above 1° K. Measurements with the ordinary Cd have shown that this has a transition point below 1° K.

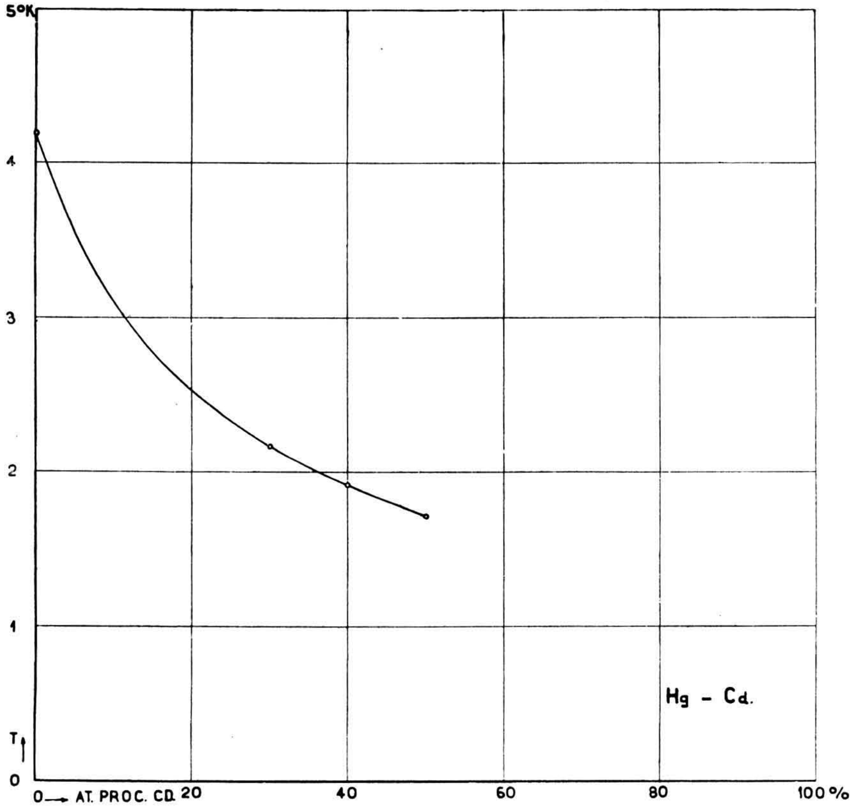

Fig. 3.

This shows again the great influence of the crystal lattice on the phenomena of supraconductivity.

Physics. — *Thermal conductivity of Indium at low temperatures.* By W. J. DE HAAS and H. BREMMER. (Communication N^0. 220*b* from the Physical Laboratory at Leyden.)

(Communicated at the meeting of February 27, 1932.)

1. We used the apparatus, with which we measured already the thermal conductivity of lead and tin[1]. Also the measuring method was entirely the same but for our aiming at a higher accuracy this time.

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[1] W. J. DE HAAS and H. BREMMER. Leiden Comm. N^0. 214*d*. These Proc. XXXIV, 3, 325, 1931.

The results obtained with lead and tin may be summarised as follows:

1⁰. When the temperature is lowered, the thermal resistance first decreases, then passes through a minimum and increases strongly at the lowest temperatures. It is not improbable that this increase is due to impurities. (We used the purest "Kahlbaum" metals).

2⁰. Below the transition point the thermal resistance is smaller in the non-supraconductive state, obtained by means of a magnetic field, than in the supraconductive state.

This general behaviour has been found for Indium also. We have given the results of the measurements in tables 1 and 2. Table 1 contains the values of the thermal resistance in Watt^{-1}, at higher temperatures, table 2 those for the temperatures of liquid helium. The latter measurements were distributed over two days and each of the two parts of table 2 gives the results of one of these days. Fig. 1 represents the change of the thermal resistance over the whole range of temperatures, fig. 2 that in the helium region only. The minimum is seen to be reached at about 18° K. Probably this must be ascribed to the less purity of the material. For tin and lead it is found at about 9° K.

TABLE I.

T	W
94	66.7
34	66.4
22.6	60.8
20.8	58.2
19.5	56.5
18.3	55.8
15.8	57.0
14.9	57.1

TABLE II.

T	W	T	W
4.84_5	97.4	4.05	120
4.27	111.	3.95	122
3.87	126.	3.85	121
3.65	134.	3.76	127
2.99	167.	3.55	137
2.63	208.	3.47	145
2.50	227.	3.26	147
2.18	291.	3.16	155
		3.06	162.5
		2.97	171

GRÜNEISEN and GOENS found as a matter of fact that, with increasing impurity similar maxima are displaced towards the higher temperatures. We used a rod made of pure indium from HILGER. After the measurements its electrical resistance was determined at a few temperatures. For the residual resistance $R_{4^\circ}/R_{273^\circ}$ we found 0.014, which is a much higher value than those which can be reached with pure lead and tin.

2. *Behaviour in the magnetic field.*

In order to find out whether, below its transition-point the behaviour of indium in a magnetic field is the same as that of tin and lead, we made measurements in different magnetic fields at one helium temperature viz.

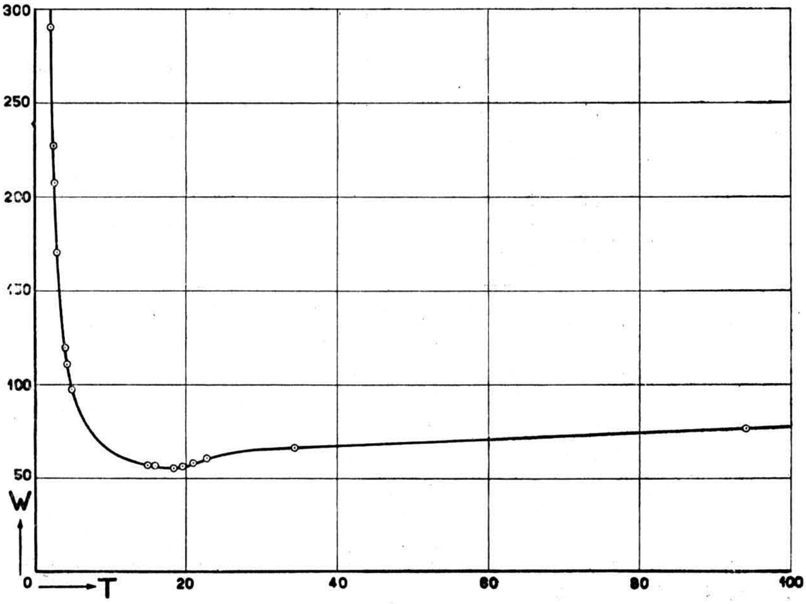

Fig. 1.

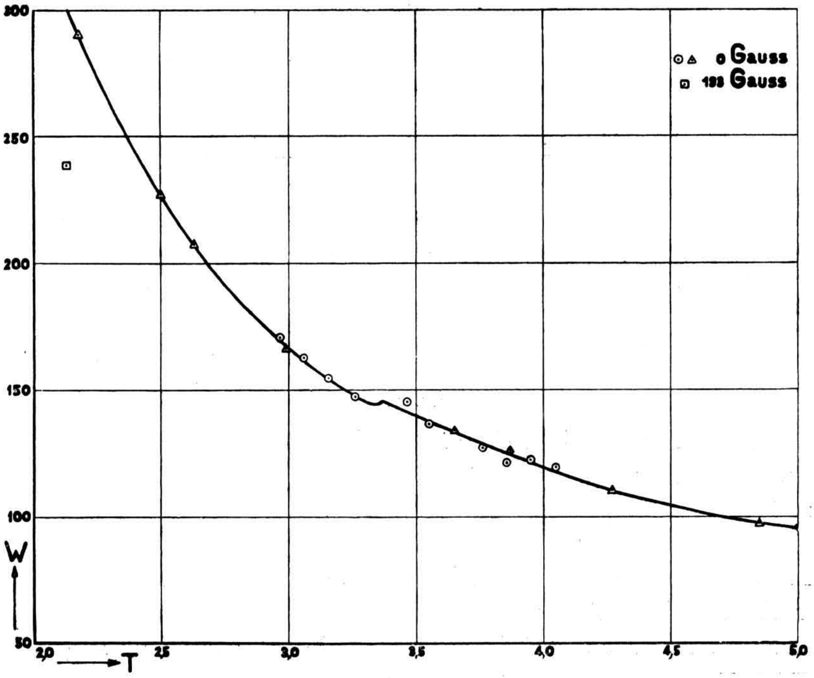

Fig. 2.

at 1°.92 K. The results are to be found in column 3 of table 3. All fields

TABLE III

T	H	W	$W_{corr.}$
2.18	0	291	304
2.18	85.6	289	301
2.18	118	291	303
2.15	159	254	257
2.13	193	239	239
2.14	659	244	244

used were longitudinal except that of 659 Gauss, which was transversal. As in high fields the thermal resistance of the rod became smaller, its mean temperature became lower, though the temperature of the bath remained constant. Therefore the measurements in different fields were not made at exactly the same temperature. By estimation we calculated the values of the thermal resistance at one and the same temperature viz. at $2°.13_5$ K. These latter values have been given in column 4 of table 3. They are represented by fig. 3. Table 5 and fig. 6 in Leyden-comm. N⁰. 214*d* [1]) are analogous.

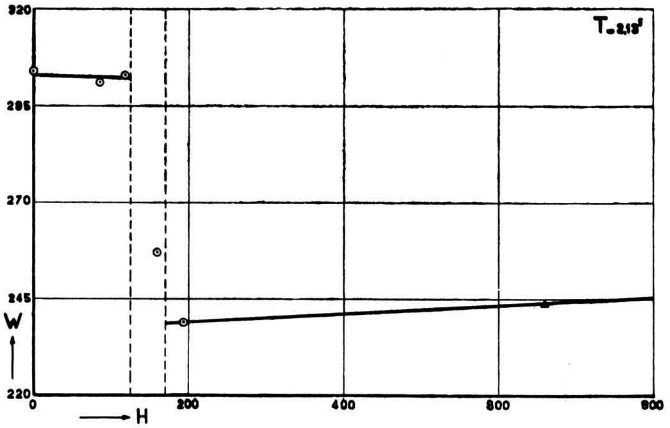

Fig. 3.

The measurement in the field of 159 Gauss showed that here the rod is still partially supraconductive. Therefore we have indicated (in the same way as in fig. 6 of Leyden-comm. N⁰. 214*d*) with dotted lines the threshold values of the field for the temperatures of the upper and lower ends of the rod during the experiment. These threshold values for a longitudinal field could only be estimated.

The only new fact stated here, is that the influences of longitudinal

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[1]) These Proc. l.c.

and transversal fields on the thermal resistance below the transition-point are nearly equal.

3. *Transition-point for the thermal resistance.*

From the measurements with tin and lead it was not evident, whether the resistance-temperature-curves for the supraconductive and the non-supraconductive states below the transition point form continuous extensions of the resistance-temperature-curves above the transition-point. We therefore repeated the measurements of indium, with a higher gas-filling in the thermometer, so that we could measure the temperatures more accurately. We also determined more points in the neighbourhood of the transition-point.

The measurements clearly give the impression, that the curve without a magnetic field shows a discontinuity at the transition-point. That this discontinuity is due to a small decrease of the thermal resistance is evident from fig. 4, where *log w* ($w =$ thermal resistance) has been plotted as a function of *log T* and where the transition temperature (3.37° K.) has been indicated by a dotted line. In fig. 4, the point at 2.13° K., determined in a field of 139 Gauss has also been indicated. We get the impression that at the transition-point a discontinuity occurs, as well for the supraconductive state as for the non-supraconductive state.

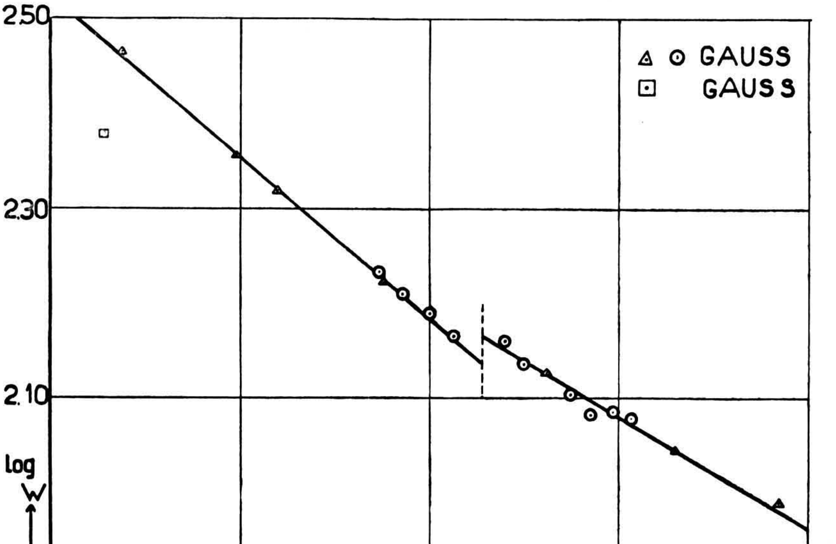

Fig. 4.

The measurements with tin were not accurate enough to have revealed a discontinuity of the same amount. The thermal resistances namely were determined here from larger temperature differences while at the same time the temperature intervals of the points determined were larger.

From the curves in fig. 4 we can further calculate that for the lower temperatures the thermal resistance in the supraconductive state is nearly proportional with $T^{-1.7}$, and in the non-supraconductive state with $T^{-1.2}$. As in the case of lead it increases more rapidly than T^{-1}. Proportionality with T^{-1} might be expected from the theory, at least for impure single-cristals. At the lowest temperatures the behaviour is probably entirely determined by chemical impurities and deformations of the lattice. According to the theory of PEIERLS [1]) if heat was transmitted by elastic waves exclusively, an impure single-cristal would have an additional thermal resistance proportional with T, which therefore cannot at all explain the strong increase at low temperatures.

As to the electronic waves, these are dispersed by the impurities and deformations without exchange of energy, as has been shown by NORDHEIM [2]). In case these waves formed the only mechanism of heat-transmission, the law of WIEDEMAN-FRANZ should be valid. As at low temperatures the electrical resistance in the non-supraconductive state is found to become constant, the thermal resistance had to become infinite as T^{-1}. Measurements of GRÜNEISEN and GOENS with impure metals at higher temperatures give a T^{-1} law.

We however find, that the thermal resistance increases more rapidly. Further experiments only can throw light upon this question.

Finally we express our thanks to Mr. J. BIERMASZ for his valuable help during the measurements, and with the calculations.

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[1]) R. PEIERLS, Ann. d. Phys. **5**, **3**, 1055, 1929.

[2]) L. NORDHEIM, Ann. d. Phys. **5**, **9**, 607, 1931.

Physics. — *Experiments to decrease the limit of the temperatures obtained.* By W. H. KEESOM. (Communication N⁰. 219*a* from the Physical Laboratory at Leiden.)

(Communicated at the meeting of February 27, 1932.)

§ 1. *Introduction.* In 1929 I described [1]) an arrangement which enabled to maintain temperatures below 1° K. in such a way that measurements can be made at those temperatures. Temperature measurements for determining the vapour pressure curve of helium were made [2]) with that apparatus down to a temperature of 0.90° K. Furthermore I could offer Messrs. DE HAAS and VOOGD an opportunity to observe gallium to be superconductive at 1.07° K. [3]).

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[1]) These Proceedings **32**, 710, 1929. Comm. Leiden N⁰. 195*c*.

[2]) W. H. KEESOM, SOPHUS WEBER and G. SCHMIDT. These Proceedings **32**, 1167, 1929. Comm. Leiden N⁰. 202*c*.

[3]) W. J. DE HAAS and J. VOOGD. These Proceedings **32**, 733, 1929. Comm. Leiden N⁰. 199*d*.