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HEAT CAPACITY OF NEODYMUM BELOW 10 K

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INTRODUCTION.- The dhcp structure of Nd consists of atoms with either local cubic or hexagonal symmetry. It is known from neutron diffraction studies /1, 2, 3/ that antiferromagnetic ordering of the hexagonal and cubic sites occurs at \( \sim 20 \) K and \( \sim 8 \) K respectively. The lower transition is complicated by hexagonal-cubic site interactions. Very recently /4/ Bak and Lebech (B.L.) have interpreted the 20 K transition in zero magnetic field in terms of triple spin density waves (S.D.W.) and it is probable that the 8 K transition in zero field involves a similar structure.

We have made heat capacity measurements on a number of specimens and in range of magnetic fields /5, 6/. We describe here new work on a single high purity specimen of Nd at temperatures from 1.5 - 10 K and in magnetic fields 0 - 1.3 T, applied in the crystallographic a direction.

EXPERIMENTAL CONSIDERATIONS.- The specimen is a flat plate \( \sim 2 \times 3 \times 0.8 \) mm, single crystal with mosaic spread \( \sim 2^\circ \) and with the c-axis perpendicular to the plane of the plate. The specimen was obtained from a rod which had been purified by Solid State Electrotransport processing /7/. Total impurity content was < 500 ppm. The heat capacity of the specimen was determined by measuring the rate of cooling of the specimen, via a weak thermal link down to 1.5 K.

RESULTS.- We have made measurements at a large number of applied magnetic fields. In figure 1 we show four representative plots. The zero B data is much richer in detail and at a higher temperature than that of Lounasmaa /8/ which was obtained on a low purity polycrystal.

Peaks 1 and 3 are of interest because their temperatures are only weakly dependent on B in the range measured. Peak 2 moves down in temperature and is eventually suppressed by increasing B as are a large number of other peaks which come and go over quite small ranges of B (As little as 50 mT).
Peaks 1 and 2 can probably be identified with the anomalies at 7.8 and 6.5 K seen in neutron diffraction work /3/ though like Lounasmaa's, their specimen shows depressed transition temperatures, probably due to much higher impurity content.

The effect of a magnetic field on multiple S.D.W.'s may be understood /5/ by the addition of a magnetic field dependent term to the Landau free energy theory of B.L. The transition to the S.D.W. with the largest magnetic susceptibility remains at the zero field temperature while the appearance of multiple S.D.W.'s occurs as a second order phase transition at a depressed temperature. We deduce from these results that at 1.3 T, only one S.D.W. is formed at 7.63 K (Peak 1) and that this persists to low temperatures. The origin of Peak 3 remains uncertain. It may be due to an incommensurate-commensurate transition such as occurs for charge density waves in layer compounds /9/.

HYSTERESIS EFFECTS.- Peaks 1 and 2 are comparatively insensitive to thermal cycling but Peak 3 is strongly dependent on the initial and final values of the temperature sweep in both amplitude and temperature. We report the detailed behaviour elsewhere /5, 6/. We note that hysteresis effects have also been observed in susceptibility experiments /10/.

CONCLUSIONS.- Our measurements show considerably more structure than earlier work on impure polycrystals. We find that the number of transitions in the 1 - 10 K range is reduced to two by the application of small magnetic fields. We drew attention to strong dependence of the lowest temperature results on thermal history. We are extending this work to other applied field directions.

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