid He^3. P. R. Roach et al. (Argonne National Laboratory, Illinois) (H.023) investigated the B phase at 21 bar with 20-MHz sound waves. Their results were in quantitative agreement with calculations done by K. Maki and H. Ebisawa (University of Southern California) and P. Wölfe (Munich) (H.007). The measurements by D. T. Lawson et al. (Duke and Cornell Universities) (H.024) were also at 20 MHz but along the melting curve in the A phase (H.024). The data are qualitatively consistent with P. deGennes texture concept with the gap axis perpendicular to the applied magnetic field. These and many other new data on textures were discussed in a very interesting mini-conference on He^3.

R. Scherm et al reported on the inelastic neutron scattering experiments at Grenoble to observe collective excitations in liquid He^3 (H.020). The investigation was performed on the cold neutron time-of-flight spectrometer, but the results indicated a wider distribution of neutrons than expected by all current theories - background is still a major problem. This group has also looked at dilute He^3 - He^4 solutions of 6%, 12% and 24% He^3. They have seen a mode lying below the usual collective excitation. They plan to study these liquids as a function of pressure in the near future.

Many interesting investigations were reported concerning bulk liquid He^4. W. A. B. Evans (University of Kent at Canterbury, U.K.) argued that for self-consistent approximations to the solution of the helium Hamiltonian beyond Hartree-Fock which consider two-body interactions, have no Bose-Einstein Condensation (H.033). He was motivated by the recent neutron scattering results from Oak Ridge where no condensate was observed. Evans also pointed out that measurements of the ac Josephson effect might settle the matter more definitively than is possible with neutrons. If the condensate exists, the Josephson frequency would be half the value it would be if the condensate were nonexistent.

The dynamic structure factor $S(Q,\omega)$ in liquid He^4 is still a very interesting problem. A.D.B. Woods et al of (Atomic Energy of Canada, Ltd., Chalk River) reported their inelastic neutron scattering determination of $S(Q,\omega)$ on the normal fluid at 4.2 K (H.049). They find a static structure factor in good agreement with both x-ray scattering and isothermal compressibility measurements. The $S(Q,\omega)$ has three peaks at low $Q, \omega = \pm Q$, which overlap and broaden rapidly with increasing Q. Nevertheless, if the mean energy of the high energy peaks are plotted, the dispersion curve is quite reminiscent of superfluid He^4. There were several theoretical investigations of $S(Q,\omega)$ in the superfluid phase. M. H. Lee (University of Georgia at Athens) discussed his calculation of the poles of $S(Q,\omega)$ based on the anisotropic Heisenberg antiferromagnetic model of superfluid He^4 (H.039). The results are in reasonable agreement with the Chalk River results. G. Whitfield (Penn. State University) discussed the analogy between rotons and polarons in pizoelectric materials (H.040). T. Nishiyama and Y. Watanabe (Osaka University) (H.041) also considered the collective excitations in superfluid He^4 using the pair theory of Iwamoto. The calculated $S(Q,\omega)$ is in better than qualitative agreement with experiment. D. Baeriswyl (RCA Laboratories in Zurich) calculated $S(Q,\omega)$ accounting for multi-roton states with marked improvement over the Feynman approximation (H.042).

Ions in superfluid and rotating helium is another active research area. R. M. Ostermeier and W. I. Glaberson (Rutgers University, N.J.) presented the measurements of the negative ion captive cross sections and the escape rate of positive and negative ions from vortices in superfluid He^4 (H.066). Some measurements were also taken in dilute He^3 solutions as well. They also reported the mobility of positive and negative ions along vortex lines in superfluid He^4 (H.068). J.D.P. van Dijk _et al_. (University of Leiden, The Netherlands) measured positive ion escape rates at lower temperatures and found them thermally activated for $T < 0.8$ K, but dominated by some other process at lower temperatures (H.067). The binding energy appears to be dependent on the electric field, being about 18 K in diminishing field and falling to about 8 K by 15 kV/cm.

G. A. Williams and R. E. Packard (University of California at Berkeley) presented their work on the trapped ion lifetimes in He^3 - He^4 superfluid mixtures for 0.01 to 1.3 K (H.094). Here, again, the positive ions were thermally activated until limited by another process, with the activation energy decreasing with increasing He^3 concentration. This disagrees with the prevalent theory by R. Donnelly and P. Roberts (Proc. Roy. Soc. A312,519 (1969)) and does not agree in detail with the Rutgers result. Negative ions behave in a much more complicated way. Packard also showed his films of the first direct observation of quantized vortices in rotating helium. This work required superb experimental technique and opens the door to a new realm of experiments.

Perhaps one of the most exciting accomplishments in the area of helium films has been the observation of persistent currents. Two groups reported on their research on this effect, H. J. Verbeek et al. (Leiden University) (H.107) and R. K. Galkiewicz and R. B. Hallock (University of Massachusetts in Amherst) (H.106). These groups and D. Petrac and T. G. Wang (California Institute of Technology in Pasadena) (H.102) have been investigating the unsettled problem of Bernoulli thinning in non-dissipative flow of helium films. With an experimental geometry designed to eliminate vapor exchange, Petrac and Wang observed no thinning, and they feel that acceleration effects may explain some of the experiments which have observed it. The Leiden and Massachusetts groups have observed the thinning. This fascinating problem is far from settled - it may be that the theory is inadequate. P. W. Forder et al. (The University of Kent at Canterbury) have yet another approach to this problem but do not yet have data (H.103).

The free surface of helium was used to bind electrons to approximate a two-dimensional electron plasma. C. C. Grimes et al. (Bell Laboratories, Murray Hill) reported on the spectroscopy of such a system measured at 130 and 220 GHz by Stark-effect tuning and they have found excellent agreement with variational calculations (H.115). Even the expected effects of magnetic fields applied along and perpendicular to the free surface have been observed. The electronic wave functions extend hundreds of Angstroms above the helium surface in this experiment!

In the session on the solid helium phases, a careful study of the magnetic field dependence of the He^3 melting curve and of the A to B superfluid phase transition was reported by the University of Florida group, R. B. Kummer et al.(H.132). The measurements which extend to about 1 mK show a critical field for the transition of 0.45 T.

Five plenary speakers presented talks on superconductivity. Dr. M. Beasley (Stanford University, Palo Alto) discussed superconducting microbridges. For short (Dayem) bridges, ones in which the width and length of the bridge are less than the bulk superconducting coherence length, the physical phenomena are reasonably well understood in terms of the Ginzburg-Landau equations. For long bridges Beasley argued that much of the behavior was dependent on phase-slip centers and inelastic scattering processes. Better time-dependent Ginzburg-Landau equations are needed before the long bridge case can be clarified.

The paper by R. Flükiger et al. (University of Geneva) addressed the problem of long range atomic order (LRO) in V_3Ga and the A15 compounds in general (S.001). The importance of LRO had been demonstrated for the A15 compounds with low transition temperatures, but the strong dependency of T_c on LRO had not convincingly been demonstrated in the high T_c A15 compounds. This paper showed that ordering effects are just as important in the high T_c compounds as in the lower T_c materials. A T_c maximum of 15.7K has been achieved for stoichiometric V_3Ga after annealing for three months at 620°C.

There were seven contributed papers related to the palladium hydrogen system. Much of the current interest in this area centers on obtaining an understanding of the occurrence of superconductivity in PdH and PdD and in alloys of Pd with, for instance, the neighboring elements Ni, Pt, Rh, Cu, Ag and Au; together with H or D. This is in view of the fact that pure Pd metal and the alloys mentioned are not superconducting, the superconductivity must be due to the H or D.

B. M. Klein and D. A. Papaconstantopoulos (Naval Research Laboratory, Washington) presented quantitative theoretical calculations of the electron-phonon interaction and T_c for PdD (S.103). Using ab initio band structure calculations for PdD and the measured phonon spectrum of PdD, they computed the electron-phonon coupling constant λ in McMillan's form of the theory. They conclude from their calculations that superconductivity in PdD is due mainly to phonon modes which are associated with deuterium.

There were three experimental papers at the meeting which supported these theoretical conclusions. Tunneling experiments on PdD by A. Eichler, et al. (KFA, Jülich, Germany) showed that the optic mode phonon-electron λ, at least qualitatively, is important for superconductivity (S.014). L. E. Sansores and R. E. Glover (University of Maryland, College Park) reported experiments on PdH formed by evaporation of Pd onto solid H, and concluded that ".... a well-ordered Pd lattice is incidental to superconductivity in PdH and makes it unlikely that an explanation can depend on details of the Pd (part) of the phonon spectrum," (S.010). D. S. Mac Lachlan, et al. (Universite de Paris-Sud, Orsay) reported in (S.011) on electrical resistivity measurements in PdH, which they analyzed to show that the optical mode λ was about three times the acoustic mode. Since Pd is so much heavier than H (or D), optic and acoustic modes can very accurately be interpreted as meaning H (or D) and Pd respectively. Therefore, this latter experiment agrees quite well with the theoretical results just described.

High temperature electrical resistivity measurement was also used by R. Flükiger, et al. (Universite de Geneve) to predict the T_c variation in $Zr_X Nb_{1-2X} Mo_X$ compounds (S.017); and by R. Fogelholm et al. (KTH, Stockholm) to explain the T_c variation in In-Sn alloys (S.111).

Professor D. Langenberg (University of Pennsylvania, Philadelphia) spoke on the non-equilibrium properties of superconducting currents. Here, other than some measurements of quasiparticle recombination rates, the theory appears to be far ahead of the experimental work.

The superconducting materials with high critical fields, H_c, were discussed by Professor Ø. Fischer (Université de Genève, Switzerland). From the practical point of view there are already materials with H_{c_2} in excess of 40 T, and the major problem in most applications is holding the magnet together at these fields! The Clogston limit, $H[T] = 1.84 \times T_c$ which assumed a dirty superconductor with no spin-orbit scattering has been exceeded even in the TiV alloys. For high-field superconductivity one needs a superconductor with a small coherence length and large spin-orbit scattering to cancel the effect of orbital paramagnetism. Fisher reported the results of the spin orbit scattering parameter for the compounds $Cu_2Mo_6S_8$, $Sn_2Mo_6S_8$, and $Pb_2Mo_6S_8$ which were 0, 13 and ∞ respectively. Thus, the $Pb_2Mo_6S_8$ compounds are superior for high-field qualities. Fischer also reported on work on even more complicated systems with large spin orbit scattering parameters. For example, for $Pb_{0.7}\ Eu_{0.3}\ Gd_{0.2}\ Mo_6\ S_8$ the H_{c_2} is greater than 65 T with a $T_c = 12$ K.

Professor W. Buchel (University of Karlsruhe, W. Germany) discussed the state of superconducting research on A-15 structures ($T_c \cong 22$ K in Nb_3Ge), in the $(SN)_x$ ($T_c \cong 0.3$ K) and in the metallic hydrates ($T_c = 16$ K for $Pd_{0.55}\ Cu_{0.45}$ + H, and it's ductile!)

Professor T. Ohtsuka (Tokoku University, Sendai) spoke of the large scale applications of superconductivity. He reviewed the pertinent materials parameters and outlined the applications to electrical power generation, storage and transmission. The attractive and repulsive methods of magnetic levitated ground transport vehicles were contrasted, and the program in West Germany and in Japan were described. Ohtsuka then showed impressive films of the 3.5-ton Japanese vehicle which has made over 200 runs on its 400-m track at velocities up to 60 km/hr! There is almost no activity in this area of technology in the United States.

The superconductivity portion of the contributed papers (weak link phenomena not included) numbered 140. Roughly 50 of these dealt with the nature of the intermediate and mixed state of type I and II superconductors; some 45 dealt with superconducting materials research; properties of thin films and proximity effects were the subject of about 20; while nucleation effects, fluctuations, and thermoelectric effects comprised most of the remaining 30.

T. Nakajima et al. (Tohoku University, Sendai, Japan) showed in (S.022) that the isotopic volume term, which normally isn't considered in discussing the isotope effect, is important in Mo. They did this by carefully measuring the lattice constants of ^{92}Mo and ^{100}Mo by x-ray diffraction and the obtaining the volume-dependent terms.

Another interesting paper was (S.019), that of J. Klein et al. (Ecole Normale Supérieure, Paris) which asked the question, "Can T_c on superconducting γ-Be be enhanced?" The point made was that although T_c of γ-Be was 9.5 K, it still behaved as if it were a weak-coupling superconductor, i.e., it had a λ of 0.5, an energy gap to T_c ratio of 3.5, and no structural anomalies in the high energy tunneling characteristics which would signify strong electron-phonon coupling. Whereas attempts to enhance T_c in strong-coupling superconductors have failed most of the time, weak-coupling superconductors can frequently be enhanced. For example, Al with a bulk T_c of 1.2 K is enhanced in thin films to have a T_c near 6.5K. If T_c in weak-coupling, γ-Be could be similarly enhanced, it would have a T_c over 30 K. No such increase has so far been observed.

J. Halbritter (University of Karlsruhe) presented (S.059), a paper on thin-film proximity effects which showed that dielectric or semiconductor coatings on a superconductor will most probably reduce the T_c of the superconductor. This is a marked contrast to the idea which stimulated research on metal-semiconductor surfaces some years ago, where it was postulated that excitonic interactions may increase T_c in such a composite material. It was claimed in the paper that the theories have in the past ignored the localized surface states of a real (imperfect) surface, and that resonant surface scattering of electrons into these surface states is actually detrimental to superconductivity. Oxygen vacancies in a M-MO surface are particularly harmful, and much care is necessary to fabricate more perfect metal/dielectric interfaces.

H. Parr (University of Oslo) presented paper (S.051) on the field dependence of penetration depth in Sn up to the superheating limit. Due to the experimental difficulties in obtaining perfect superheating, such experiments had not previously been performed. For H such that $H_{sh} > H > H$, where H_{sh} is the superheating limit, a very sizable field-dependence appears with an ultimate enhancement of the penetration depth by 50% over the zero-field value. The experiment consisted of fabricating and measuring the AC susceptibility of a flawless 15 to 30-μm-diameter sphere of Sn. The AC signal is then proportional to the skin-depth of Sn.

Interesting superconducting tunneling measurements on NbC were reported by J. Geerk et al. (Kernforschungszentrum, Karlsruhe) in (S.106).

They obtained the tunneling density of states $\alpha^2(\omega)F(\omega)$ in the energy range 0.30 meV covering the acoustic mode region (mainly the Nb vibrations) and showed that the main contribution to λ in NbC is from these phonons. This is in agreement with the theoretical calculations of Klein and Papaconstantopoulos of NRL reported in 1974. Other tunneling measurements on clean and granular aluminum films were presented in (S.109) by M. Dayan and G. Deutscher (Tel-Aviv University, Israel). They showed that the enhancement of T_c in the latter appears to be associated with an increase in the electron-phonon interaction with no significant change in the shape of the phonon spectrum.

Two papers on pressure effects in superconducting materials were presented. One (S.029), by H. Balster and J. Wittig (KFA, Jülich, W. Germany), showed that pressure-induced structural instabilities in La produced an enhancement of T_c at 25 and 53 kbars. The authors suggest that these structural instabilities are similar to those seen in Ce, and they claim that the electronic band structure of La is similar to that of Ce, i.e., it has 4f electron bands near the Fermi surface. In the following paper, (S.030), the pressure research performed recently at the NRL by D. U. Gubser and A. W. Webb was reported. Here it was found that currently accepted theories of the volume-dependence of the electron-phonon interaction were not valid at pressures greater than 25 kbar for Al. The data followed an unexplained empirical relation which linearly related changes in T_c to pressure-induced volume changes in the superconductor.

A number of papers concerning the kinetics of current-induced transitions in a superconducting wire to the normal state were given. As the critical current is reached in the wire, a radial electrical field appears and changes in the magnetic induction of the wires are observed. These effects occur because the current in the wire begins to flow along helically shaped curves. The magnetic flux lines also redistribute themselves in a helical pattern. Papers (S.036) by H. D. Wiederick et al. (Royal Military College, Kingston, Canada) and (S.037) by B. Makiej et al. (Institute for Low Temperature and Structure Research, Warsaw) presented observations of these effects.

Two papers (S.038) by W. C. Overton of Los Alamos and (S.039) by Overton et al. presented theoretical and experimental evidence for an asymmetry in the velocity of destruction of superconductivity by current in a type II wire. By slightly raising the temperature of a spot in the middle of a wire such that the J_c was exceeded at that point, and then measuring the thermal propagation of the spot both in the direction of and oppoite to the current flow, they were able to establish the asymmetric relation that the thermal propagation was faster in the direction of the current.

One of the many topics considered under the general heading of Type II superconductors was that of flux flow. J. Schelten and G. Lippmann (KFA, Jülich) discussed in (S.088) their use of neutron diffraction methods to measure directly the flow velocity of flux induced by a current. The relation $\underline{E} = \underline{v}_L \times \underline{B}$ which had been questioned both theoretically and experimentally as to its validity, was shown to be obeyed.

The plenary sessions contained five talks concerned with the low temperatures properties of solids. Professor P. Nozieres (Grenoble) contrasted the simple physical ideas and the elaborate mathematical techniques associated with the Kondo effect. He gave an elegant explanation of the power of the idea of scaling in general and its application to the Kondo problem. Nozieres believes the mathematical game is now over. Perhaps now a more realistic Hamiltonian will receive some attention.

Professor R. Orbach (University of California at Los Angeles) reviewed the state of our understanding of the dynamic properties of dilute magnetic alloys. In particular, he described the magnetic resonance and relaxation work, and showed the connection of the g-shift and linewidth with the Kondo problem. If the coefficient of the TlnT term in the electrical resistivity is also known, then it is possible to determine the exchange parameter, J, and the Kondo temperature, T_K. Orbach discussed some of the results of his group and others.

Professor F. Koch (University of Munich, West Germany) discussed the anisotropic thermal scattering of electrons in metals. His technique is to populate a point on the Fermi surface and to watch the diffusion of the population which is due to the thermal scattering. He also discussed the radiofrequency size effect as a means of determining the thermal scattering. The results in Cu, Ag, and Au seem good, but for these cases the Fermi surface is simple and the other necessary parameters in the analysis are well known. More complicated systems will probably be much more difficult to analyze.

Professor I. F. Silvera (University of Amsterdam) provided an excellent review of the state of our knowledge on the solid phases of the isotopes of hydrogen. He described the prevalent theoretical work, pointing out that a lambda point is predicted for the liquid phase at 5.7K! Unfortunately, nature has hidden this from us because hydrogen solidifies near 14 K. Raman, inelastic neutron scattering and nuclear magnetic resonance studies on these solids are now rather extensive.

Academician A. Abrikosov (USSR Academy of Science, Moscow) presented a theoretical description of materials intermediate between metals and dielectrics. He calculated the critical exponents for the conductivity and susceptibility for gapless semiconductors such as lightly doped HgTe. He discussed the $Bi_{1-x} Sn_x$ system and was quite critical of the use of the simple Lax theory to interpret the experimental data. For pure Bi he argued that two excitonic phases could be achieved by applying a magnetic field despite materials preparation problems.

There were nine sessions of contributed papers under the general title "Low Temperature Properties of Solids." These papers were grouped under the headings: Lattice Properties and Phonons (11 papers); Electronic Transport Phenomena (21 papers); Electron Energy States and de Haas-van Alphen Effect (10 papers); Magnetically Ordered Systems (21 papers); Magnetic Alloys (16 papers); Dilute Magnetic Systems and the Kondo Effect (31 papers); Magnetism and Superconductivity (8 papers); and Miscellaneous Topics (15 papers).

An interesting paper (L.006) by Y. Hiki and Y. Kogure (Tokyo Institute of Technology, Tokyo) was concerned with measurements of the total conductivity and specific heat of Cu-Al polycrystalline alloys (2-12% Al) into which dislocations were introduced. They observed anomalies in the measured quantities which they explained in terms of "quasi-local" phonon modes which are localized around the dislocations and which can hop between the dislocations.

P. Rödhammer, et al. (Max-Planck-Institut für Festkörperforshung, Stuttgart) discussed in (L.009) their measurements of the low-temperature specific heat of TaC and HfC in terms of the measured and calculated phonon spectra of these materials. They emphasize that the Debye temperature $\theta_D(T)$ can be accurately determined for superconductors only when the measurement of the specific heats are done in high magnetic fields (to suppress superconductivity). When this is done, they show how the phonon anomalies in TaC manifest themselves in the specific heat.

The papers on magnetically ordered systems covered a wide range of materials and techniques. L. A. Prozorova et al. (Institute of Physical Problems, Moscow) reported in (L.050) their observations of spin waves traveling along a rod of antiferromagnetic $CsMnF_3$. They estimate that the lifetime of the spin waves is about 2 μsec, in agreement with previous measurements by V. Minkiewicz et al. at Berkeley, and that these propagate with the group velocity calculated from the dispersion law measured by A. Portis and coworkers many years ago.

J. L. Genicon and R. Tournier (Very Low Temperature Research Center, Grenoble) observed the electronic magnetic moments included by the nuclear moments in some Van Vleck compounds by a classical magnetization measuring technique (L.053). A.10-T superconducting solenoid was used in this study of $PrIn_3$ and $(Pr_{0.1}La_{0.9})Sn_3$. These materials may become important in the future as systems with good thermal conductivity for adiabatic demagnetization to temperatures below 1 mK (see the work described below in the technique section). The nuclear moment is enchanced according to these measurements in $PrIn_3$ by a factor of about 6.2 by the Van Vleck mechanism. In (L.056) A. R. Levin et al. (Hebrew University, Jerusalem) spoke of their measurements of the exchange interaction of gadolinium impurities in another Van Vleck system, $PrNi_5$, and the best of the nuclear adiabatic coolants of this type. It appears that the dominant mechanism of exchange is with and through the conduction electrons.

There were several interesting low temperature specific heat investigations of magnetically ordered intermetallic compounds and alloys. In (L.051) C. A. Luengo et al. (University of California at San Diego) measured the ferromagnet UPt and isostructural nonmagnetic compounds ThPt. The measurements show a magnetic component of the specific heat to contain a $T^{3/2}$ term consistent with noninteracting spin waves and an entropy change of $0.9k_B \ln 2$ per UPt unit despite the low saturation moment of $\sim 0.3\mu_B$ per UPt. Apparently Hund's rule expectations are unfulfilled and the bandwidth is very narrow, about 1/20 of that of Ni.

The low temperature specific heat of the Gd_xCr_{1-x} Rh compounds have the largest values ever measured in the 4-10 K range. These ferromagnetically ordering materials were studied by J. Olijhoek and H.C.A. Nauts (Philips Research Laboratories, Eindhoven) (L.052). The system is particularly interesting because GdRh is ferromagnetic at 20 K and ErRh is antiferromagnetic at 3 K. They also studied the effects of dilution by replacing Gd in GdRh with nonmagnetic Y.

The low temperature specific heat of the AuFe alloys was studied by L. E. Wenger and P. H. Keesom (Purdue University, West Lafayette) (L.068). In the alloys with less than 12 at.% Fe previous measurements of some properties seem to indicate mictomagnetic effects, while others suggest a sharp ordering temperature. The specific heat results show no anomaly greater than 3% in the temperature region where the magnetic susceptibility shows a pronounced mictomagnetic-like cusp! They conclude that there is no evidence of cooperative magnetic ordering and that the data also do not support the original picture of mictomagnetism. (But a modified mictomagnetic picture could be used - the magnetic regions must order internally at $T \gtrsim 50$ K and relax fast until the "freezing" temperature.)

Another interesting system was studied by R. A. Levy and J. A. Rayne (Carnegie-Mellon University, Pittsburgh) (L.069) $(Pd_{0.5}Ag_{0.5})Fe_{0.01}$ was studied by the Mössbauer effect and electrical resistivity measurements. The behavior was similar to $PdH_{0.6}Fe_{0.01}$ which was described as a spin glass by J. A. Mydosh at Jülich (soon to be at Leiden) and also by J. Burger et al. (Universite Paris-Sud, Orsay) (L.073).

A very interesting study was made by K. Nagamine et al. (University of Tokyo and the University of California at Berkeley) by using the decay positrons from polarized positive muons implanted in a 150-ppm Fe in Pd sample (L.091) At this concentration the giant moments associated with the Fe order antiferromagnetically at about 0.4 K. The results were not consistent with other measurements; they suggest the polarization of the conduction electrons is too uniform.

Dr. M. Krusius (Technical University of Helsinki, Finland) gave the first of the plenary talks on techniques. He spoke on the present state of the art of refrigeration in the low and submillikelvin range for bulk samples, especially liquid He^3. After some comparison of various possible refrigeration techniques for these ultra low temperatures, he presented the technical details of the work of the Finnish group on nuclear adiabatic demagnetization of Cu, In, and Cu-In assemblies. Nuclear temperatures below 0.2 mK have been achieved for over 12 hours; however, the lowest temperature to which another substance has been cooled (He^3) is presently about 0.7 mK. Thermal relaxation times due to the Kapitza (thermal boundary) resistance and extraneous heat leaks are now the major problems. The use of silver assemblies, though expensive, may provide a better system.

One of the most exciting plenary presentations was given by Professor P. K. Hansma (University of California at Santa Barbara), who spoke on a spectroscopic technique for investigating the vibrational modes in organic compounds by using electron tunneling. The technique was developed by J. Lambe and R. Jaklevic (Phys. Rev. 165, 821 (1968)). Low temperatures are required only to reduce thermal broadening of the spectroscopic lines. The experimental procedure is to place a few tens of Angstroms of the substance to be examined between two metal contacts and measure the tunneling current through this junction. Electrons are absorbed and scattered when their energy coincides with an excitation energy of the tunnel barrier. The technique is quite simple electronically and results in the same information as obtained by Raman and infrared spectroscopy. Though the technique is somewhat specialized, it will have application to catalysis and other surface properties, especially those involving an alumina surface. The technique is even more easily applied than light scattering because only a few atomic layers of the material are required. This is clearly an interesting and emerging field.

Professor H. Kinder (KFA Laboratory, Jülich) spoke on the relative merits of various techniques of ultrahigh frequency phonon spectroscopy.

He pointed out that the heat pulse technique has more ease and capabilities than most people have realized.

In the contributed papers of Techniques and Special Topics Section there were 22 on refrigeration, nuclear alignment, and thermometry; 37 on weak link structures; 21 on low temperature instrumentation; 13 on systems of low dimensionality; and 22 others on radiofrequency size effects, non-helium quantum fluids, phase transitions, and miscellani.

Under the heading of refrigeration at low temperatures, it was apparent that considerable effort had been expended to develop nuclear refrigeration in order to extend the temperature range to near 0.1 mK. K. Andres et al. (T.001) (Bell Laboratories, Murray Hill, NJ) told of cooling bulk He^3 with the Van Vleck paramagnetic rare earth intermetallic, $PrNi_5$. These materials have a good thermal conductivity, being metals, and moments about 10 times the nuclear magnetic moments. Starting from 20 mK and in 2.0 Tesla they reach about 1.3 mK in 0.010 Tesla. They were able to maintain a temperature below 2 mK with a He^3 sample of 0.8 cm^3 for 50 hours, while the thermal relaxation rate between the $PrNi_5$ assembly and the He^3 cell was in the order of 1/2 hour.

Several low temperature experimental groups are developing dilution refrigerators which circulate both He^3 and He^4. In this case, it is believed possible to lower the continuous operating temperature of a dilution refrigerator to 4 mK or below. In the final or lowest temperature mixing chamber, superfluid He^4 will be injected through a superleak, and mixed with He^3. The dilute mixture will fall, by gravity, to the lower mixing chamber and force the concentrated He^3 in that chamber upward into the top chamber. Heat exchange between these two fluids is therefore accomplished because they are in intimate contact with one another; no physical heat exchanger is then needed. Experimental testing of these double circulating He^3- He^4 refrigerators by G. Frossati et al. (Very Low Temperature Research Center at Grenoble (T. 004)) and by F. A. Staas and H.C.M. van der Waerden (Philips Research Laboratories, Eindhoven (T.005)) has not yet produced a refrigerator capable of more than a standard dilution refrigerator, but work is continuing. This idea was first discussed by the Leiden group who did not present their work at this Conference, but rumor has it that they have been somewhat more successful but have not yet reached the goal of continuous refrigeration below 5 mK.

Although thermomentry at these lowest temperatures is always a concern, an intercomparison of the He^3 data obtained at different laboratories using different thermometers showed that the temperature scales used were accurate to about 5% to temperatures below 1 mK. In (T.016) R. J. Soulen and H. Marshak (NBS, Washington, D.C.) reported on a study comparing two absolute thermometers, the noise thermometer and the nuclear orientation thermometer, in the temperature range from 10 to 35mK. They observed that both thermometers gave identical readings within 1%. Hence, we can now put considerable faith in these low temperature thermometry measurements. A miniconference on thermometry, chaired by R. Hudson (NBS, Washington, D.C.), was well attended and was rather optimistic in nature because of these results and others.

The session on instrumentation was well attended as people were curious to learn of the latest developments in cryogenic gravitation wave attennae, in the superconducting gyroscope being developed to test relativity, and in SQUIDs used for biomedical measurements. Of these three topics, the biomedical SQUID systems appear to have realized the greatest development. J. Ahopelto et al. (Tech. University of Helsinki, Otaniemi) explained their SQUID gradiometer technique in (T.067) for measuring human magnetic fields generated by the heart and brain in an unshielded environment. One impressive slide they showed was the recording of the magnetic field generated by the human fetus.

The session on systems of low dimensionality was perhaps most notable in that, except for one talk on band structure calculations in the inorganic polymer SN_x, there was no mention of superconductivity! Most of the studies performed on the compounds were aimed at understanding their magnetic properties - many of them form antiferromagnetic compounds. Superconductivity in the SN_x compounds was discussed mostly in an evening miniconference where it was reported that attempts to fabricate thin films of SN_x have failed to produce a superconductor.

Under the grouping of "weak links" were a number of interesting papers, some of which were quite pertinent to SQUID development which is occurring in the Navy. For instance, L. B. Holdman et al. (Marshall Space Flight Center and the University of Alabama, Huntsville) reported on using Ge overcoatings on microbridges to protect their qualities in (T.054). Unprotected microbridges degrade in time with oxidation and are extremely susceptible to destruction by small electrostatic currents at room temperature. The Ge coatings protect the device from oxidation, and at room temperature, shunt the current which might destroy the microbridge while having no adverse effects on the characteristics of the microbridge at low temperature since the coating is then insulating.

G. Deutscher et al. (Tel-Aviv University) reported on work in (T.043) which was partially undertaken at NRL with S. Wolf and M. Nissenoff;

SQUIDs made with granular Al films were fabricated and tested. Since the critical current density is small in the granular Al films, the weak link constriction in the SQUID could be physically much larger and hence easier to fabricate.

A very novel experiment was reported by A. Barone et al. (various labs in Italy) in (T.023). They formed a Pb-CdS-In structure which, due to the photoconductivity of CdS, formed a light-sensitive tunnel junction. In the absence of light, there is essentially no Josephson tunneling; however, when light is applied, a Josephson current appears. The paper reported on the temperature-dependence of the light-induced Josephson current.

There were several papers in the L section which utilized the spectroscopic technique described by Hansma. S. de Cheveigne et al. (L'Ecole Normale Superieure, Paris) discussed their work on copper phtalocyanin in (L.127). In this material the electronic transitions had been previously measured and the optically forbidded singlet-triplet transition at 1.15 eV had been seen, while the allowed singlet-singlet transition at 1.8 eV had not! Their results confirm this difficulty. Some theoretical work is needed here. D. G. Walmsley et al. (New University of Ulster, Coleraine, N. Ireland) displayed their measurements of tunneling spectroscopy on several organic chlorides in (L.128). The differences between these results and optical studies were thought to be due to chemisorption. In general the energies were all shifted to lower values.

The Commission announced that the XVth Low Temperature Physics meeting will be held in August 1978 in Grenoble, France. It should be a very interesting and important meeting with many participants. Even more innovative solutions will be needed to avoid too many parallel sessions - otherwise it may be the first two-week Low Temperature Conference!