Physics. — *Disturbance of the superconductivity of the compound Bi_5Tl_3 and of the alloys Sn-Sb and Sn-Cd by magnetic fields.* By W. J. DE HAAS and J. VOOGD. (Comm. N⁰. 199*c* from the Phys. Lab. at Leiden).

(Communicated at the meeting of September 28, 1929).

In collaboration with Prof. E. VAN AUBEL we found, that the compound Bi_5Tl_3 already becomes superconductive above the boiling point of helium (4.2° K.) [1]. We now tried to determine its magnetic threshold value at the boiling point of helium. This threshold value proved to lie so high, that the solenoid always used in the other experiments (H up to 1250 gauss) did not suffice, so that we were obliged to use an electromagnet to reach field intensities strong enough to disturb the supraconductivity.

The compound Sb_2Tl_7 too, which becomes superconductive above 4.2° K., demands a field higher than 1250 G. to disturb its superconductivity at 4.2° K. [2]. The further investigation of the magnetic disturbance of the superconductivity of Bi_5Tl_3 showed, that the fall of the magnetic threshold value with decreasing temperature is much steeper here than for pure superconductors.

In order to find out whether this also is a general property of alloys, we chose for the further research solid solutions of bismuth in tin and of cadmium in tin and especially used the eutectics of the systems *Sn-Bi* and *Sn-Cd*. In collaboration with Prof. E. VAN AUBEL we had already investigated these solid solutions with respect to the temperature transition point (thermal transition curve) [3].

§ 2. Bi_5Tl_3.

We worked with the rod that had also been used the second time for the investigation of the resistance [4]. This rod was mounted in a removable helium cryostat which after having been filled with liquid helium was placed between the pole pieces (diameter 16 cm.) of an electro-magnet (type Weiss, Oerlikon make). The field intensity was measured ballistically. Also the inhomogeneity was investigated and it proved to be less than 1 % along the rod.

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1) These Proceedings, **32**, 218, 1929.
2) These Proceedings, **32**, 731, 1929. Comm. Leiden 197*d*.
3) These Proceedings, **32**, 715, 1929. Comm. Leiden 197*b*.
4) These Proceedings, **32**, 731, 1929. Comm. Leiden 197*d*.

We give the results of these determinations in table I and in fig. 1.

TABLE I.
$Bi_5\,Tl_3$ (magnetic field transversal).

H	*R*	*T*	*p*
3865	0	4.20^8	766
4038	0.000221		
4151	0.000436		
4181	0.000496		
4254	0.000582		
4634	0.000597		
4149	0	4.03^8	647
4240	0.000058		
4283	0.000158		
4392	0.000350		
4627	0.000594		
4851	0.000594		
5836	0.000604		
4402	0	3.88^4	549
4654	0.000245		
4773	0.000480		
4874	0.000579		
5245	0.000597		
5049	0.000134	3.61^1	399
5275	0.000471		
5405	0.000579		
5577	0.000594		
5868	0.000594		
5423	0.000087	3.39^0	299
5575	0.000342		
5961	0.000595		
5846	0.000585		

From the figure we can find the value of the magnetic field, for which the resistance is restored to half of its original value ($H_{W^{1/2}}$). In table II

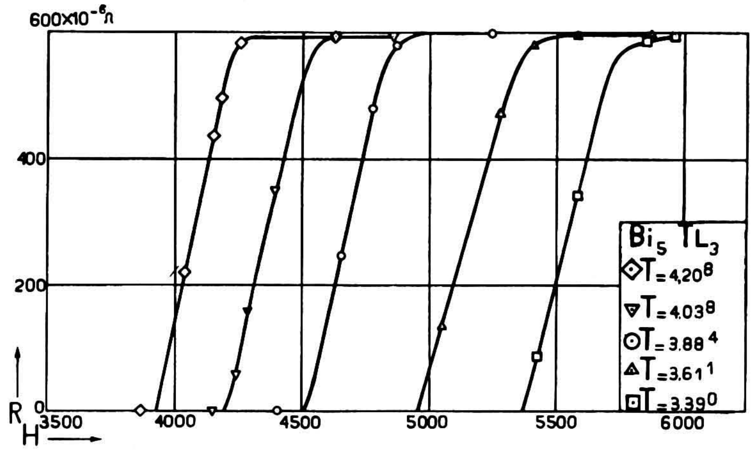

Fig. 1.

the values of $H_{W^{1/2}}$ are given for the different temperatures. Fig. 2 represents the curve of $H_{W^{1/2}}$ as a function of the temperature. For comparison this same curve has been plotted for pure lead (derived from the determinations of W. TUYN and H. KAMERLINGH ONNES [1])).

We see, that the inclination of this curve is much steeper for Bi_5Tl_3 than for lead.

By extrapolation we can make from the figure an estimate of the transition point of Bi_5Tl_3, for which we find approximately 6.5° K.

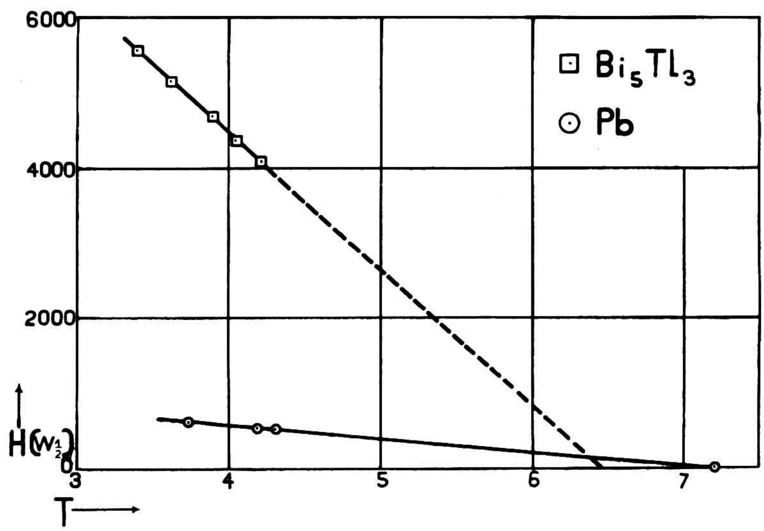

Fig. 2.

[1]) Comm. Leiden 174a. Journal of the Franklin Institute, **201**, 379, 1926.

TABLE II.

$Bi_5\,Tl_3$.

$Hw^{1/2}$	T
4080	4.20^{8}
4360	4.03^{8}
4680	3.88^{4}
5150	3.61^{1}
5560	4.39^{0}

§ 3. *Sn-Bi.*

We worked with a rod of the eutectic mixture, which according to the melting point diagram consists of a solid solution of bismuth in tin and a solid solution of tin in bismuth. The superconductivity of the rod is a consequence of the continuity of the layers of the solid solution of bismuth in tin and the magnetic transition figure must be ascribed to this solid solution [1]).

The longitudinal fields were obtained by means of a solenoid surrounding the helium cryostat. In table III we give the determinations of the magnetic transition figures, plotted in fig. 3.

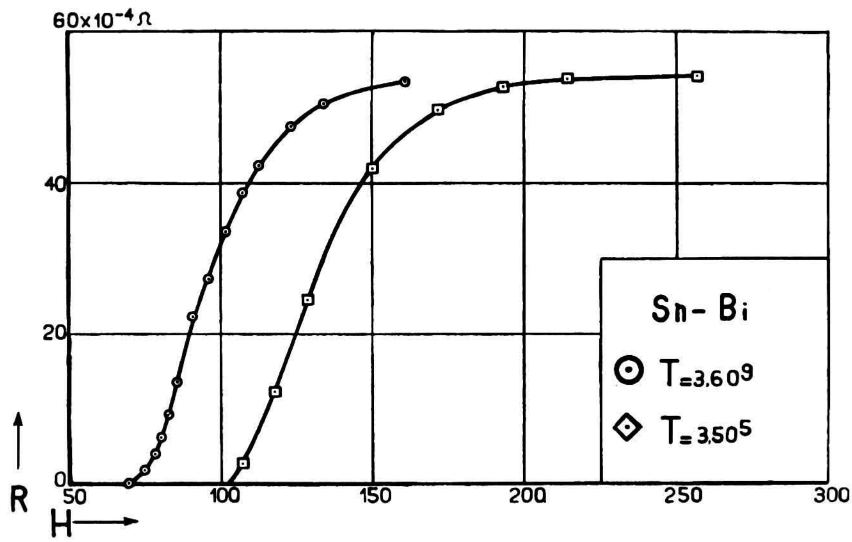

Fig. 3.

We see, that the magnetic field in which the return of the resistance

1) These Proceedings, **32**, 715, 1929. Comm. Leiden 197*b*.

TABLE III.

Sn—Bi.

H	R	T	p
69.5	0.000017	3.60^9	398
74.9	0.000168		
78.1	0.000392		
80.3	0.000613		
82.6	0.000902		
85.6	0.001357		
91.0	0.002225		
96.3	0.002731		
101.7	0.003351		
107.0	0.003861		
112.4	0.004233		
123.1	0.004748		
133.8	0.005055		
160.5	0.005351		
107.0	0.003845		
80.3	0.000617		
107.0	0.000262	3.50^5	349
117.7	0.001227		
128.4	0.002440		
149.8	0.004181		
171.2	0.004962		
192.6	0.005274		
214.0	0.005380		
256.8	0.005425		
171.2	0.004968		
117.7	0.001223		

begins and that in which the resistance has reached again its original value, lie at a great distance.

This must be ascribed, if not wholly then at all events partly to the fact, that the current has to choose its path through the differently orientated layers of the solid solution and that the current vector has all directions We have therefore to do both with the transverse and with the longitudinal action of the magnetic field.

In table IV we give the values of $H_{W^{1/2}}$ with the corresponding temperatures.

TABLE IV.

Sn—Bi.

$H_{W^{1/2}}$	T
95	3.60^9
130	3.50^5

In fig. 5 these values have been plotted with those of *Sn-Cd* and those of pure tin [1]) (derived from the determinations of W. TUYN and H. KAMERLINGH ONNES).

It is seen, that for *Sn-Bi* the values of $H_{W^{1/2}}$ increase more rapidly with decreasing temperature than for pure tin.

§ 4. *Sn-Cd.*

Here too we worked with a rod of the eutectic mixture, in which it is the solid solution of cadmium in tin that becomes superconductive [2]).

In the same way as for *Sn-Bi* the magnetic transition curves were determined here. The results are given in table V and are plotted in fig. 4. With respect to the form of the transition figures the same remarks may

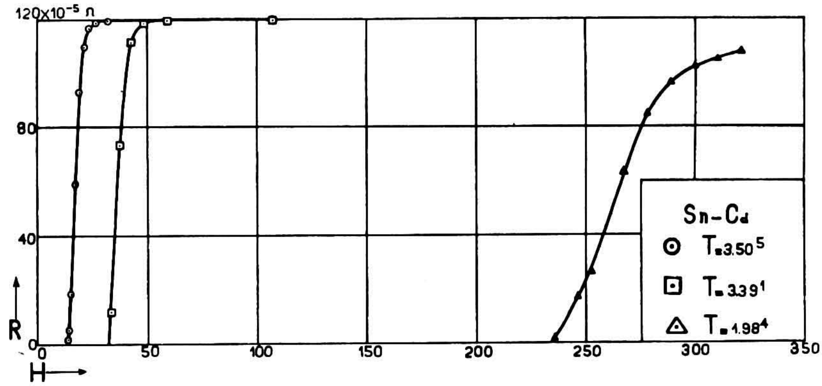

Fig. 4.

[1]) Comm. Leiden 174*a*. Journal of the Franklin Institute, **201**, 379, 1926.

[2]) These Proceedings, **32**, 715, 1929. Comm, Leiden 197*b*.

TABLE V.
Sn—Cd.

H	*R*	*T*	*p*
12.84	0	3.50[5]	349
13.27	0.000016		
13.91	0.000051		
14.98	0.000187		
17.12	0.000594		
19.26	0.000931		
21.40	0.001100		
23.54	0.001169		
26.75	0.001190		
32.10	0.001195		
21.40	0.001108		
17.12	0.000605		
13.91	0.000059		
33.2	0.000118	3.39[1]	299
37.5	0.000734		
42.8	0.001116		
48.2	0.001186		
64.2	0.001197		
107.0	0.001197		
42.8	0.001127		
37.5	0.000736		
32.1	0.000040		
235.4	0.000019	1.98[4]	17.0
246.1	0.000131		
252.5	0.000265		
267.5	0.000634		
278.2	0.000847		
288.9	0.000964		
299.6	0.001023		
310.3	0.001053		
321.0	0.001079		
288.9	0.000965		
267.5	0.000634		
246.1	0.000123		

be made as in the case of *Sn-Bi*. Table VI gives the values of $H_{W^{1/2}}$, which have been plotted in fig. 5.

TABLE VI.
Sn—Cd.

$H_{W^{1/2}}$	T
17.5	3.50[5]
36	3.91[1]
266	1.98[4]

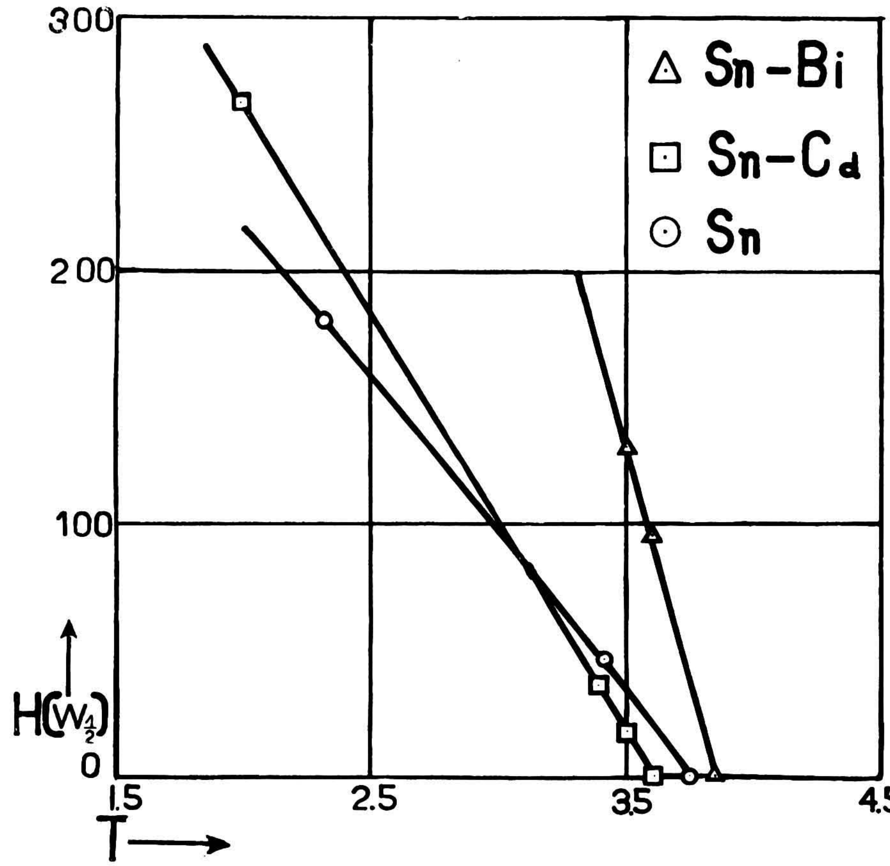

Fig. 5.

The difference with pure tin is less pronounced which may be ascribed perhaps to the fact, that in the eutectic *Sn-Cd* the percentage of cadmium is considerably lower than that of bismuth solved in tin in the eutectic *Sn-Bi*.

§ 5. The result of these measurements with alloys is, that in all cases investigated the value of $H_{W^{1/2}}$ increases more rapidly with decreasing temperature than in the case of the pure superconductors. We can also express this by saying, that for the same temperature distance from the transition point higher field intensities are required to restore the resistance. This unexpected result may become of use in magnetic researches because of the high values of $H_{W^{1/2}}$ found for Bi_5Tl_3.

We found, that at 3.4° K. a field of 5.3 kilogauss did not yet disturb the superconductivity of Bi_5Tl_3. We have not yet extended our investigations to still lower temperatures. An extrapolation however of the data would predict that at a temperature of 1.3° K. a field of about 9 kilogauss would not yet disturb the superconductivity. *This would render possible the production of magnetic fields of this order of magnitude with a solenoid from Bi_5Tl_3 wire without production of heat.* It is evident however, that besides this eventual practical application, the phenomenon itself is of the highest importance.