ing because anomalies on the order of one gamma will have to be extracted from a background noise of 40 or 50 gamma. The other, monitoring deep-seated resistivity changes, may prove to be the way of the future, as electrical resistivity is inherently more sensitive to changes in crack geometry and pore fluid contents than are seismic velocities.

There seem to be no serious objections to dilatancy in some form or other as being the cause of observed precursory phenomena. This is generally assumed to be coupled with condensed pore fluid flow, but Dr D. L. Anderson (Cal. Tech.) has suggested that the water-steam transition may be adequate. Water in voids at temperatures in excess of 100° C would vaporize if the void space increased sufficiently to drop the pressure. Vapour-filled interstices could be expected to behave much like dry ones; consequently compressional wave velocities would drop. As fluid moved in from surrounding areas and fluid pressure rose, the vapour would condense and the voids become water saturated again, raising the P-wave velocity. This rise in velocity will not necessarily happen before the earthquake. If the regional stress accumulates sufficiently quickly, voids may open as fast as fluid can move in and the fluid pressure will not rise. Thus, an earthquake may occur while the seismic velocity is at a depressed value.

In a seismically active area such as the San Andreas fault system, the crust may be dilatant all the time. It is important then that in either a water or a water-steam dilatancy model, the anomalous region is not the dilatant one, but the undersaturated one, the region of low pore pressure or dry voids. If this undersaturation fails to happen, as it would if stress accumulation were quite slow, then no seismic anomaly would precede an earthquake. Conversely, an undersaturated region exhibiting low seismic velocities could recover without experiencing an earthquake.

Given current understanding of the causes of shallow focus shocks and their likely precursors, the plea of Dr C. B. Raleigh (NCER) for restraint in predicting damaging earthquakes is altogether appropriate. Earth scientists must be wary of crying wolf. For one thing, it is not certain that the trends from limited observational evidence can be extrapolated to large events. For another, the social consequences of predicting a large earthquake should not be taken lightly. Earthquakes are not like hurricanes, for which the danger persists only over a short and well-defined period. Suppose the population was evacuated and the earthquake failed to occur within the predicted time interval?

LOW TEMPERATURE PHYSICS

Below One Millikelvin

from our Condensed Matter Correspondent

A TEMPERATURE below 1 mK has been reached by adiabatic demagnetization of magnetically diluted cerium magnesium nitrate. The experiment was performed at the Nuclear Physics Institute of the Czechoslovak Academy of Sciences at Rez, by M. Koláč, K. Svec, R. S. Safrata, J. Matas and T. Těthal (*J. low temp. Phys.*, **11**, 297; 1973).

The adiabatic demagnetization of paramagnetic crystals has been in use as a cooling technique since the 1930s and is, in essence, extremely simple. These crystals contain ions which possess net magnetic moments which are not aligned in any preferred direction but which are changing their orientations in a random way, due to the thermal vibrations of the lattice. By applying a magnetic field, these moments can all be aligned, which reduces the entropy of the system so that heat must be carried away to keep the temperature constant. If the crystal is then thermally isolated, so that its entropy cannot change, and the magnetic field slowly reduced to zero, it will cool because, in zero magnetic field, its entropy will correspond to a very much lower temperature. The ultimate limit on the final temperature which can be attained in this way is determined by the tendency of the magnetic ions to align spontaneously below a certain critical temperature T_c, due to their own mutual interaction. In order to minimize these interactions, and thus T_c, crystals are chosen which have very large unit cells so that the magnetic ions are well separated from each other. In pure cerium magnesium nitrate (CMN), for example, interactions between the magnetic cerium ions limit the final temperature to about 2 mK.

To reach even lower temperatures, the mutual interaction of the magnetic moments must be reduced, and one approach has been to turn to systems, such as copper nuclei, in which the moments are themselves smaller. In practice, although it is relatively easy to demagnetize copper nuclei adiabatically to about 10^{-6} K, the usefulness of the technique is limited by the great length of time (days or weeks) taken for the system of nuclear moments to transmit its "cold" to anything else. From this point of view, CMN is a more convenient refrigerant for cooling, for example, liquid ^{3}He, because equilibrium times are then typically of the order of minutes, although, of course, the final temperatures obtained using the pure salt are too high for some experiments.

An alternative way of reducing interactions between the magnetic ions, which was discussed in detail by B. M. Abraham, O. Brandt, Y. Eckstein, J. B. Ketterson, M. Kuchnir and P. Roach of the Argonne National Laboratory (*Phys. Rev.*, **187**, 273; 1969), is to increase their average separation by replacing most of them by ions which, though chemically similar, are non-magnetic. These authors estimated that, with about 90% of the cerium ions in CMN replaced by lanthanum ions, it ought to be possible to reach a final temperature near 0.7 mK. This is the experiment which has now been performed by the group at Rez.

Temperature measurement near 1 mK represents a formidable problem and there is, as yet, no internationally agreed temperature scale in this region. It is customary to express experimental results in terms of a magnetic temperature T^* deduced from measurements of the magnetic susceptibility of CMN, which is assumed inversely proportional to the temperature (Curie's law). Using their diluted crystal, the Rez group report that they reached a final T^* of 0.86 mK, which they believe does not differ greatly from the real (thermodynamic) temperature, and which is in reasonable agreement with the theoretical predictions of the Argonne group.

The significance of this result must be seen in the context of the recent discovery of the new phases of liquid ^{3}He, which is known to undergo two separate phase transitions near 2 mK, only one of which can be reached by demagnetizing pure CMN. There is evidence to suggest that these new phases may have superfluid properties, and a period of intense experimental and theoretical endeavour is already in progress to try and understand their nature. They may be somewhat akin to the electron gas in a superconducting metal, but, alternatively, they may represent completely new states of matter.

Only one cooling technique, adiabatic compression of liquid ^{3}He across the solidification curve, has so far been successful in cooling the liquid through both transitions, and it suffers from the inevitable inconvenience that solid, as well as liquid, ^{3}He is always present in the cell once cooling has commenced. The Rez workers have now shown that research on both of the new phases should be greatly facilitated through use of magnetically diluted CMN as refrigerant.

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