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A Study of the Process of Electrical Conduction in Films of India Ink

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of
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INTRODUCTION

The grid leak used in radio engineering often is an ink film. It is used as a path of escape of electrons from the grid. This path is necessary, for electrons collect on the grid and cause it to become negatively charged. Since a vacuum tube will not function unless the grid is charged positively with respect tothe filiament, the necessity of the grid leak is obvious. The rate of absorbtion of electrons by the grid, and of their removal by the grid leak can be controlled to a certain extent by varying this grid leak resistance. Figure 1 shows the use of the grid leak (R) in a wireless receiving set. The commercial India Ink grid leaks are made of a sheet of cardboard about an eighth of an inch wide and an inch long, covered on both sides with India Ink which serves as the conductor.

Although the exact constituents and the method of manufacture of India Ink are business secrets, we know that India Ink is a colloidal suspension of small particles of carbon and liquid glue called size.

In this work I tried to determine three things. First, whether or not this ink colloid showed Kataphoresis. Second, the effect of moisture on the resistance. Third, whether the conductivity of the ink film was metallic or electrolytic.

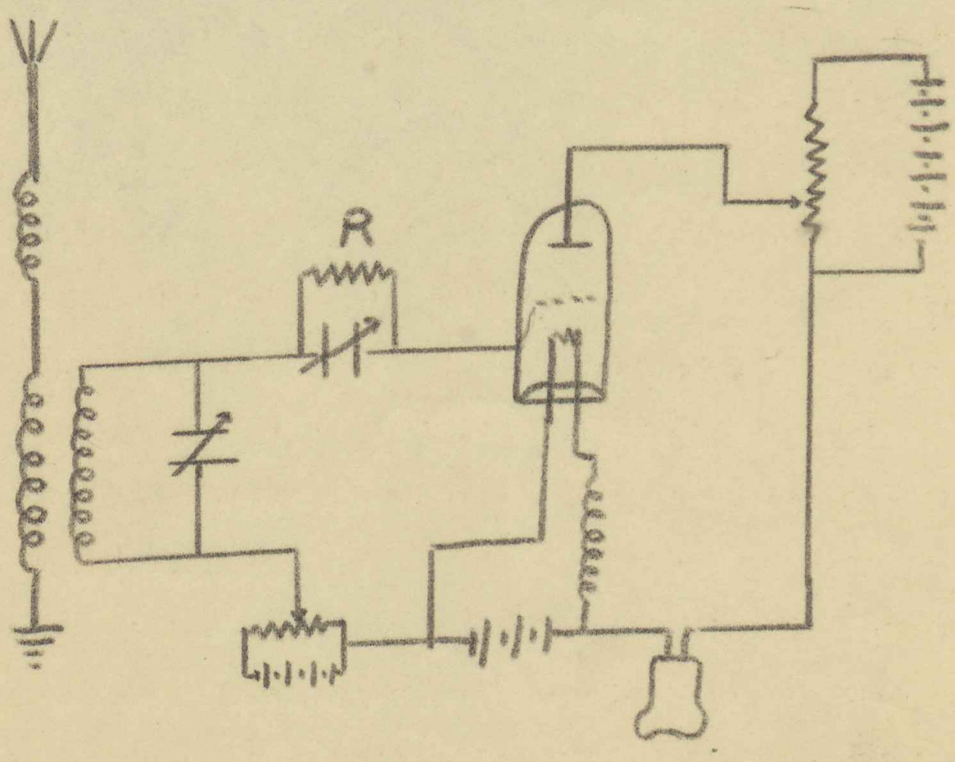


Fig. 1

APPARATUS

To test for kataphoresis, I used a U tube with side arms and copper wires for electrodes as is shown in Figure 2. I used a solution containing 5cc of ink in 50cc of solution, and a potential difference of 6 volts from a storage battery.

To find the effect of dilution on the resistance of solutions of ink in water, I used a conductivity cell and a Wheatstone bridge. Of course in measuring the resistance of solutions I had to use high frequency alternating current and telephone receivers. I used a variable condenser to balance the capacity of the conductivity cell. Figure 3 shows the conductivity cell, with the long and short distances between the electrodes. Figure 4 shows the wiring diagram used for this work, showing the oscillating circuit I used as a source of high frequency alternating current, and the Wheatstone bridge, where r_1, r_2, and R are variable and X is the resistance to be measured.

To determine the effect of humidity on the resistance of the ink films, I placed some grid leaks, which I made, in desiccators containing different salts, whose aqueous vapor tension was available from tables. I measured the resistance with the same Wheatstone bridge arrangement as is shown in Figure 4. Later I found that I could use direct current and a galvanometer instead of alternating current and telephones. Since this increased the accuracy of my measurements, I made this replacement. Figure 5 shows the

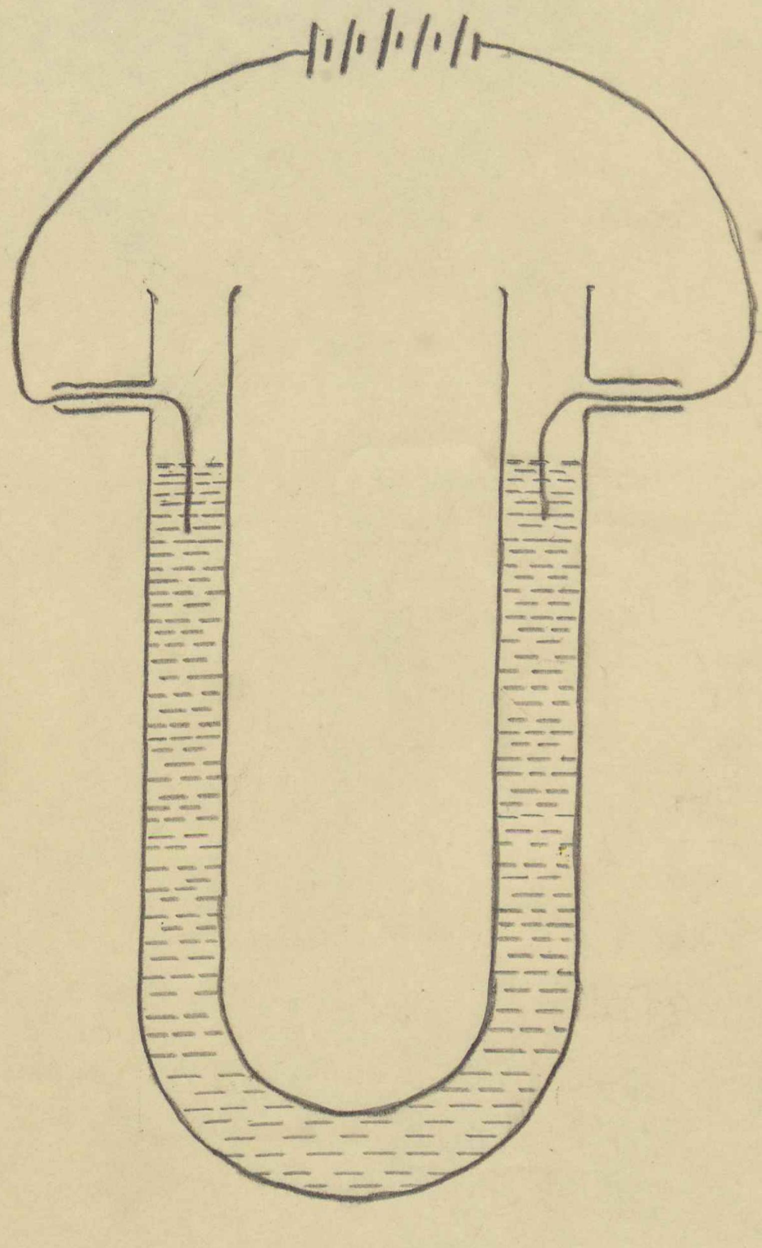


Fig. 2

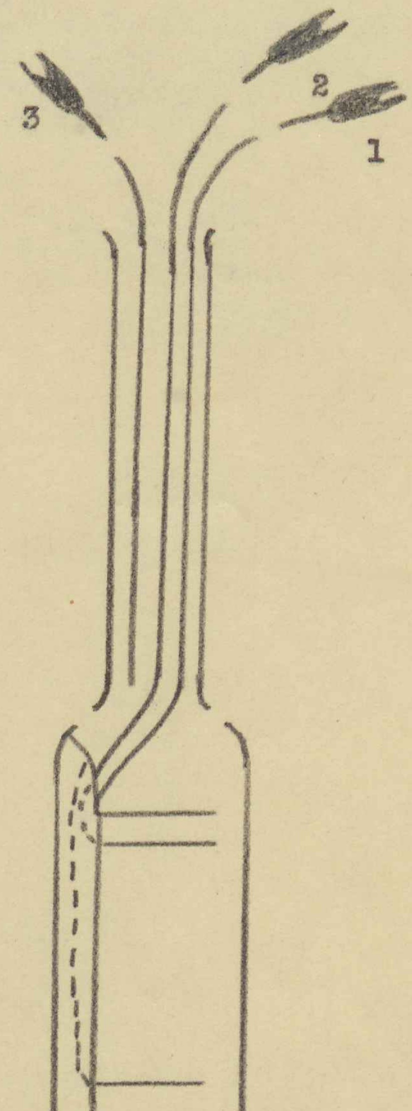


Fig. 3

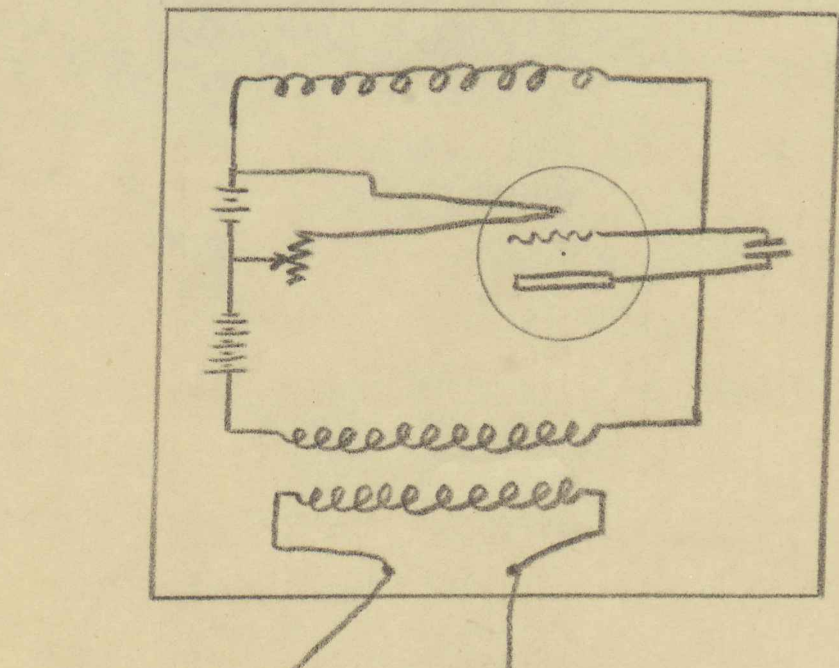


Fig. 4

type of desicciator fitted with wires which I used.

To find whether the conduction was metallic or electrolytic I used desiccators such as shown in Figure 5 and measured resistances with the Wheatstone bridge of Figure 4 using dirrect current and galvanometer. As a source of current through the grid leak I used a D.C. generator.

RESULTS

I kept a potential difference of six volts between the electrodes as shown in Figure 2 for seventy hours. During this time most of the carbon moved into the space about the anode leaving the rest of the solution transparent, but dark brown in color.

Measuring the resistance of solutions containing various proportions of ink and water I obtained the comparative results of table 1. These results are plotted in the curves of Figures 6 and 7.

TABLE 1

cc of ink in 100cc of solution	Resistance short space	Resistance long space	
.0625	4,950	46,300	ohms
.1250	3,700	32,000	"
.2500	2,300	21,600	"
.5000	1,320	12,100	"
1.0000	810	7,400	"
2.0000	460	4,300	"
3.0000	297	2,850	"
4.0000	190	1,600	"
5.0000	130	1,100	"
6.6666	114	1,070	"
8.3333	114	1,060	"

In studying the effect of humidity on the resistance of ink films in the form of grid leaks, I placed some of them in desiccators containing anhydrous calcium chloride and measured the change in resistance as they were dried out. Believing that the card board was not

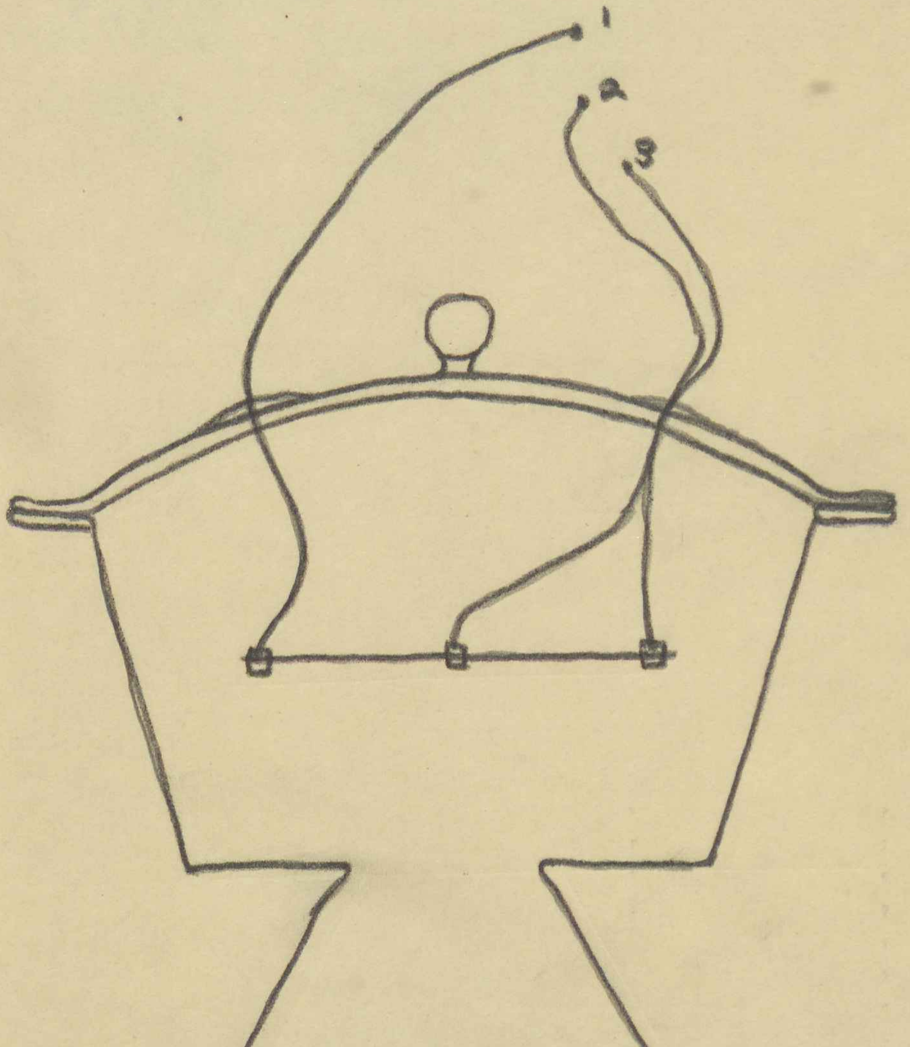


Fig. 5

rigid enough, I made some by coating with India Ink some microscope slides whose surfaces had been roughened with hydrofluoric acid. These I subjected to the above treatment also. These results are shown in Table 2. Also I took a grid leak which had been dried out with calcium chlotide and put it over hydrated copper sulphate which gives a pressure of water vapor over it of 7mm. The changes of resistance are shown in Table 3.

TABLE 2

Run 1 (using cardboard)

Time	Resistance
0	410,000 ohms
1 hr	160,000 "
18hrs	310,000 "
24hrs	300,000 "
30hrs	300,000 "
42hrs	300,000 "

Run 2 (using glass)

Time	Resistance
0	370,000 ohms
2 days	1200,000 "
3 days	1240,000 "
4 days	1300,000 "
5 days	1370,000 "
6 days	1400,000 "
7 days	1400,000 "
9 days	1500,000 "

Run 3 (using glass)

Time	Resistance
0	150,000 ohms
1 hr	329,000 "
2 hrs	400,000 "
1 day	400,000 "
5 days	400,000 "
8 days	400,000 "
11days	400,000 "

Run 4 (using glass)

Time	Resistance
0	280,000 ohms
1 hr	310,000 "
2 hrs	280,000 "
3 hrs	320,000 "
4 hrs	300,000 "
2 days	160,000 "
3 days	250,000 "
10days	160,000 "

TABLE 3

Time	Resistance
0	201,000 ohms (when placed in desiccator)
3 hrs	238,000 "
1 day	240,000 "
4 days	300,000 "
8 days	255,000 "
10days	256,000 "
19days	275,000 "

To determine whether the conduction was metallic or electrolytic I placed a grid leak in the desiccator shown in Figure 5 using hydrated copper sulphate and passed a direct current through it from 1 to 3. Table 4 shows some of my results.

TABLE 4

Run 1 (Over Copper Sulphate)

Time	Resistance 1-3	1-2	2-3	Ratio 1-2/2-3
0	240,000	117,000	120,000	.975
70	275,000	138,000	133,000	1.038

Run 2 (Over Anhydrous Calcium Chloride)

Time	1-3	1-2	2-3	
0	200,000	98,000	100,700	.978
19 days	200,000	100,000	100,000	1.000

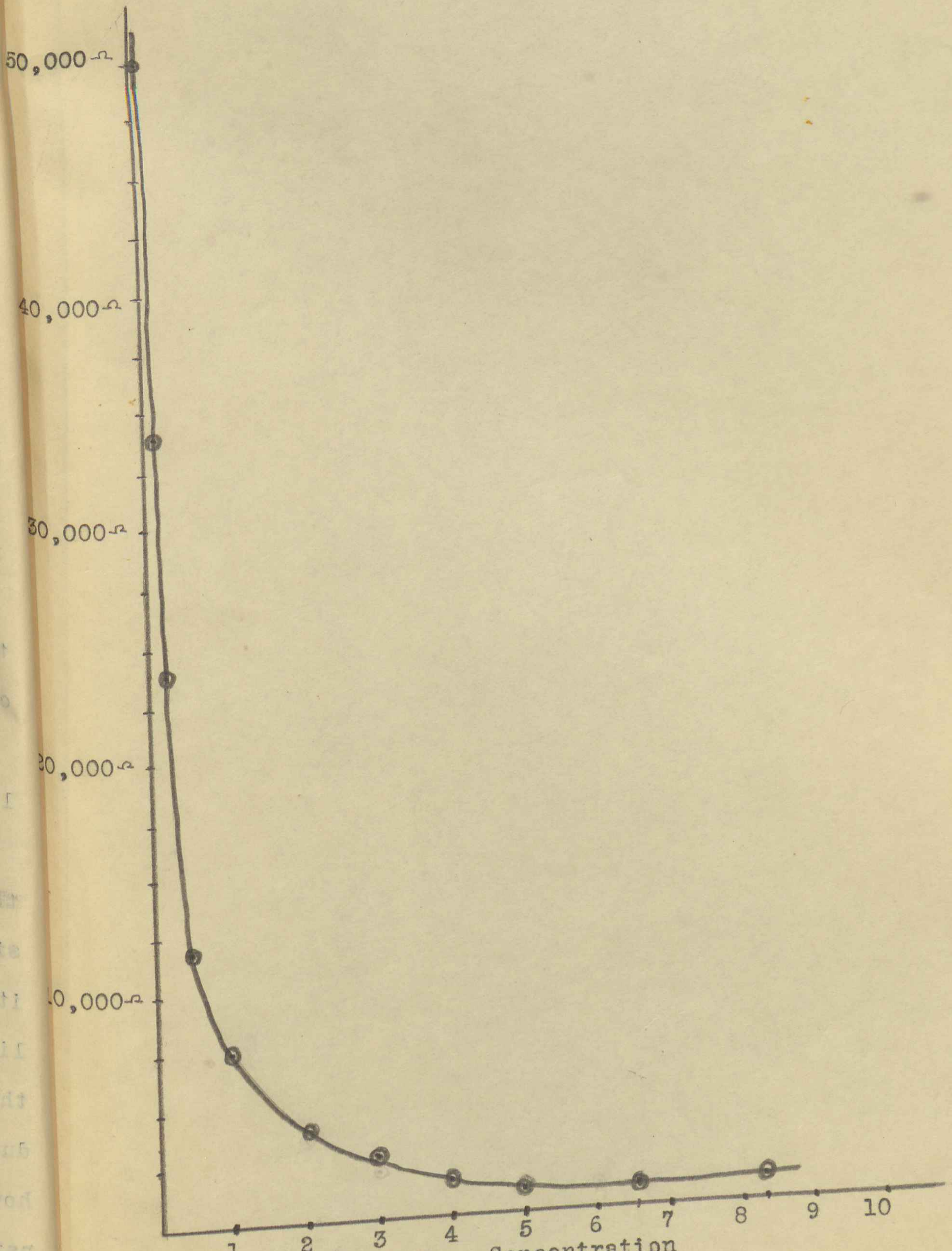
CONCLUSIONS

For the first, the ink solution shows kataphoresis, and the results prove that the carbon particles have a negative charge in this colloid.

Since the resistance of the ink solutions increased with dilution, it must be that it is the carbon particles which carry the current, and not the supporting colloid.

My results on the effect of humidity on the resistance of grid leaks are not definite enough to draw any conclusions from.

The ratio of the resistance of the part of the grid leak on the positive side to the resistance of the part on the negative side is slightly larger after the current has been passed through it. However, this change is not large enough to lead to the belief that the carbon particles carry the current by passing from the positive to the negative terminal, that is, electrolytic conduction, or rather kataphoresis. Since this change is very small, however, I am led to believe that the conduction is, for the most part, metallic.



50,000-Ω
40,000-Ω
30,000-Ω
20,000-Ω
10,000-Ω
1
2
3
4
5
6
7
8
9
10
Concentration

Fig. 6

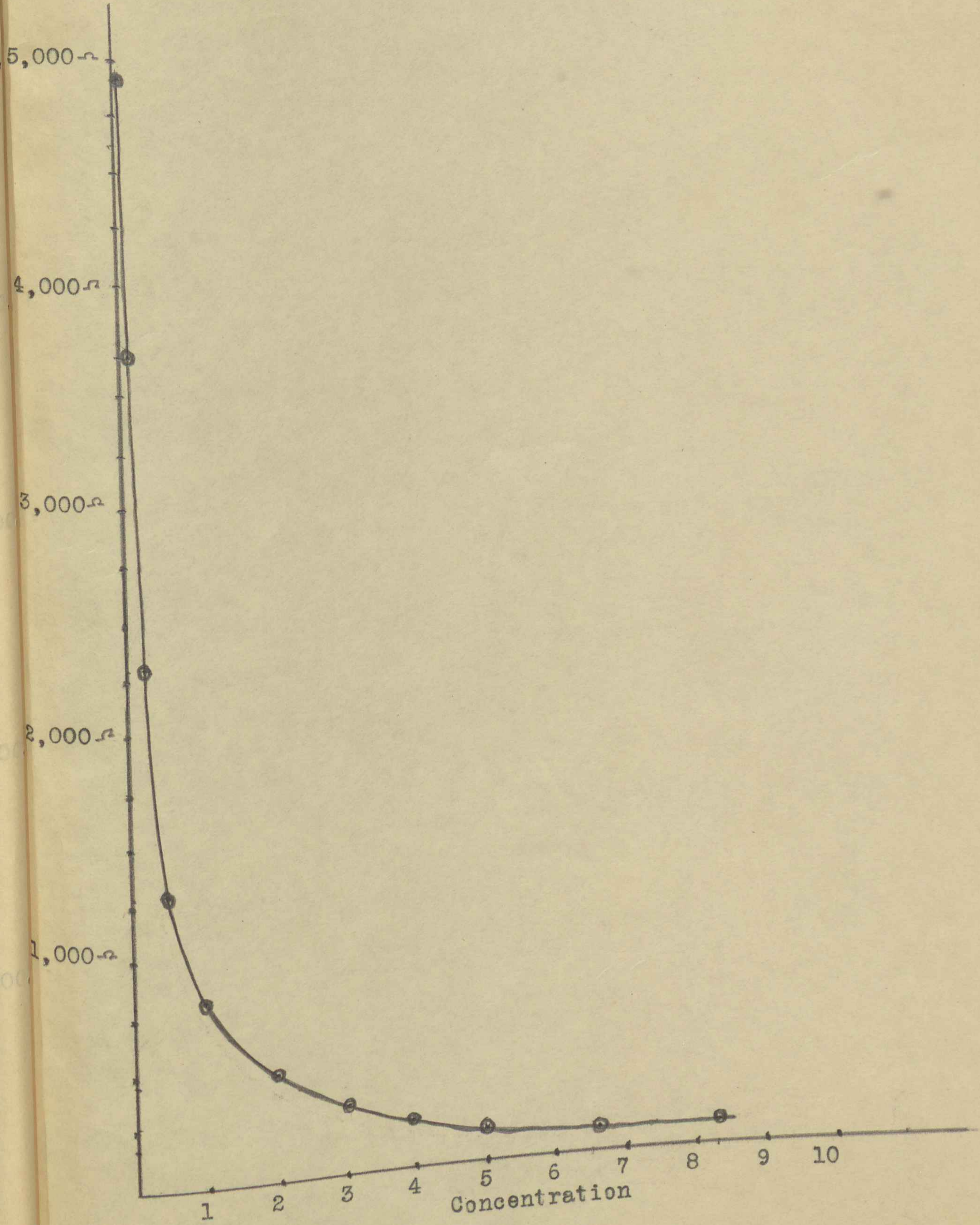


Fig. 7