Physics. — *The influence of pressure on the electrical conductivity of gold up to 1000 atmospheres.* By A. MICHELS and P. GEELS. (18th communication of the "VAN DER WAALS-Fund.") (Communicated by Prof. J. D. VAN DER WAALS.)

(Communicated at the meeting of October 29, 1927).

These measurements complete an investigation on the influence of pressure on the conductivity of gold, the preliminary results of which were given in the 17th communication [1]).

It must be repeated that the material used in this investigation was gold-wire in a hard drawn state so that the influence of tempering might afterwards be investigated.

The method of measurement.

The bridge circuit depicted in figure 1, which has been described by F. E. SMITH [2]), was used in place of the WHEATSTONE bridge used in the preliminary investigation.

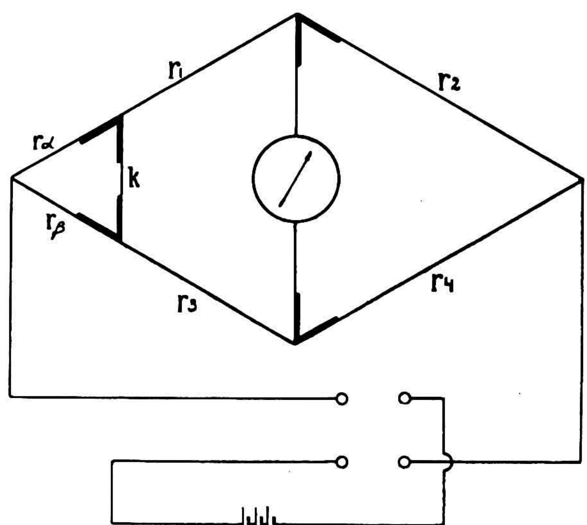

Fig. 1.

The peculiarity of this circuit, like that of the THOMPSON-bridge, is that

[1]) These Proceedings **30**, (1927) 47.

[2]) Phil. Magazine 1912. Bd, **24**, p 562.

the influence of the resistances of the leads is reduced to below the accuracy of observation.

As it is hoped to return to the advantages and disadvantages of this method, as well as to the best choice of the resistances, in a later communication, it will be sufficient to state here that :

$$\frac{r_\alpha}{r_\beta}=\frac{r_1}{r_3}=\frac{r_2}{r_4},$$

r_α and r_β being made of the order of 1000 ohms, whilst k was kept as small as possible ; r_1 was the measuring wire, and variations in the temperature were compensated by a gold wire r_3, which was not put under pressure (l.c.).

r_2 and r_4 are the coils of standard resistances of 1000 ohms with a calibrated variable resistance introduced into one of each pair of leads for regulation and for the compensation of the pressure effect.

Following the usual method, the coils of the standard resistances were commutated in each measurement in order to compensate for any irregularities in the resistances of the two coils. (This appeared necessary as deviations of the order of 5×10^{-6} were obtained, due to differences in the temperature coefficients.) The deflection of the galvanometer was observed by commutating the bridge current, the effects of thermal currents being thus eliminated.

The sensitivity.

The sensitivity of the circuit was sufficient to cause an alteration of resistance of 4×10^{-7}, when an ordinary MOLL galvanometer and a measuring current of 3 milliamps was used. This corresponds to a temperature difference of the measuring wire of 10^{-4} degrees.

Calculation showed that the increase in temperature of the gold wire resulting from the above measuring current, would not give an error greater than this.

The accuracy of the pressure measurements up to 250 atmospheres was greater than that of the resistance measurements.

As the new pressure balance for higher pressures had not been completed, the old, although improved, high pressure balance of the "VAN DER WAALS Fund" had to be used for 250—1000 atmospheres, and an accuracy cannot be claimed of more than 1 in 1000.

The observations were made in two series, one from 0—250 atms., with pressure intervals of 50 atms., and the other from 0—1000 atms. with pressure intervals of 200 atms. A few points overlap, and provide a good connection between the two series.

The measuring wire was once heated for a considerable time at 40° between two sets of measurements from 0—250 atmospheres.

In order to economise space all the results are not communicated.

The results of the measurements.

The tables below give :

Table I a series of measurements up to 250 atms. before the tempering at 40° ;

Table II a series after the tempering ;

Table III the results over the pressure range 0—1000 atms.

The tables are subdivided, and give under :

a. the total change of resistance per original Ohm ;

b. the change of resistance per Ohm per kilogram, per sq. centimetre for the various pressure intervals.

TABLE I*a*.

$$-\frac{\triangle w}{w} \times 10^6.$$

Pressure in Kg/cm²	51.5	101.5	151.5	201.5	251.5
16.95°	258^6	503^6	742^5	977^1	1206^1
28.46°	252^5	493^4	729^1	959^2	1185^5

TABLE I*b*.

$$-\frac{\triangle w}{\triangle p \,.\, w} \times 10^6.$$

Pressure in Kg/cm²	0—51.5	51.5—101.5	101.5—151.5	151.5—201.5	201.5—251.5
16.95°	5.02	4.90	4.78	4.69	4.58
28.46°	4.90	4.82	4.71	4.60	4.53

TABLE II*a*.

$$-\frac{\triangle w}{w} \,.\, 10^6$$

Pressure in Kg/cm²	51.5	101.5	151.5	201.5	251.5
18.75°	255^6	497^9	734^2	963^6	1183^6
18.87°	255^5	497^3	733^8	964^2	1183^6
28.5°	251^8	487^1	713^2	929^0	1136^4
28.2°	251^3	489^0	$71\ \ ^8$	930^8	1136^9
40.0°	244^8	469^0	677^7	878^6	1071^0

TABLE II*b*.

$$-\frac{\Delta w}{\Delta p\, w} \,.\, 10^6$$

Pressure in Kg/cm²	0—51.5	51.5—101.5	101.5—151.5	151.5—201.5	201.5—251.5
18.75°	4.96	4.85	4.73	4.59	4.40
18.87°	4.96	4.84	4.73	4.61	4.39
28.5°	4.89	4.71	4.52	4.32	4.15
28.2°	4.88	4.75	4.52	4.32	4.12
40.0°	4.75	4.48	4.17	4.02	3.85

TABLE III*a*.

$$-\frac{\Delta w}{w} \,.\, 10^6$$

Pressure in Kg/cm²	209.4	408.3	607.1	806.0	1004.8
20.9°	994^8	1819^1	2506^9	3118^4	3699^5
28.3°	968^2	1763^1	2424^7	3029^6	3609^3
39.1°	917^8	1668^0	2298^0	2894^3	3473^3

TABLE III*b*.

$$-\frac{\Delta w}{\Delta p\, w} \,.\, 10^6$$

Pressure in Kg/cm²	0—209.4	209.4—408.3	408.3—607.1	607.1—806.0	806.0—1004.8
20.9°	4.75	4.14	3.46	3.07	2.92
28.3°	4.62	4.00	3.33	3.04	2.92
39.1°	4.38	3.77	3.17	3.00	2.91

Discussion of the results.

1°. A deviation of 1.3×10^{-6} from a mean was obtained in one case in the measurements below 250 atmospheres, the remainder of the measurements showing a much better agreement.

As was expected, the measurements with the large pressure-balance did not give such good results, the maximum deviation from the mean amounting to 4×10^{-6}.

The deviations correspond to a temperature variation of $^1/_{3000}$° for the lower pressures, and $^1/_{1000}$° for the higher.

2°. The tempering of hard drawn wire for a considerable time at 40° appears to have a very noticeable influence on the pressure effect.

In connection with this it must be mentioned that, although the wire had previously been compressed to 1300 atms. with the result that the hysterisis phenomena did not appear in the normal measurements, these phenomena reappeared after the tempering, but were diminished after first raising the pressure.

It thus appears almost impossible to compare the results of work on the pressure influence on metal resistances, unless the history of the wire is given accurately. All that is known of the temperature treatment of the gold wire used by BRIDGMAN is, that it was tempered between 0° and 140°—150°. BRIDGMAN, therefore, used a more strongly tempered metal, and this is in agreement with the pressure coefficient found by him (between 0—1000 atms. mean 3.1×10^{-6} at 250), for the latter deviates considerably from the present measurements in the same direction as does the coefficient found after tempering to 40°. In view of the tempering mentioned, it is doubtful whether BRIDGMAN determined his coefficients with sufficient reproducibility. Also, it is noteworthy that BRIDGMAN does not give a single intermediate determination between 0 and 1000 atmospheres, and that he has only attempted to determine the curve by a sort of extra-interpolation method, whilst the present measurements indicate, that the curve is most important in the region of lower pressures.

Again, BRIDGMAN did not observe any noticeable hysterisis phenomena such as is mentioned above.

A graphical representation of the present results is given in Fig. 2, and

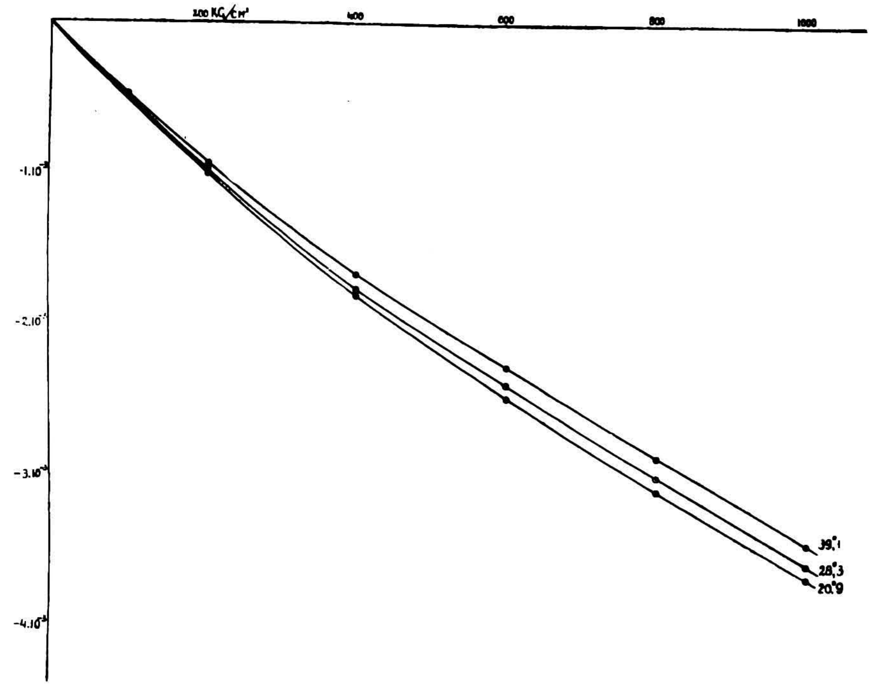

Fig. 2.

the deviation from the linear equation of the pressure effect, i.e. the deviations from the straight line drawn between the first and last points of Fig. 2, are plotted in Fig. 3.

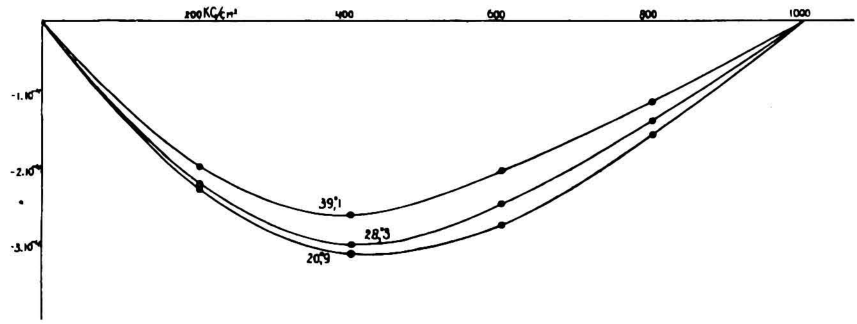

Fig. 3.

As BRIDGMAN has also published a graph similar to Fig. 3 it is possible to compare his and the present results.