

Thermometry and thermal contact below 50 millikelvin

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The temperature range below 50 millikelvin (50 mK) has increased in importance during the last few years, mainly for the following two reasons :

1 The development of the dilution refrigerator based on the reversible dilution of liquid ^3He - ^4He mixtures through the passage of ^3He atoms across the boundary between the concentrated and dilute phase. This permits the production and the maintenance of constant temperatures down to 10 mK and even below.

2 The recent promising advances made in nuclear 'refrigeration'. The production of temperatures down to about 0.5 microkelvin (0.5 μK) by the isentropic demagnetization of nuclear magnetic moments (nuclear 'cooling') is fairly well established, but the temperatures so reached are those of the system of nuclear spins and it is only in the last few years that significant cooling of the sample as a whole — conduction electrons and lattice — has been achieved (nuclear 'refrigeration'). This development is likely to open up the temperature range below 1 mK for general experimentation.

Many thermometric techniques have been developed for the μK and mK temperature range over the last few decades, it was felt that the time had come for a detailed discussion of this problem by people who are directly involved. Moreover, since energy transfer is very sluggish at low temperatures, the question of thermal contact becomes of paramount importance in thermometric techniques and this subject was also included in the discussion.

Unlike in the Gordon Conferences and in the other Europhysics Study Conferences where $2/3$ or $1/2$ of the time is usually devoted to formal presentations, at the Albé Conference there were no lengthy papers or lectures. The main subjects — the various thermometric methods and the different types of thermal contact — were each introduced by a discussion leader with a talk which never exceeded 30 minutes and which in most cases within a few minutes developed into a free discussion. None of the contributions from the participants lasted for more than about ten minutes and the result was a lively

debate in which heated controversies alternated with persuasive arguments. However, in spite of strongly held and freely expressed views, the proceedings were good-natured and the discussions were punctuated by plenty of merriment. The general tone of the meeting can be well exemplified by the reply by one of the discussion leaders to a participant who raised a point: 'I didn't think that this point was worth mentioning, but thank you for mentioning it', a remark which was greeted with loud laughter in which the questioner himself joined wholeheartedly.

The discussion covered practically all thermometric methods, both primary and secondary, and several techniques as yet not well-developed were treated side by side with well-tried techniques. Primary thermometers, (those whose indications can be related directly to the thermodynamic temperature scale) included methods based on electrical noise, bulk magnetic properties (both paramagnetic susceptibility and nuclear susceptibility), osmotic pressure of ^3He in ^4He , melting pressure of ^3He , nuclear orientation (γ -ray anisotropy), Mössbauer effect nuclear magnetic resonance, and finally nuclear spin conduction electron relaxation time. The secondary thermometers included various resistance thermometers (carbon, germanium, silicon, dilute alloys with magnetic impurities), thermocouples and dielectric constant of glasses e.g. strontium titanate.

The subject of heat transfer was treated under two headings, namely thermal contact between liquid helium and a solid, and thermal contact between two solids. This discussion, apart from emphasizing some of the main unsolved problems and controversies in this area, included a useful exchange of views about practical ways of establishing good thermal contact.

It was generally agreed that the conference achieved one of its objectives, namely to provide a forum for a discussion in depth between experts in the field. It was to some extent a pity that the conference did not succeed in agreeing on one well-defined and reproducible thermometric method for the temperature range between, say, 1 and 50 mK. It may well be however that

this conference will stimulate various research groups to take a more active part in thermometry and to compare their results so that eventually, perhaps in a few years' time, a generally accepted temperature scale will emerge.

The meeting was held in a French holiday camp (VVF=Villages, Vacances, Familles) situated in a pleasant, secluded part of the Vosges mountains, about 2 km from the nearest habitation, the small village of Albé. Thanks to the timing and placing of this conference many low temperature physicists who attended the European Physical Society's Low Temperature Conference in Freudenstadt in the Black Forest were able to attend the Albé conference as well. There were 62 participants and the geographical distribution was gratifyingly widespread: 13 from the UK, 11 each from the US and France, 8 from the Netherlands, 4 each from Finland and the Fed. Rep. Germany, 3 each from Canada and Israel, and 1 each from Belgium, Denmark, Japan, Sweden and Switzerland. The meetings were held in the mornings between 9 and 12.30 in the afternoons between 17.00 and 18.15 and in the evening between 20.15 and 22.30. Thanks to the pleasant surroundings and the excellent facilities offered by the VVF informal discussions continued during walks, lengthy drink sessions and leisurely meals resulting in 16 hour 'working - day' for most participants.

The following took a prominent part as discussion leaders or by surveying certain specific fields: M. Aalto, A.C. Anderson, L.J. Challis, R.P. Hudson, W.J. Huiskamp, N. Kurti, A.J. Leggett, O.V. Lounasmaa, R.J. Soulen, N.J. Stone, D. Thoulouze, J.C. Wheatley, and W.P. Wolf.

The general philosophy of the conference and its programme was decided by an International Organising Committee consisting of W.J. Huiskamp (Netherlands), O.V. Lounasmaa (Finland), V.P. Peshkov (USSR), D. Thoulouze (France), and N. Kurti (U.K.), while the detailed organisation was left in the hands of the two last named who were ably assisted by Mme Jullien of Grenoble, France. The financial help received from the British Oxygen Company and L'Air Liquide is gratefully acknowledged.