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Electrolysis of neutral solutions of $ZnSO_4$

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Department:

ELECTROLYSIS OF NEUTRAL SOLUTIONS OF $ZnSO_4$.

BY

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A

THESIS

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INDEX.

ELECTROLYSIS OF NEUTRAL SOLUTIONS OF $ZnSO_4$.

Purpose:

The purpose of the following experiments was to obtain informations concerning the character of the deposits, the efficiency, et c. in the electrolysis of neutral solutions of $ZnSO_4$.

Apparatus and Procedure:

The apparatus used consisted of twelve electrolytic cells connected in series. Each cell was capable of holding about one and a half liter of solution. During the circulation of the solution the electrolyte was kept at a constant height in the cells by means of the following arrangement. An opening was made in the end wall of the glass jar, and a glass tube, furnished with a stopcock, was bent 90 degrees at the extremities, but in opposite directions. The glass tube was next inserted through the opening in the jar and placed such that the portion of the tube inside the cell remained vertical. The glass tube was held in place and leakage was prevented by means of sealing wax. The electrodes consisted of two anodes of lead and a cathode of aluminum. The cathode was placed between the anodes and at a distance of 1 1/4 of an inch from each anode surface. The cathode plate was held in position by being clamped in an aluminum bar placed across the edges of the cell. By having two sets of cathode plates, one plate could be slipped into the clamp immediately after the removal of one plate for the purpose of stripping. The electrodes were made such that the active surface of the electrodes remained eight square inches. The cells were all connected in series and the current was obtained through a bank of electric globes. By means of the electric globes and a rheostat the current could be adjusted to any desired strength, as read on the ammeter inserted in the circuit. The drop of voltage in each individual cell was measured by connecting temporarily the anode and the cathode with a voltmeter. A copper voltameter was at first connected in series with the cells, but due to the high voltage no satisfactory results could be obtained, and the voltameter was discarded. The current was kept as constant as possible by means of the rheostat. Great difficulties were found due to the fact that the current was from time to time furnished by two different power plants with different voltages. This invariably caused a change in the current which could not always be immediately compensated for by means of the rheostat. The current densities given are therefore only approximate and the theoretical amounts of zinc deposited

are calculated from the theoretical amount of current which passed through the apparatus during 48 hours.

The circulation of the electrolyte was obtained by siphoning the solution from glass jars(7 liter capacity)into the electrolytic cells.Eight hours were in most cases required for transferring the electrolyte from the feed cells.to the electrolytic cells.The purpose of the siphons was twofold.They furnished a means of circulation and gave a plendid stirring of the solution in the electrolytic cells.From the overflows in the cells, the electrolyte dripped into funnels placed in large glass bottles.In the funnel was placed a filter paper and an alundum cone filled with zinc oxide.The alundum cone served two purposes: It served as a container for the zinc oxide and prevented the destruction of the filter paper due to the impact of the drops. The purpose of the zinc oxide was to keep the strength of the solution the same all the time.It is a matter of fact that a certain amount of sulfuric acid,equivalent to the amount of zinc deposited,is always formed.Zinc oxide is insoluble in water,but any sulfuric acid present will dissolve the zinc oxide and furnish the same amount of zinc sulfate as was originally decomposed. To prevent any acid from escape coming in contact with the zinc oxide in the alundum cones,an amount of zinc oxide was always left on the bottom of the bottles in which the solution was collected.When the feed cells became empty the stopcocks were closed and the solutions were poured from the bottles into the feed cells Each cell had a different strength of solution.The solutions were made up by dissolving chemically pure zinc sulfate in distilled water.In this connection it should be mentioned that a very rapid and quite accurate method of determining the strength of the solutions may be accomplished by means of an accurate set of hydrometers.Tables of the specific gravities of zinc sulfate solutions are given by Schiff,Kohlrausch,and others.Determinations may be made till less than one tenth of one percent.All the experiments were conducted for 48 hours.and without interrupting the current.The latter should be carefuly avoided as the acid formed in the cell immediately dissolves some of the zinc deposited on the cathode.Only the zinc was weighed which remained on the cathode when the latter was pulled out of the solution.In the weak solutions the bulk of the zinc invariable remains on the bottom of the cell or floats on the solution.The strength of the solutions, the current densities,and the results obtained are found in the following pages.Solution lost due to evaporation,and decomposition was replaced every day.

Table 1.

Nr. of cell.	Voltage. (volts)	Current. (amp. sq/ft.)	Zn deposited. (g.)	Strength of solution.
1.	6,2 volts. (17 hrs. run.)	4,5	1,904. (Zn/ZnO)	1/4 % $ZnSO_4$.
2.	3,7 volts. (17 hrs run)	4,5.	4,283.	1/2 % $ZnSO_4$.
3.	3,6 volts. (17 hrs run)	4,5.	6,305.	3/4 % $ZnSO_4$.
4.	3,4 volts. (17 hrs run)	4,5.	4,860.	1 % $ZnSO_4$.
5.	3,2 volts. (17 hrs. run)	4,5.	4,463.	2 % $ZnSO_4$.
6.	3,1 volts (17 hrs run).	4,5.	6,927.	3 % $ZnSO_4$.
7.	3,0 volts (17 hrs run).	4,5.	7,762.	5 % $ZnSO_4$.
8.	2,9 volts. (17 hrs run).	4,5.	8,880.	7,5 % $ZnSO_4$.
9.	2,83 volts. (17 hrs run).	4,5.	11,026.	10 % $ZnSO_4$.
10.	2,79 volts. (17 hrs run).	4,5.	9,707.	12,5 % $ZnSO_4$
11.	2,75 volts. (17 hrs run).	4,5.	8,520.	15 % $ZnSO_4$.
12.	2,71 volts. (17 hrs run).	4,5.	9,616.	20 % $ZnSO_4$.

Table 1.(cont).

Nr.	Theoretical amount of Zn.	Effieieney. %	Action in cell.
1.	14,64.g.	13,oo %.	Strong evolution of gas, foaming and bubbling.
2.	14,64.g.	29,25.%.	Quiet action.
3.	14,64.g.	43,07 %.	Quiet action.
4.	14,64.g.	33,19 %.	Quiet action.
5.	14,64.g.	30,49.%.	Quiet action.
6.	14,64.g.	47,31.%.	Quiet action.
7.	14,64.g.	53,02.%.	Quiet action.
8.	14,64.g.	60,65.%.	Quiet action.
9.	14,64.g.	75,31.%.	Quiet action.
10.	14,64.g.	66,30.%.	Quiet action.
11.	14,64.g.	58,20.%.	Quiet action.
12.	14,64.g.	65,68.%.	Quiet action.

Table 1(cont).

Nr.	character of deposit.
1.	Black,slimy,and very porous mass of zinc which partly floats on top of the solution and partly sinks to the bottom and collects in a heap below the cathode.Zn exceedingly voluminous while in cell.When dewatered a black slime is left.Strong formation of ZnO takes place.The ZnO forms a white,flaky cover over the solution.Some of the ZnO sinks to the bottom and intermingle with the slimy Zn in the cell.Much ZnO adheres to the cathode,especially at the edges and at the line of contact between the surface of the solution and the cathode.Little metallic Zn found on the cathode.Deposit in cell did not seem to dissolve rapidly
2.	Exceedingly mossy and spongy Zn.The color lighter than that of the Zn in cell 1.Spongy mass formed which conneets the anode with the cathode and the cathode with the bottom of the cell. The zinc adheres so loosely that the evolution of gas makes the mossy Zn swing to and fro.Zn accumulated at bottom of cell. No ZnO formed.Apparently little resolution.
3.	Fine,mossy deposit.Deposit more stable and sprouts shorter than in cell 2.Zn on bottom of cell.Mossy material cover entire cathode.Light gray color.Little resolution.
4.	Mossy material and long sprouts.The mass is more stable and not disturbed by the formation of gas.Less mossy material around edges than in cell 3.Zn on bottom of cell.Light gray color.Little resolution.Deposit can be removed very easily.
5.	Spongy and mossy around edges.Only one short sprout.Bulk of Zn at edges.Zn on bottom of cell.The Zn looks granular and passes into solution rapidly.
6.	Mossy and spongy deposit,especially around edges.Bulk of deposit at edges.Deposit on the bottom of the cell is very much like that in cell 5,but it does not seem to pass into solution so rapidly.Gray color,little lighter than that of the Zn in cell 5.Larger sprouts than in cell 5.
7.	Mossy deposit.Almost total deposit at edges.No "trees". Deposit at bottom of cell dissolvs rapidly.Light gray color.
8.	Mossy deposit,especially at edges.Light gray color at edges. The deposit on the bottom of the cell did not seem to dissolve as rapidly as the deposit in cell 7 did.
9.	Mossy deposit,but not so much around edges.Edges of a very light gray color.Deposit quite compact.Deposit on bottom of cell.
10/	Mossy deposit,especially around edges.Deposit on bottom of cell dissolved rapidly.Light gray color
11.	Mossy deposit,especially around edges.Strong resolution.
12.	Mossy at edges.Quite large sprouts.Strong resolution.

Table 1.

Vertical column:-Str. of sol. Horizontal column:-Effe.

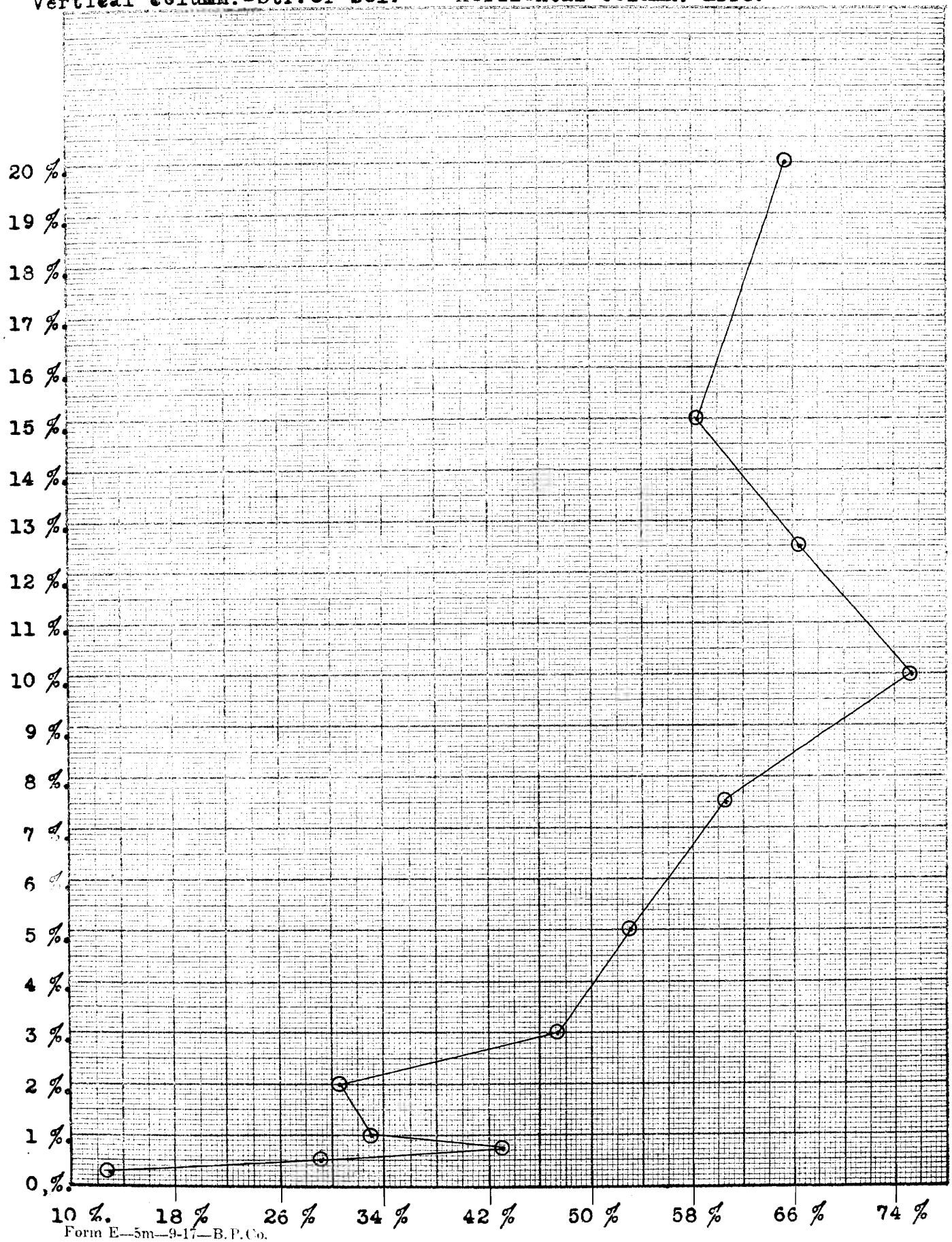


Table 2.

Nr. of cell.	Voltage. (volts).	Current. (amp. sq/ft.)	Zn deposited. g.	Strength of solution.
1.	5,8. (15 hrs. run)	9,0	0,805.	1/4 % $ZnSO_4$.
2.	3,8. (15 hrs. run).	9,0.	3,509.	1/2 % $ZnSO_4$.
3.	3,7. (15 hrs. run).	9,0.	5,452.	3/4 % $ZnSO_4$.
4.	3,65. (15 hrs. run).	9,0.	5,936.	1 % $ZnSO_4$.
5.	3,45. (15 hrs. run).	9,0.	17,719.	2 % $ZnSO_4$.
6.	3,37. (15 hrs. run).	9,0.	16,325.	3 % $ZnSO_4$.
7.	3,37. (15 hrs. run).	9,0.	25,505.	5 % $ZnSO_4$.
8.	3,50. (15 hrs. run).	9,0.	25,670.	7,5 % $ZnSO_4$.
9.	3,17. (15 hrs. run).	9,0.	27,105.	10 % $ZnSO_4$.
10.	2,80. (15 hrs. run).	9,0.	25,530.	12,5 % $ZnSO_4$.
11.	2,80. (15 hrs. run).	9,0.	25,552.	15 % $ZnSO_4$.
12.	3,00. (15 hrs. run).	9,0.	26,479.	20 % $ZnSO_4$.

Table 2(cont).

Nr.	Theoretical amount of Zn.	Efficiency.	Action in cell.
1.	29,28 g.	2,75 %.	Quiet action.
2.	29,28 g.	11,98 %.	Quiet action.
3.	29,28 g.	18,62 %.	Quiet action.
4.	29,28 g.	20,27 %.	Quiet action.
5.	29,28 g.	60,52 %.	Quiet action.
6.	29,28 g.	55,75 %.	Quiet acti on.
7.	29,28 g.	87,11 %.	Quiet action.
8.	29,28 g.	87,69 %.	Quiet action.
9.	29,28 g.	92,56 %.	Quiet action.
10.	29,28 g.	87,19 %.	Quiet action.
11.	29,28 g.	87,26 %.	Quiet action.
12.	29,28 g.	90,43 %.	Quiet action.

Table 2(cont).

Nr.	Character of deposit.
1.	Mossy material which partly floats on top of the solution and partly sinks to the bottom and collects in a heap below the cathode. Exceedingly porous and voluminous material. Somewhat less slimy than the Zn obtained in cell 1, exp. 1. No rapid resolution.
2.	Almost entire deposit in the form of sprouts on the edges of the cathode. The mossy deposit falls off and collects on the bottom of the cell. Deposit of a lighter color and less porous than the deposit obtained in cell 1. No Zn floating on the surface. No rapid resolution.
3.	The sprouts are not quite as modsy as in cell 2. At bottom of cell are sprouts which have fallen off. Dark color. No resolution Zn crumbles on being removed.
4.	Deposit very much like that obtained in cell 3, but the deposit is heavier on the cathode. Sprouts on bottom of cell. The color is darker than that of the Zn in cell 3. No rapid resolution. Zn crumbles on being removed.
5.	Smooth deposit and feww prouts. Light gray color. ONly a few sprouts have fallen off and collected on the bottom of the cell. The Zn on bottom of cell dissolves rapidly. Mossy material here and there on the cathode.
6.	Deposit very much like that in cell 5, but the sprouts are lonher and more stable. No Zn on bottom of cell. Deposit smooth but for a few pits and very small sprouts at the edges.
7.	Deposit not very even. Very little sprouting except at lower edge. Sprouts of mossy material. Dark rim at surface of solution. Sprouts very short. Light gray color. No Zn on bottom of cell.
8.	Deposit not as smooth as the deposit in cell 7. Deposit not very even. End sprouts, especially at lower edges. Mossy Zn near surface of solution. Spots of dark, mossy material on cathode. Light gray color of bulk of Zn. No Zn in cell.
9.	Light gray color. Deposit quite smooth but not even on one side. Deposit slightly pitted. No end sprouts except at lower edges and at corners. Sprouts small. Pronounced edge of mossy at surface of solution. No Zn i n cell.
10/	Light gray deposit. Deep vertical furrows. Not many end sprouts and only at lower edges and corners. Dark rim near surface of solution. No Zn in cell.
11.	Deposit not very even on one side. Vertical furrows not so pronounced as in cell 10. More sprouts than in cell 10. Light gray color, but dark line near surface of solution. No Zn in cell.
12.	Deposit even but not smooth, although the vertical furrows are not well pronounced. At edges is found a rim of globular sprouts, crowded at corners. Light gray color, but a rim of mossy and dark xtals at surface of solution. No Zn in cell.

Table 2.

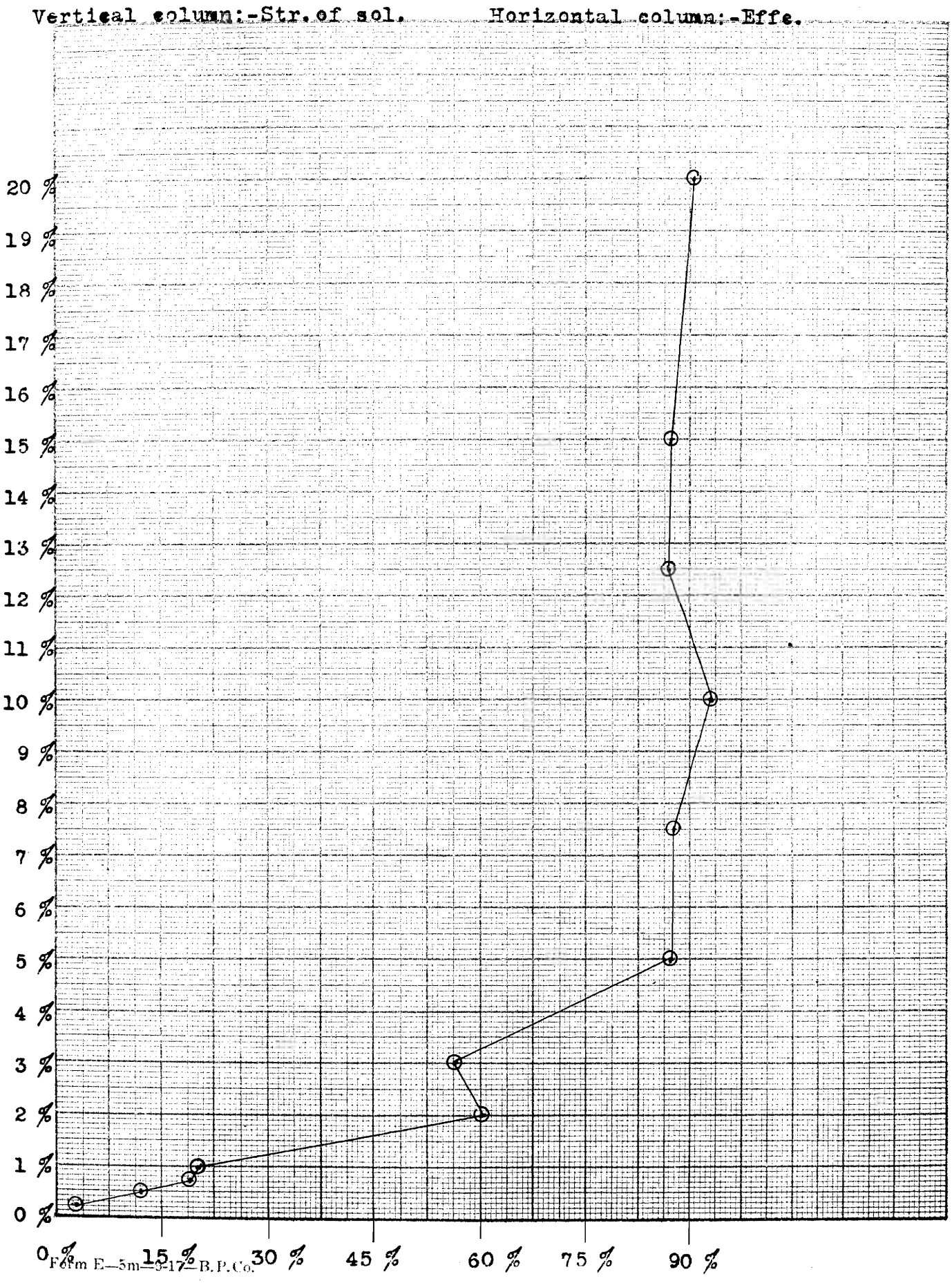


Table 3.

Nr. of cell.	Voltage. (volts).	Current. (amp. sq/ft.)	Zn deposited. g.	Strength of solution.
1.	7,10.	13,5.	1,700.	1/4 % $ZnSO_4$.
2.	4,80.	13,5.	6,442.	1/2 % $ZnSO_4$.
3.	4,30.	13,5.	9,773.	3/4 % $ZnSO_4$.
4.	4,40.	13,5.	9,249.	1 % $ZnSO_4$.
5.	3,80.	13,5.	22,322.	2 % $ZnSO_4$.
6.	3,70.	13,5.	30,053.	3 % $ZnSO_4$.
7.	3,30.	13,5.	37,979.	5 % $ZnSO_4$.
8.	3,10.	13,5.	40,476.	7,5 % $ZnSO_4$.
9.	3,15.	13,5.	41,141.	10 % $ZnSO_4$.
10	3,00.	13,5.	34,584.	12,5 % $ZnSO_4$.
11.	2,90.	13,5.	38,627.	15 % $ZnSO_4$.
12.	2,80.	13,5.	39,102.	20 % $ZnSO_4$.

Table 3(cont).

Nr.	Theoretical amount of Zn.	Efficieney.	Acton in cell.
1.	43,92 g.	3,87 %.	Quiet action.
2.	43,92 g.	14,69 %.	Quiet action.
3.	43,92 g.	22,25 %.	Quiet action.
4.	43,92 g.	2i,06 %.	Quiet action.
5.	43,92 g.	50,82 %.	Quiet action.
6.	43,92 g.	68,43 %.	Quiet action.
7.	43,92 g.	86,47 %.	Quiet action.
8.	43,92 g	92,16 %.	Quiet action.
9.	43,92 g.	93,67 %.	Quiet action.
10.	43,92 g.	78,74 %.	Quiet action.
11.	43,92 g.	87,95 %.	Quiet action.
12.	43,92 g.	89,03 %.	Quiet action.

Table 3(cont.)

Nr.	Character of deposit.
1.	Mossy and exceedingly porous Zn. The Zn partly floats in the solution and partly collects on the bottom of the cell. When dewatered and dried the Zn crumbles into dust. Some ZnO with the fine and mossy deposit on the cathode. The Zn is difficult to remove from the cathode and much scraping is necessary. Gray color.
2.	Very mossy and porous Zn. The bulk of the Zn falls off and collects in the cell. Deposit on cathode heavier than in cell 1. Deposit does not crumble as easily as in cell 1. Gray color.
3.	Spongy and mossy deposit. Deposit sticks better to the cathode and does not crumble so easily as the deposit in cell 2. Mossy sprous fallen off and collected on bottom of cell. Some Zn has a bright metallic lustre. Gray color of the bulk of the deposit.
4.	Mossy deposit of a darker color than that in cell 3. Sprouts fallen off and collected on bottom of cell.
5.	Deposit much more compact than in any of the previous cells. Light gray, pitted deposit with patches of dark, mossy Zn. Large sprouts. Sprouts fallen off and collected in cell. Sprouts are "tree" like. The rim of edge sprouts is not very pronounced.
6.	Deposit quite smooth and with a high rim of of edge sprouts , crowded at corners. Sprouts at corners "tree" like and quite stable. Some sprouts on the bottom of the cell.
7.	Light gray, slightly pitted deposit. A few small sprouts here and there on the cathode plate. Vertical furrows very little pronounced. Edge sprouts all around. Sprouting greater at lower edge and corners. Sprouts not very large. Dark rim near the surface of the solution.
8.	Deposit very pitted on the cathode plate. Edge sprouts larger than in cell 7, but not so crowded at corners. Light gray color of deposit.
9.	Deposit very pitted, but the pits are much larger than they were in cell 8. Rim of edge sprouts not very pronounced. except at lower edges and at the corners. Color somewhat darker than that of the Zn in cell 8. Dark rim at surface of solution.
10/	Very pronounced, vertical furrows and sprouts which, on the cathode plate, has been shaped by the ascending gas bubbles. Heavy rim of dark and light gray edge sprouts of mossy appearance. Color of deposit much darker than that in the previous cell.
11.	Light gray deposit which is almost smooth and which has a rim of large, globular edge sprouts.
12.	Deposit on cathode plate very much like the deposit in cell 11. Rim of edge sprouts is, however, very heavy and sprouts are less globular and more like moss than they are in cell 11. Light gray deposit.

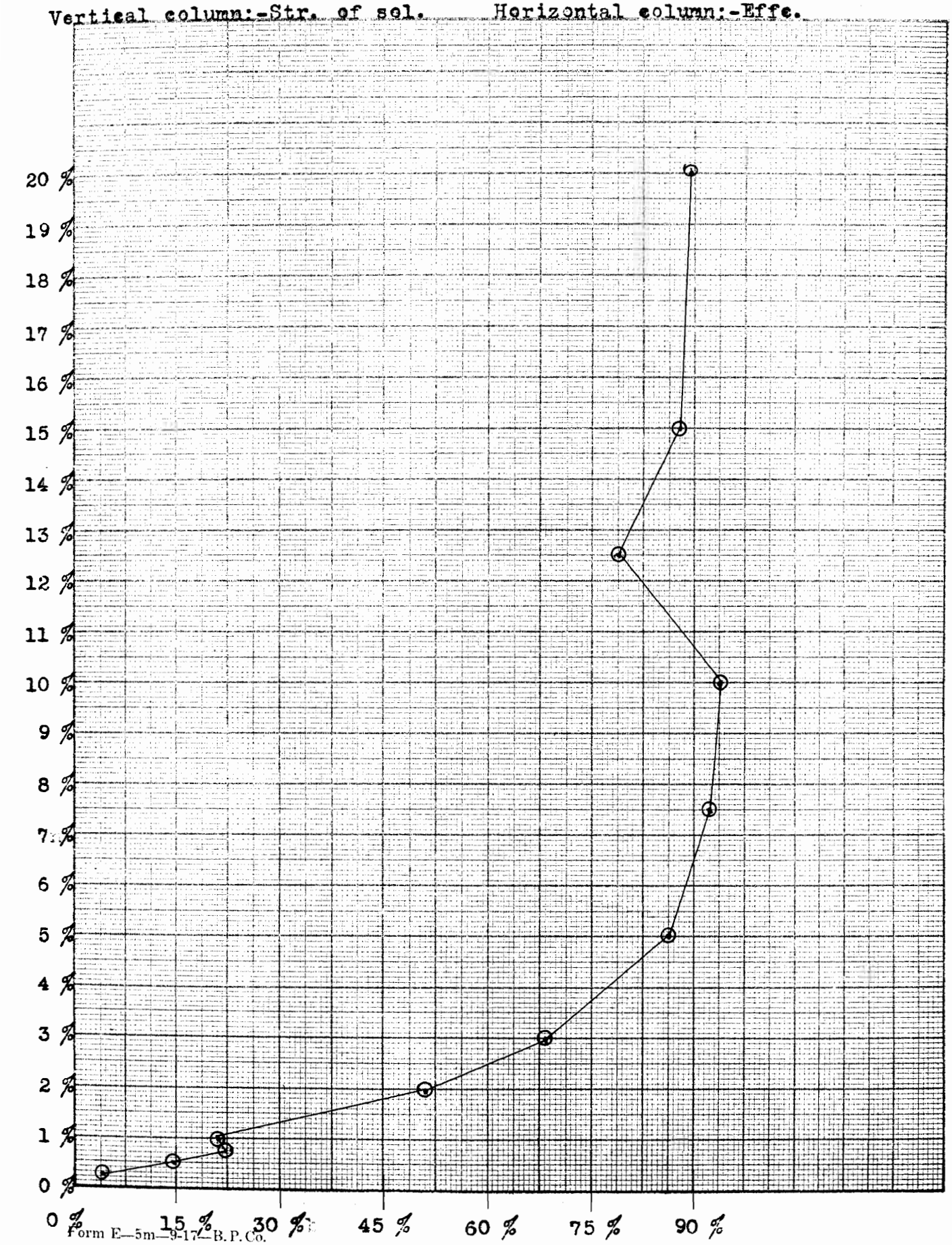

Vertical column:-Str. of sol.
Horizontal column:-Effc.
20 %
19 %
18 %
17 %
16 %
15 %
14 %
13 %
12 %
11 %
10 %
9 %
8 %
7 %
6 %
5 %
4 %
3 %
2 %
1 %
0 %
0 %
15 %
30 %
45 %
60 %
75 %
90 %

Table 4.

Nr. of cell.	Voltage. (volts.)	Current. (amp. sq/ft.)	Zn deposited. g.	Strength of solution.
1.	7,0	18.	0,748.	1/4 % $ZnSO_4$.
2.	5,5.	18.	5,750.	1/2 % $ZnSO_4$.
3.	5,0.	18.	7,598.	3/4 % $ZnSO_4$.
4.	5,5	18.	9,305.	1 % $ZnSO_4$.
5.	2,5.	18.	33,835.	2 % $ZnSO_4$.
6.	3,5.	18.	39,610.	3 % $ZnSO_4$.
7.	3,5.	18.	41,990.	5 % $ZnSO_4$.
8.	3,0.	18.	42,877.	7,5 % $ZnSO_4$.
9.	3,3.	18.	43,620.	10 % $ZnSO_4$.
10.	3,4.	18.	36,120.	12,5 % $ZnSO_4$.
11.	3,2.	18.	44,165.	15 % $ZnSO_4$.
12.	3,0.	18.	44,190.	20 % $ZnSO_4$.

Table 4(cont).

Nr of cell.	Theoretical amount of Zn.	Efficiency.
1.	58,56 g.	1,28 %.
2.	58,56 g.	9,82 %.
3.	58,56 g.	12,97 %.
4.	58,56 g.	15,89 %.
5.	58,56 g.	57,78 %.
6.	58,56 g.	67,64 %.
7.	58,56 g.	71,70 %.
8.	58,56 g.	73,22 %.
9.	58,56 g.	74,49 %.
10/	58,56 g.	61,58 %.
11.	58,56 g.	75,42 %.
12.	58,56 G/	75,46 %.

Table 4(cont).

Nr.	Character of deposit.
1.	Very spongy and mossy zinc which floats on the solution and collects in aheap below the cathode.Exceedingly voluminous.Deposit crumbles when being removed from the cathode.
2.	Mossy zinc.Color lighter than that of the zinc in cell 1.Zinc very voluminous.Zinc does not crumble when being removed.
3.	Deposit very much like that in cell 2,but is heavier.
4.	Deposit mossy and spongy.More stable than in previous cell.
5.	Large "trees" at corners.Edge sprouts.Many small sprouts on one side of the cathode.
6.	Light gray deposit.Heavy edge sprouting .Deposit only smooth on one side.
7.	Rim of edge sprouts.Deposit quite smooth.
8.	Rim of edge sprouts not so well pronounced as in cell 7.Deposit quite smooth.
9.	Edge sprouts little pronounced.Sprouting heavier on lower edge. Light gray deposit.Dep sit quite smooth.End sprouts globular.
10.	Heavy rim of dark colored,mossy end sprouts.Deposit on cathode slightly furrowed vertically.Light gray and pitted deposit.
11.	Heavy rim of globular edge sprouts,especially at low er edge and at corners.Light gray deposit.Deposit smooth.
12.	Very pronounced edge of sprouts.Light gray deposit.

Table 4.

Vertical column:-Str. of solution. Horizontal column:-Effc.

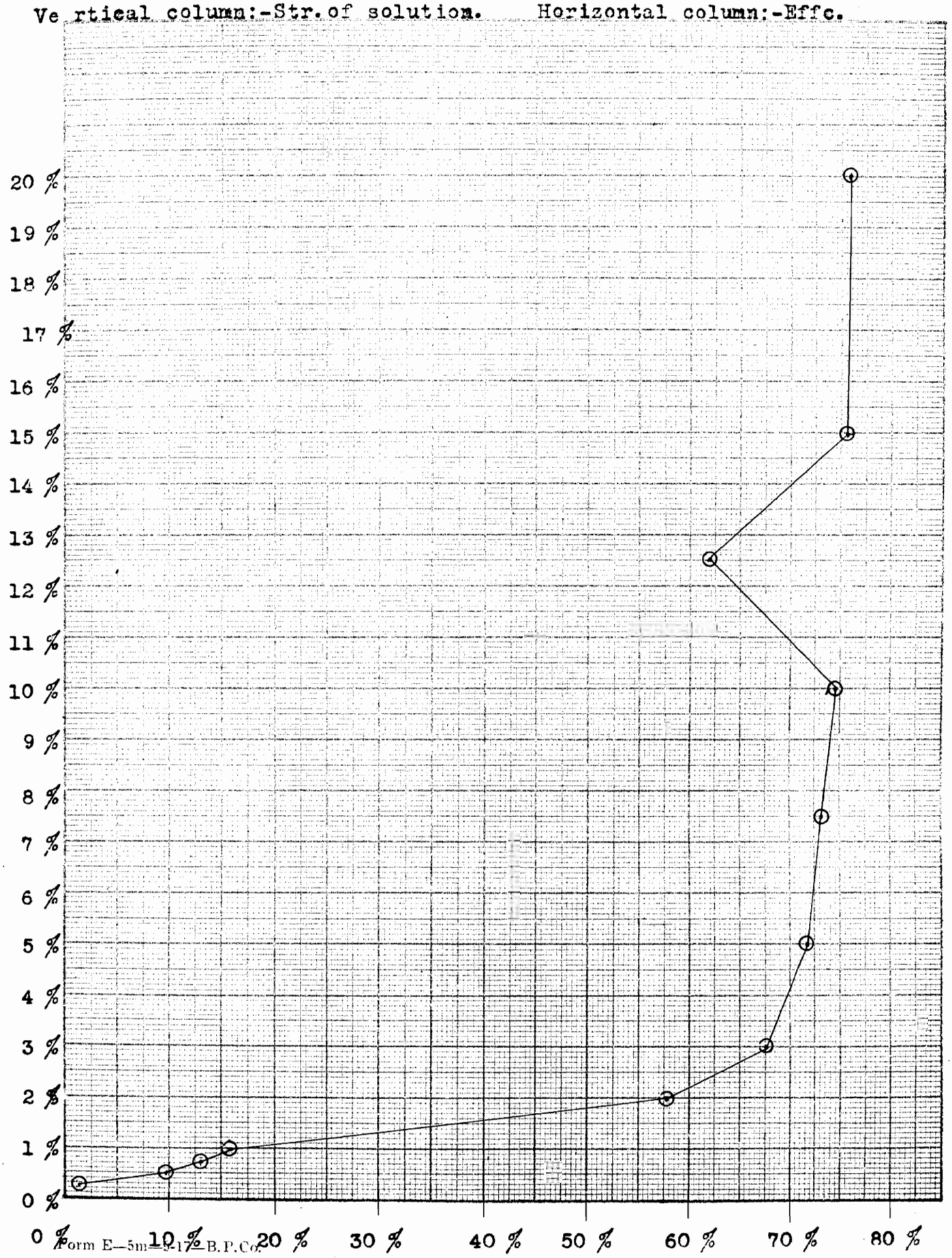


Table 5.

Nr of cell.	Voltage. (volts).	Current. (amp sq/ft).	Zn deposited. g.	Strength of slution.
1.	16,0.	22,5.	0,130.	1/4 % $ZnSO_4$.
2.	4,8.	22,5.	4,940.	1/2 % $ZnSO_4$.
3.	4,0.	22,5.	8,062.	3/4 % $ZnSO_4$.
4.	3,8.	22,5.	10,792.	1 % $ZnSO_4$.
5.	3,6.	22,5.	27,000.	2 % $ZnSO_4$.
6.	3,0.	22,5.	53,000.	3 % $ZNSO_4$.
7.	3,6.	22,5.	55,775.	5 % $ZnSO_4$.
8.	3,7.	22,5.	56,132.	7,5 % $ZnSO_4$.
9.	3,3.	22,5.	45,527.	10 % $ZnSO_4$.
10.	3,3.	22,5.	48,475.	12,5 % $ZnSO_4$.
11.	3,0.	22,5.	55,692.	15 % $ZnSO_4$.
12.	3,0.	22,5.	53,378.	20 % $ZNSO_4$.

Table 5(cont).

Nr of cell.	Theoretical amount of Zn.	Efficiency.
1.	73,20 g.	0,18 %.
2.	73,20 g.	6,75 %.
3.	73,20 g.	11,01 %.
4.	73,20 g.	14,74 %.
5.	73,20 g.	36,88 %.
6.	73,20 g.	72,40 %.
7.	73,20 g.	76,19 %.
8.	73,20 g.	76,68 %.
9.	73,20 g.	62,19 %.
10.	73,20 g.	66,22 %.
11.	73,20 g.	76,08 %.
12.	73,20 g.	72,92 %.

Table 5(cont).

Nr.	Condition of deposit.
1.	Black, slimy zinc floating in the cell. Strong evolution of gas.
2.	Mossy, spongy deposit which crumbles when being removed from the cathode. Bulk of zinc in the cell.
3.	Mossy, spongy deposit which crumbles on being removed fron the cathod e. Bulk of zinc in the cell.
4.	Mossy, spongy zinc. Bulk of zinc falls off when sprouting. Deposit on cathode smooth and of a lighter color than that of the zinc in previous cell. Only little sprouting on one side of the cathode.
5.	Large "trees" and mossy deposit at edges. Sprouts over the entire surface of the cathode. Dark gray color.
6.	Light gray deposit. Pitted and much sprouting. Rim of edge sprouts. Clusters at corners.
7.	One side very smooth and free from any edge sprouts. Oppositeside covered with a great number of small sprouts and has a rim of edge sprouts. Deposit thin on the smooth side , very heavy on the other side.
8.	Light gray deposit. Slightly pitted. Rim of edge sprouts.
9.	Light gray deposit . Small sprouts all over the c athode. Rim of edge sprouts.
10.	Light gray deposit with a rim of mossy edge sprouts. Deposit smooth on one side. Spro uting on the other s ide.
11.	Heavy rim of globularedge sprouts. Light gray color. Deposit quite smooth.
12.	Deposit pitted and furrowed vertically. Very pronounced edge of sprouts. Light gray color.

Table 5.

Vertical column:-Str. of sol. Horizontal column:-Effc.

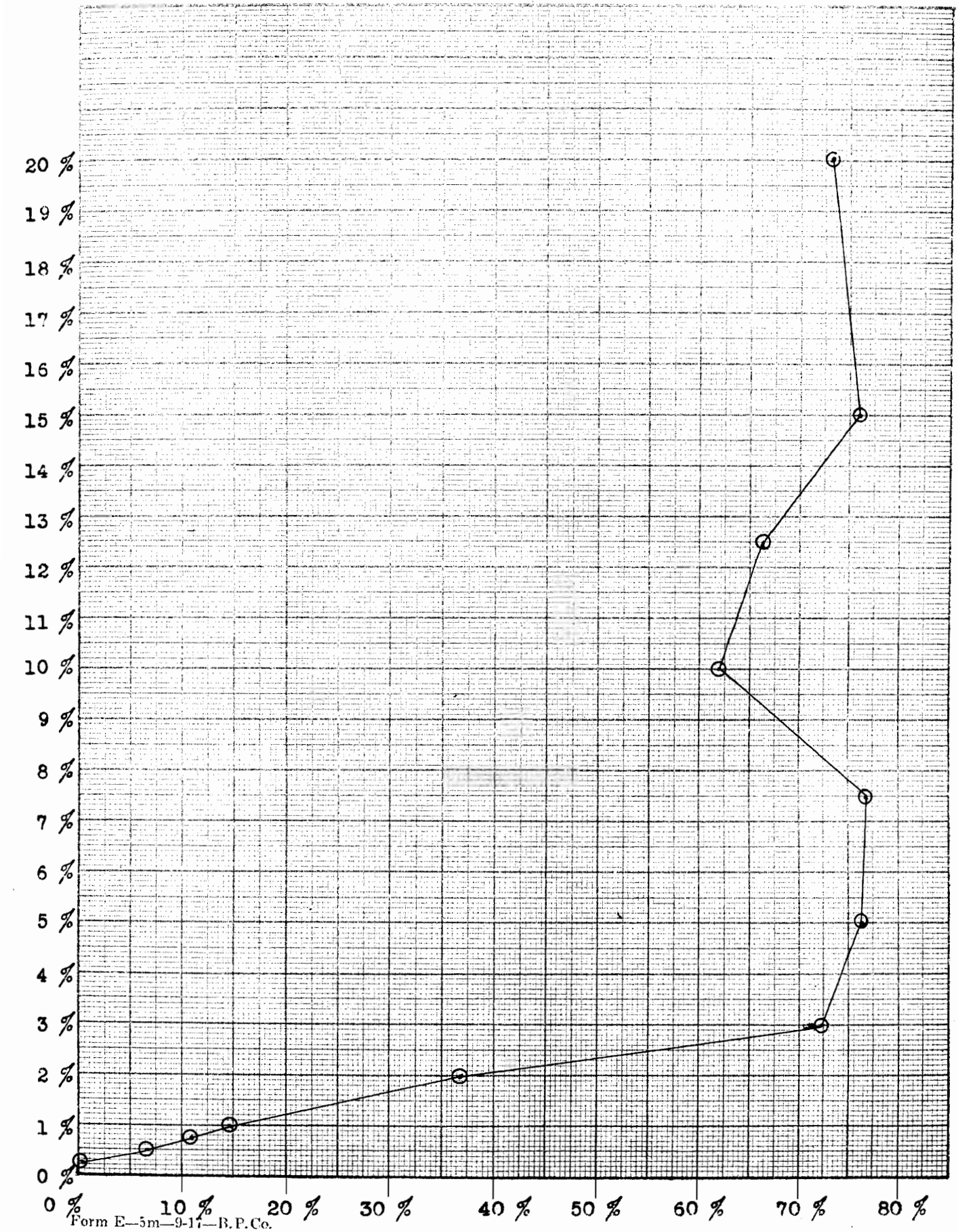


Table 6.

Nr of cell.	Voltage (volts)	Current (amp sq/ft)	Zn deposited g.	Strength of solution.
1.	22,0.	27.	0,240	1/4 % $ZnSO_4$.
2.	5,2.	27.	4,707	1/2 % $ZnSO_4$.
3.	4,4.	27.	9,527.	3/4 % $ZnSO_4$.
4.	4,2.	27.	12,300.	1 % $ZnSO_4$.
5.	4,2.	27.	24,330.	2 % $ZnSO_4$.
6.	1,7.	27.	36,320.	3 % $ZnSO_4$.
7.	3,4.	27.	49,637.	5 % $ZnSO_4$.
8.	3,6	27.	66,570.	7,5 % $ZnSO_4$.
9.	3,0.	27.	68,670.	10 % $ZnSO_4$.
10.	3,1.	27.	58,890.	12,5 % $ZNSO_4$.
11.	3,2.	27.	67,990.	15 % $ZnSO_4$.
12.	3,0.	27.	66,280.	20 % $ZnSO_4$.

Table 6(cont).

Nr. of cell.	Theoretical amount of Zn.	Efficiency.
1.	87,84 g.	0,27 %.
2.	87,84 g.	5,36 %.
3.	87,84 g.	10,84 %.
4.	87,84 g.	14,00 %.
5.	87,84 g.	27,70 %.
6.	87,84 g.	41,35 %.
7.	87,84 g.	56,51 %.
8.	87,84 g.	75,79 %.
9.	87,84 g.	78,17 %.
10	87,84 g.	67,04 %.
11.	87,84 g.	77,34 %.
12.	87,84 g.	75,45 %.

Table 6(cont).

Nr.	Character of deposit.
1.	Exceedingly mossy and spongy material which floats in the cell.
2.	Spongy and mossy material. Bulk of zinc in the cell.
3.	Very much like the deposit in cell 2, but the deposit on the cathode is heavier. Zinc does not crumble on being removed.
4.	Light gray deposit. Mossy sprouts on the surface of the cathode Zinc does not crumble when being removed from the cathode.
5.	Much sprouting at edges. Sprouts are mossy and fan shaped. Light gray deposit. Deposit on cathode is quite smooth.
6.	Much sprouting at cathode surface and at edges. Large clusters of sprouts at corners. Light gray deposit.
7.	Much sprouting at corners and on the cathode surface. Light gray deposit.
8.	Light gray deposit. Deposit very smooth on one side of the cathode. Much sprouting on the opposite side. Thin deposit on smooth side. Heavy deposit on the opposite side.
9.	Light gray deposit. Edge sprouting only pronounced at the lower edge. Deposit deeply pitted on one side.
10.	Light gray deposit. Heavy rim of mossy edge sprouts. Cathode surface smooth but for a few sprouts.
11.	Light gray deposit with heavy rim of compact edge sprouts.
12.	Very heavy rim of compact edge sprouts. Much sprouting on surface of cathode.

Table 6.

Vertical column:-Str. of sol. Horizontal column:-Eff.

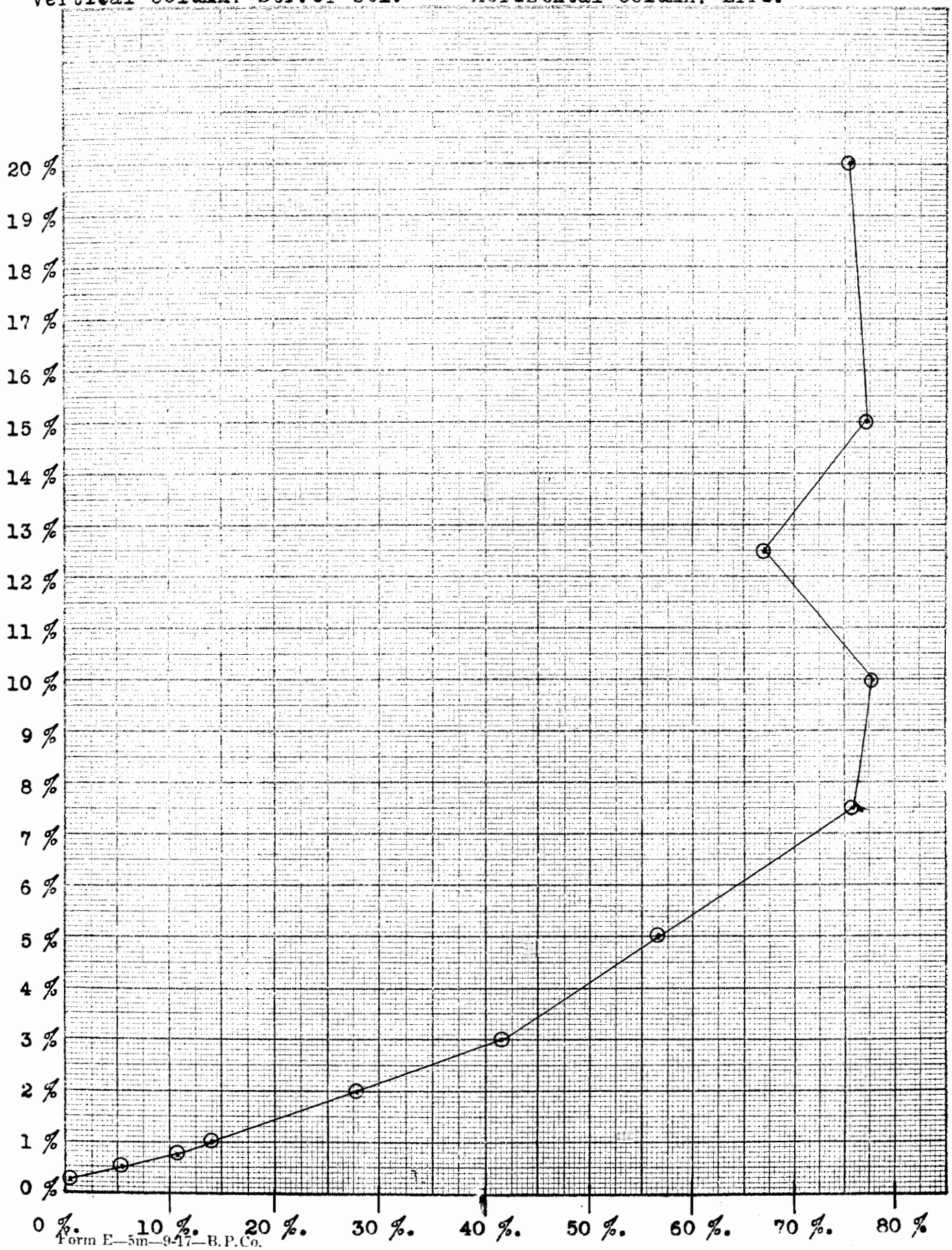


Table 7(cont).

Nr. of cell.	Voltage. (volts)	Current. (amp sq/ft).	Zn deposited. g.	Strength of solution.
1.	18,0.	31,5.	1,432 g.	1/4 % $ZnSO_4$.
2.	4,6.	31,5.	4,302 g.	1/2 % $ZnSO_4$.
3.	4,6.	31,5.	11,200 g.	3/4 % $ZnSO_4$.
4.	4,0.	31,5.	14,935 g.	1 % $ZnSO_4$.
5.	3,6.	31,5.	38,455 g.	2 % $ZnSO_4$.
6.	3,6.	31,5.	48,980 g.	3 % $ZnSO_4$.
7.	3,8.	31,5.	79,040 g.	5 % $ZnSO_4$.
8.	3,2.	31,5.	84,260 g.	7,5 % $ZnSO_4$.
9.	3,0.	31,5.	91,855 g.	10 % $ZnSO_4$.
10.	3,0.	31,5.	51,275 g.	12,5 % $ZnSO_4$.
11.	3,4.	31,5.	82,070 g.	15 % $ZnSO_4$.
12.	3,0.	31,5.	86,255 g.	20 % $ZnSO_4$.

Table 7(cont).

Nr of cell.	Theoretical amount of Zn.	Efficiency.
1.	102,48 g.	1,39 %.
2.	102,48 g.	4,20 %.
3.	102,48 g.	10,93 %.
4.	102,48 g.	14,57 %.
5.	102,48 g.	37,52 %.
6.	102,48 g.	47,80 %.
7.	102,48 g.	77,13 %.
8.	102,48 g.	82,22 %.
9.	102,48 g.	89,63 %.
10.	102,48 g.	50,03 %.
11.	102,48 g.	80,08 %.
12.	102,48 g.	84,17 %.

Table 7.

Nr.	Character of deposit.
1.	Exceedingly spongy and mossy material which floats in the cell and collects below the cathode. Deposit very voluminous and of a dark gray color. Foaming and bubbling.
2.	Deposit very much like that in cell 1, but more stable and of a lighter color. Deposit does not crumble so easily when being removed from the carhode.
3.	Deposit similarto the deposits in the previous cells, but more stable. Bulk of zinc in cell.
4.	Color of de posit much lighter than in the previous cases. Deposit on cathode quite compact. Much sprouting at edges. Zincon bottom of cell.
5.	Long, mossy, and fern shaped sprouts at the e dges . Cathode surface covered with small sprouts. Edge sprouts adhere very loosely. Deposit on cathode quite compact and easy to strip.
6.	Light gray deposit with mossy and fern like edge sprouts. Much sprouting on surface of cathode. Edge sprouts much more stable than in cell 5.
7.	Dark gray deposit. Very long, mossy, and fern like edge sprouts. Sprouts over one inch long. Bulk of deposit in the form of sprouts. Deposit on cathode plate quite thin.
8.	Light gray deposit. Deposit quite smooth on one side, heavy and covered with compact, globular edge sprouts on the other si de. Only edge sprouts on one side of the cathode.
9.	Light gray deposit. Deposit quite smooth on one side, compact and globular sprouts on the other side. Rim of compact edge sprouts.
10.	Entire cathode covered with mossy sprouts of little stability. Few edge sprouts. Sprouts shaped by the bubbles.
11.	Light gray deposit. Heavy rim of globular edge sprouts. Small sprouts on the entire cathode surface.
12.	Light gray deposit with a very pronounced and compact rim of globular edge sprouts.

Table 7.

Vertical column:- Str. of sol. Horizontal column:- Effc.

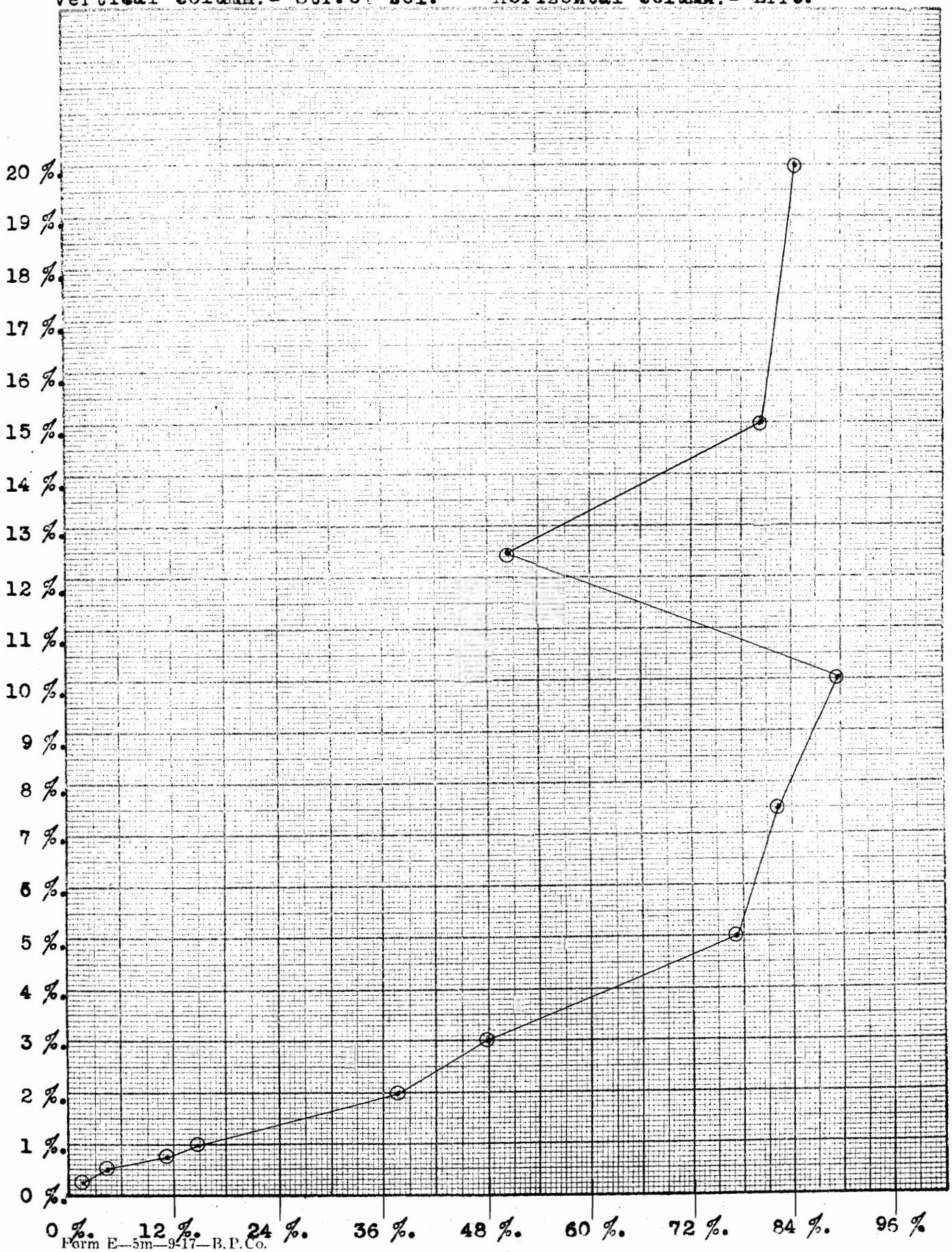


Table 8.

Nr of cell.	Voltage. (volts).	Current. (amp.sq/ft).	Zn deposited. g.	Strength of solution.
1.	10,0.	36.	1,825.	1/4 % $ZnSO_4$.
2.	16,0.	36.	0,607.	1/2 % $ZnSO_4$.
3.	7,5 .	36.	8,770.	3/4 % $ZnSO_4$.
4.	7,0.	36.	12,920.	1 % $ZnSO_4$.
5.	5,2.	36.	35,035.	2 % $ZnSO_4$.
6.	5,0.	36.	29,780.	3 % $ZnSO_4$.
7.	5,6.	36.	60,670.	5 % $ZnSO_4$.
8.	4,8.	36.	82,477.	7,5 % $ZnSO_4$.
9.	3,8.	36.	93,810.	10 % $ZnSO_4$.
10/	4,2.	36.	65,620.	12,5 % $ZnSO_4$.
11.	3,5.	36.	85,050.	15 % $ZnSO_4$.
12.	3,0.	36.	85,109.	20 % $ZnSO_4$.

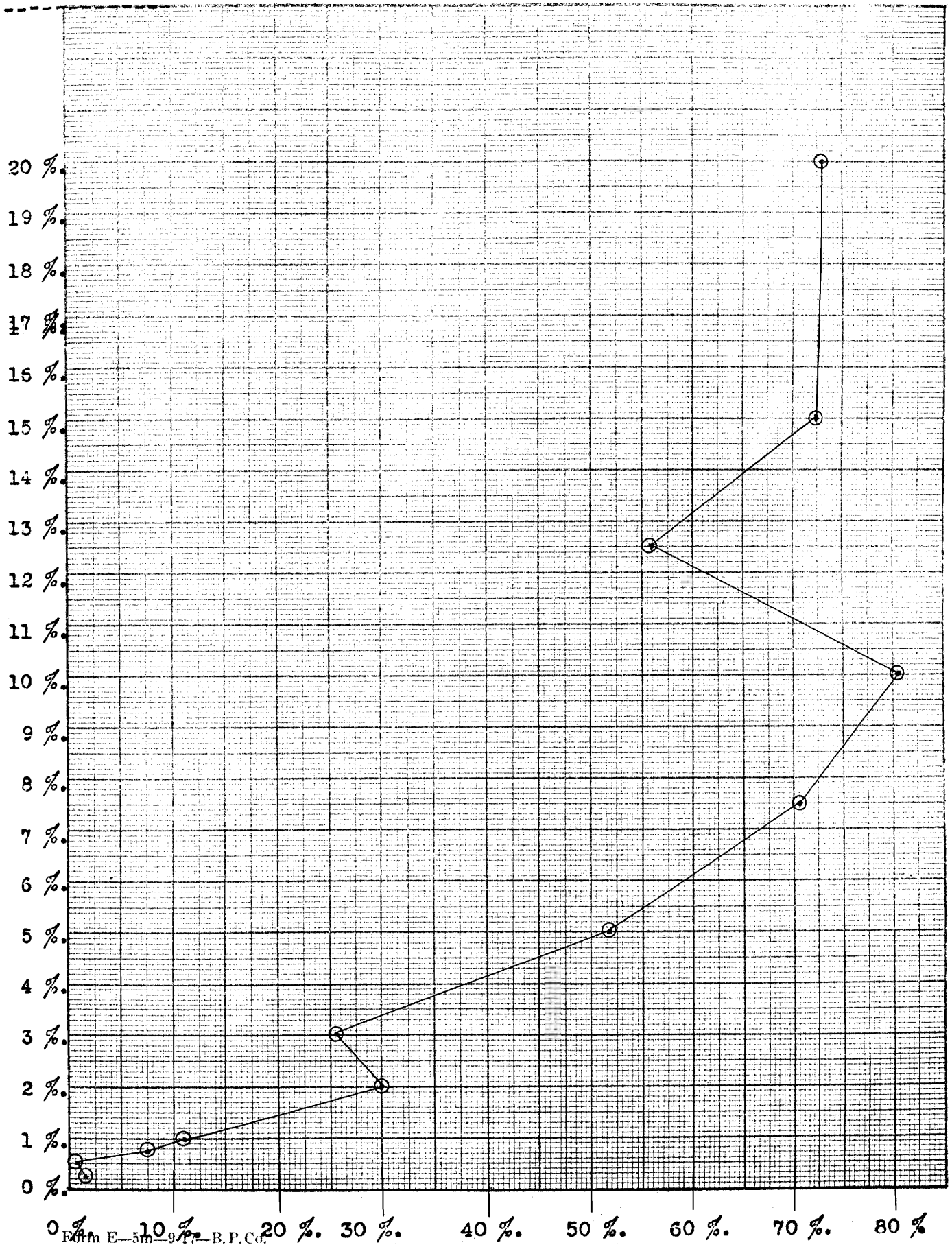
Table 8 (cont).

Nr of cell.	Theoretical amount of Zn.	Efficiency.
1.	117,12 g.	1,56 %.
2.	117,12 g.	0,52 %.
3.	117,12 g.	7,49 %.
4.	117,12 g.	11,03 %.
5.	117,12 g.	30,00 %.
6.	117,12 g.	25,43 %.
7.	117,12 g.	51/80 %.
8.	117,12 g.	70,42 %.
9.	117,12 g.	80,10 %.
10.	117,12 g.	56,03 %.
11.	117,12 g.	72,62 %.
12.	117,12 g.	72,67 %.

Table 8. (cont).

Nr.	Character of deposit.
1.	Mossy and spongy material which collects in the cell and floats in the solution. Dark color. Very voluminous. Zn crumbles when being removed from the cathode. Bulk of zinc in cell. Foaming and bubbling.
2.	Deposit very much like that in cell 1. Spongy and mossy material which floats in the cell. Little zinc on the cathode. Deposit crumbles easily. Dark color.
3.	Mossy and spongy material, but more stable than in any of the previous cases. Dark color. Bulk of zinc in cell.
4.	Color of deposit lighter than in previous case. Deposit much more stable than in cell 3 and does not crumble when being removed from the cathode. Bulk of zinc in cell.
5.	Sprouting over the netire cathode surface. Mossy and spongy edge sprouts. Edge sprouts adhere very loosely.
6.	Sprouts on cathode surface very small. Large, mossy, and fern like sprouts at corners and at the edges.
7.	Large, mossy, and fern shaped sprouts at edges and on cathode surface. Sprouts adhere very loosely.
8.	Light gray deposit. Heavy rim of globular and compact edge sprouts. One side of the cathode covered with sprouts, other side of cathode smooth.
9.	Heavy rim of compact and globular edge sprouts. Light gray deposit. Deposit smooth and thin on one side, heavy and covered with sprouts on the opposite side.
10.	Heavy sprouts at edges and on the cathode surface. Sprouts shaped by the bubbles. Color darker than that of the zinc in cell 9. Sprouts may easily be broken off.
11.	Light gray deposit. Heavy rim of large, globular, and very compact edge sprouts. Sprouting on cathode surface. Surface also have traces of the gas bubbles.
12.	Very heavy rim of large, compact edge sprouts. One side of the cathode heavy and covered with globular sprouts, opposite side smooth and thin. Light gray color.

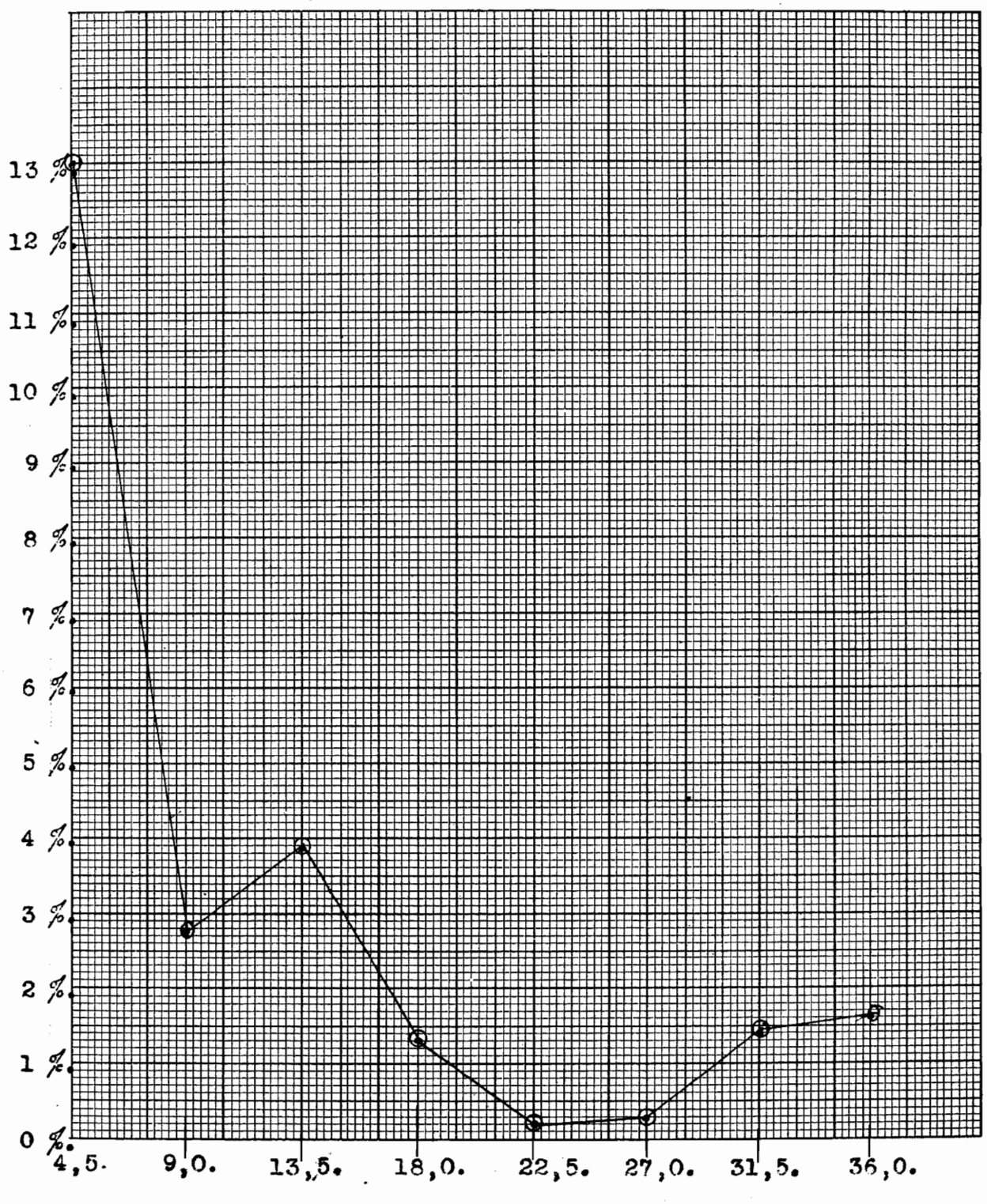
Table 8. Vertical column:-Str. of sol. Horizontal column:-Effe.



Efficiency-current density curve.

Strength of solution:-1/4 % $ZnSO_4$.

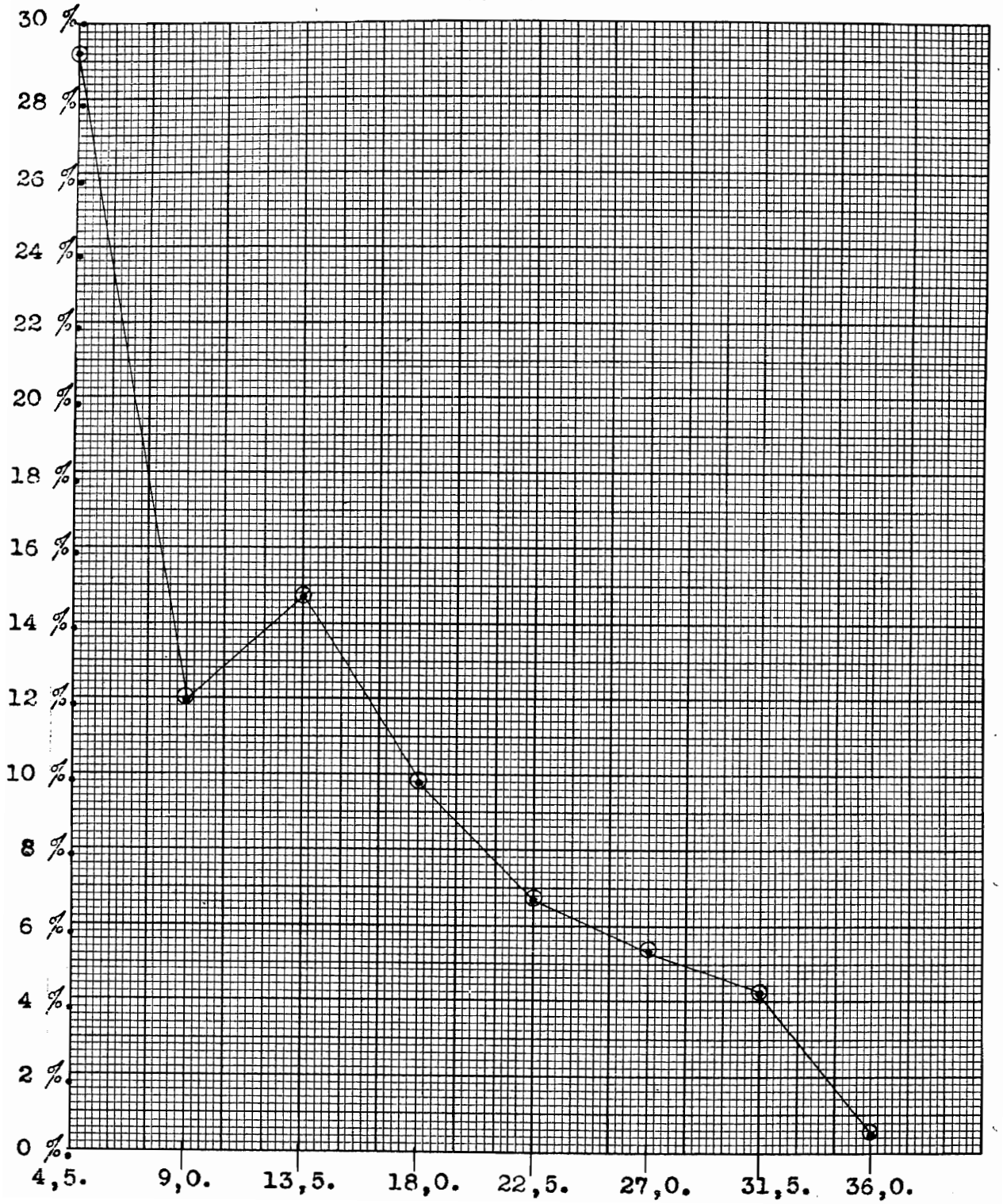
Vertical column:-Effe. Horizontal column:-Amp.pr sq/ft.



Efficiency-current density curve.

Strength of solution:-1/2 % $ZnSO_4$.

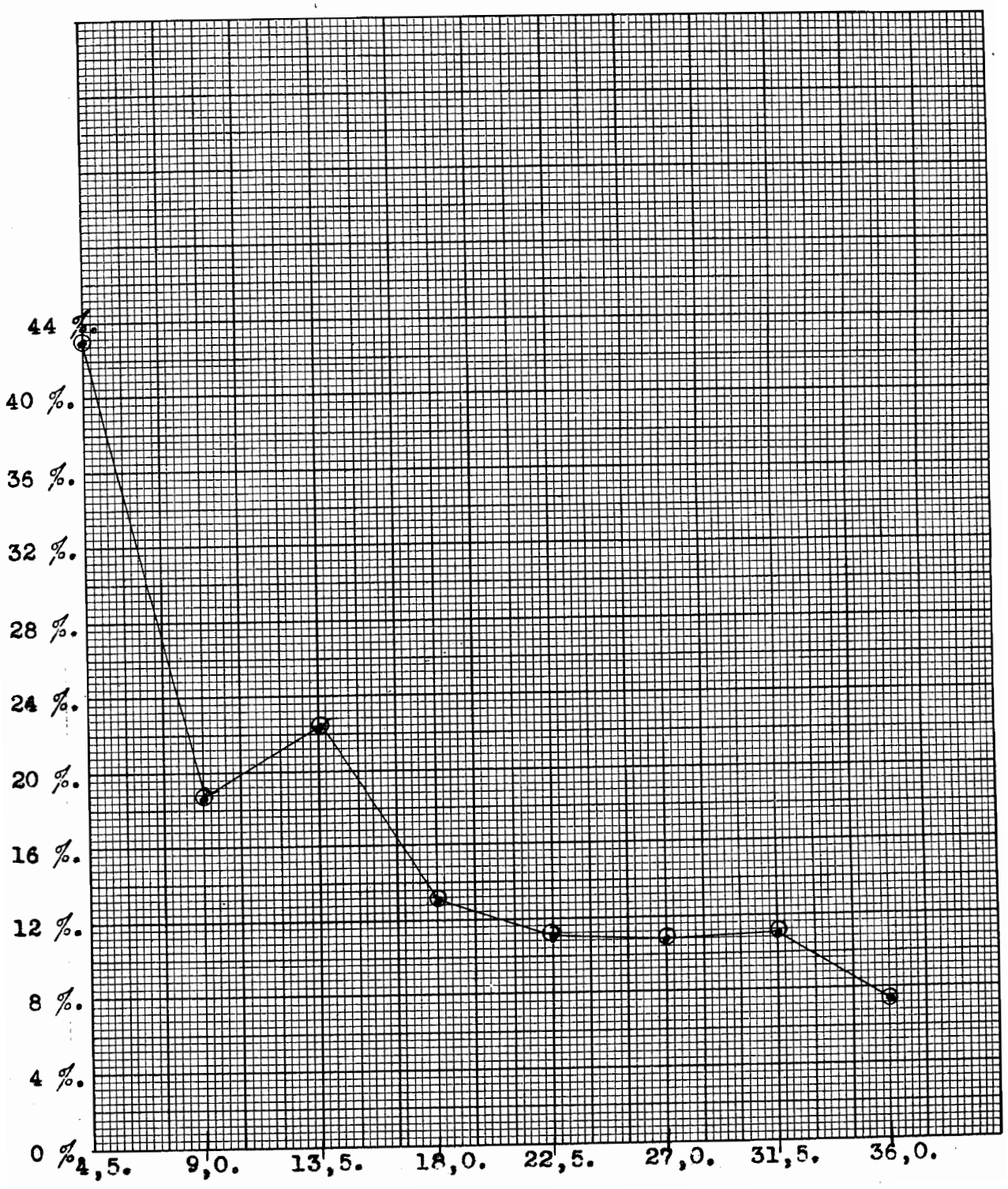
Vertical column:-Effc. Horizontal column:-Amp. pr sq/ft.



Efficiency-current density curve.

Strength of solution:-3/4 % $ZnSO_4$.

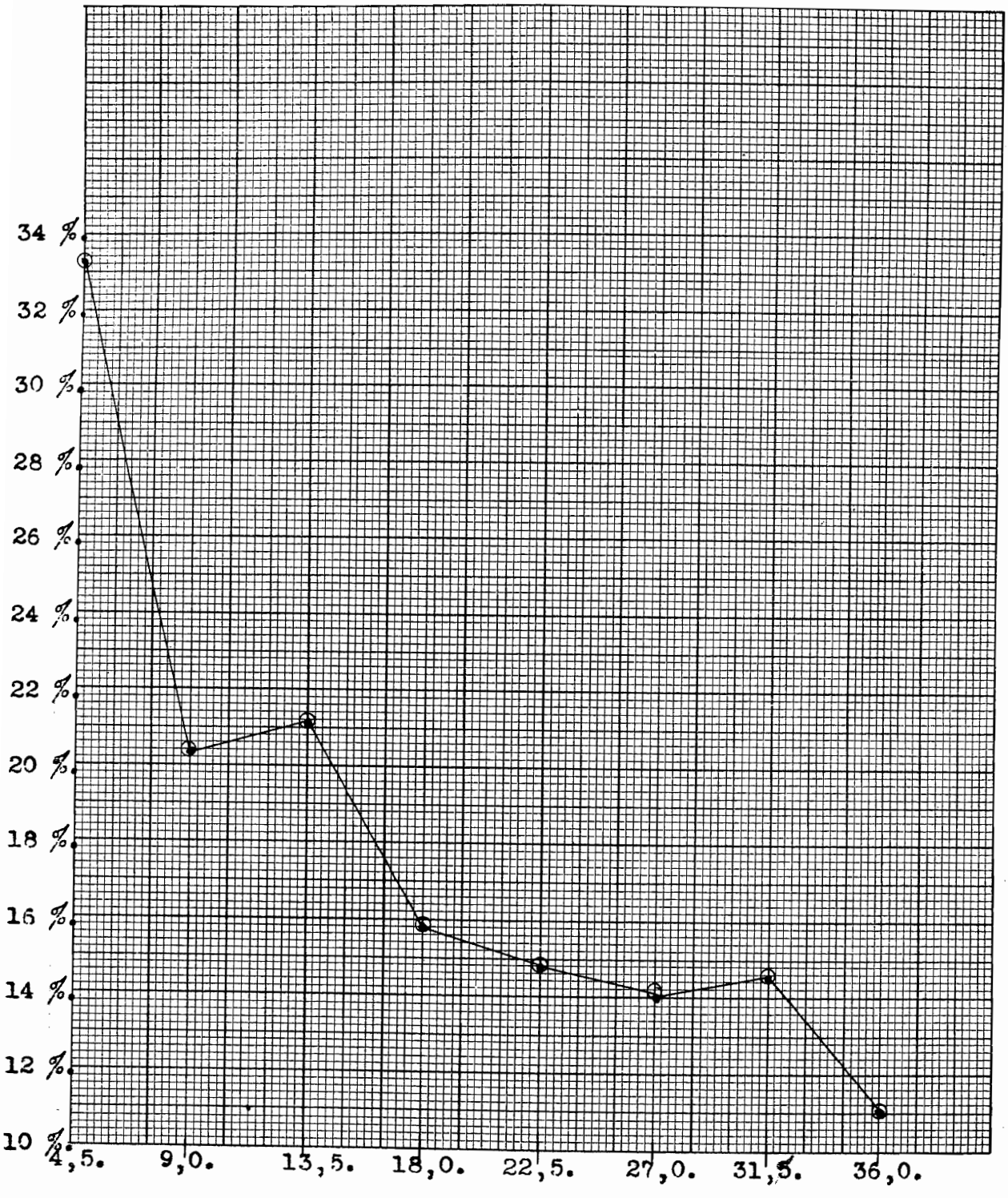
Vertical column:-Effe. Horizontal column:-Amp. pr sq/ft.



Effieiency-current density curve.

Strength of solution:-1 % $ZnSO_4$.

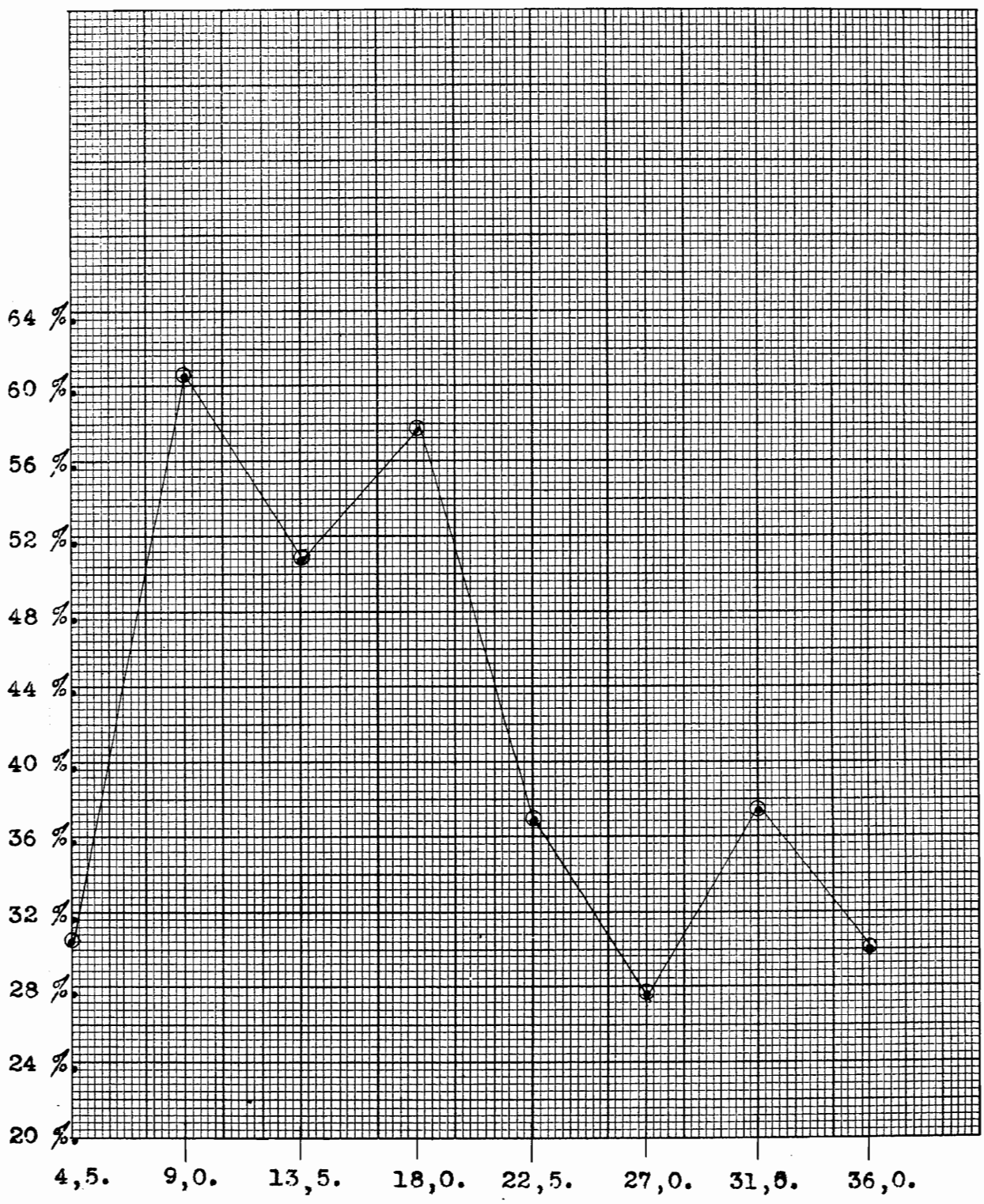
Vertical column:-Effe. Horizontal column:-Amp. pr sq/ft.



Efficiency-current density curve.

Strength of solution:-2 % $ZnSO_4$.

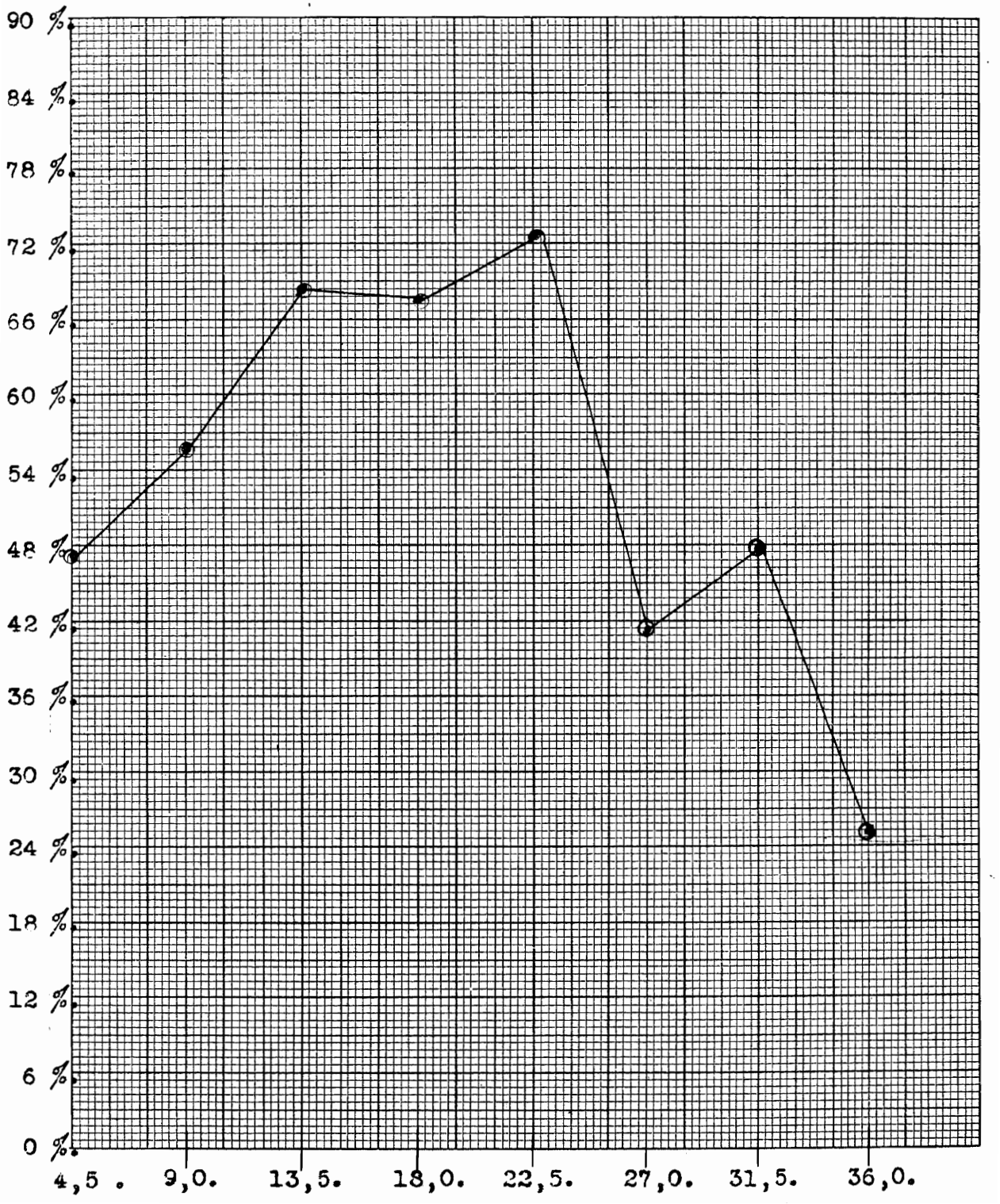
Vertical column:-Effe. Horizontal column:-Amp.pr sq/ft.



Efficiency-current density curve.

Strength of solution:-3 % $ZnSO_4$.

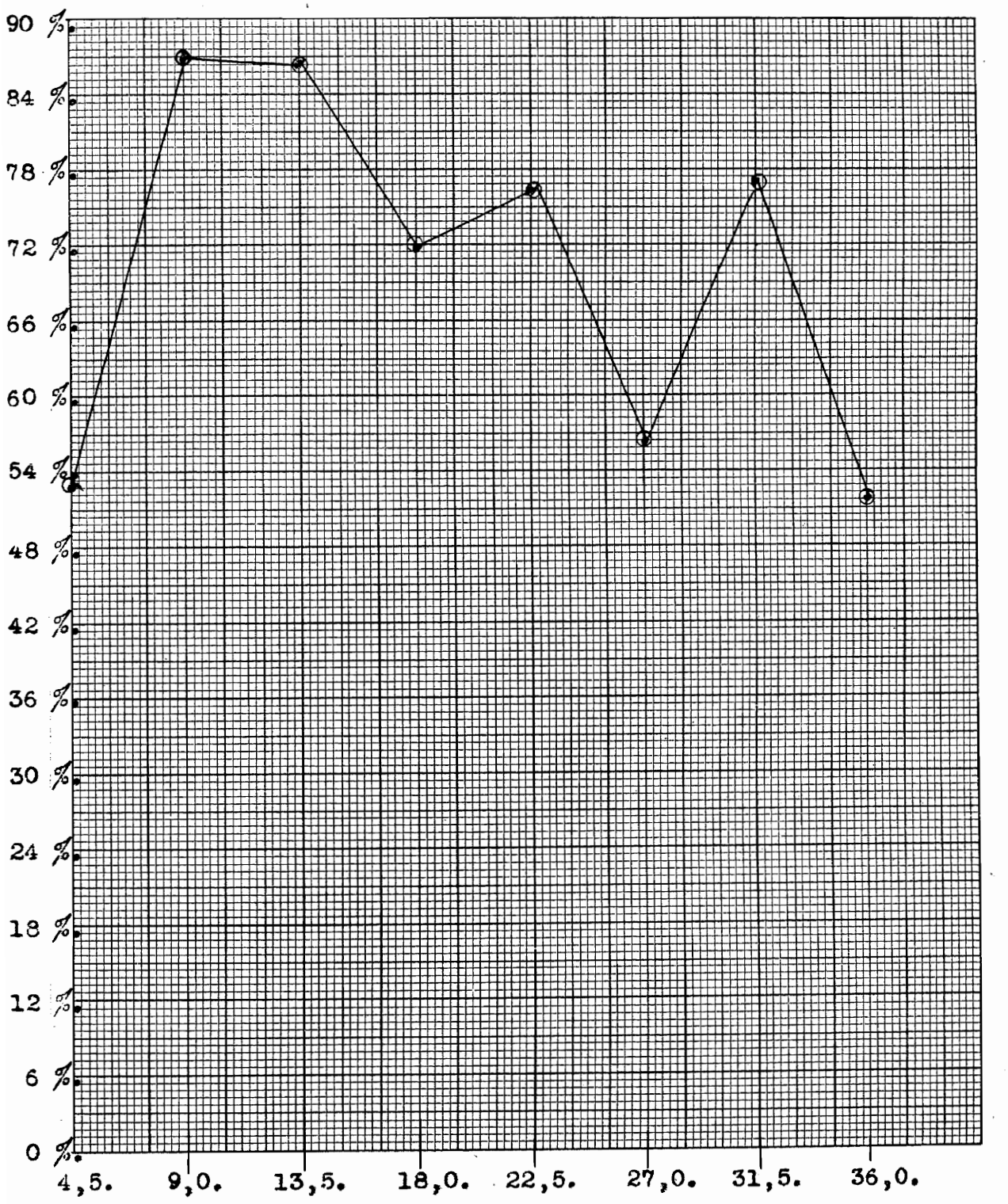
Vertical column:-Effe. Horizontal column:-Amp. pr sq/ft.



Efficiency-current density curve.

Strength of solution:-5 % $ZnSO_4$.

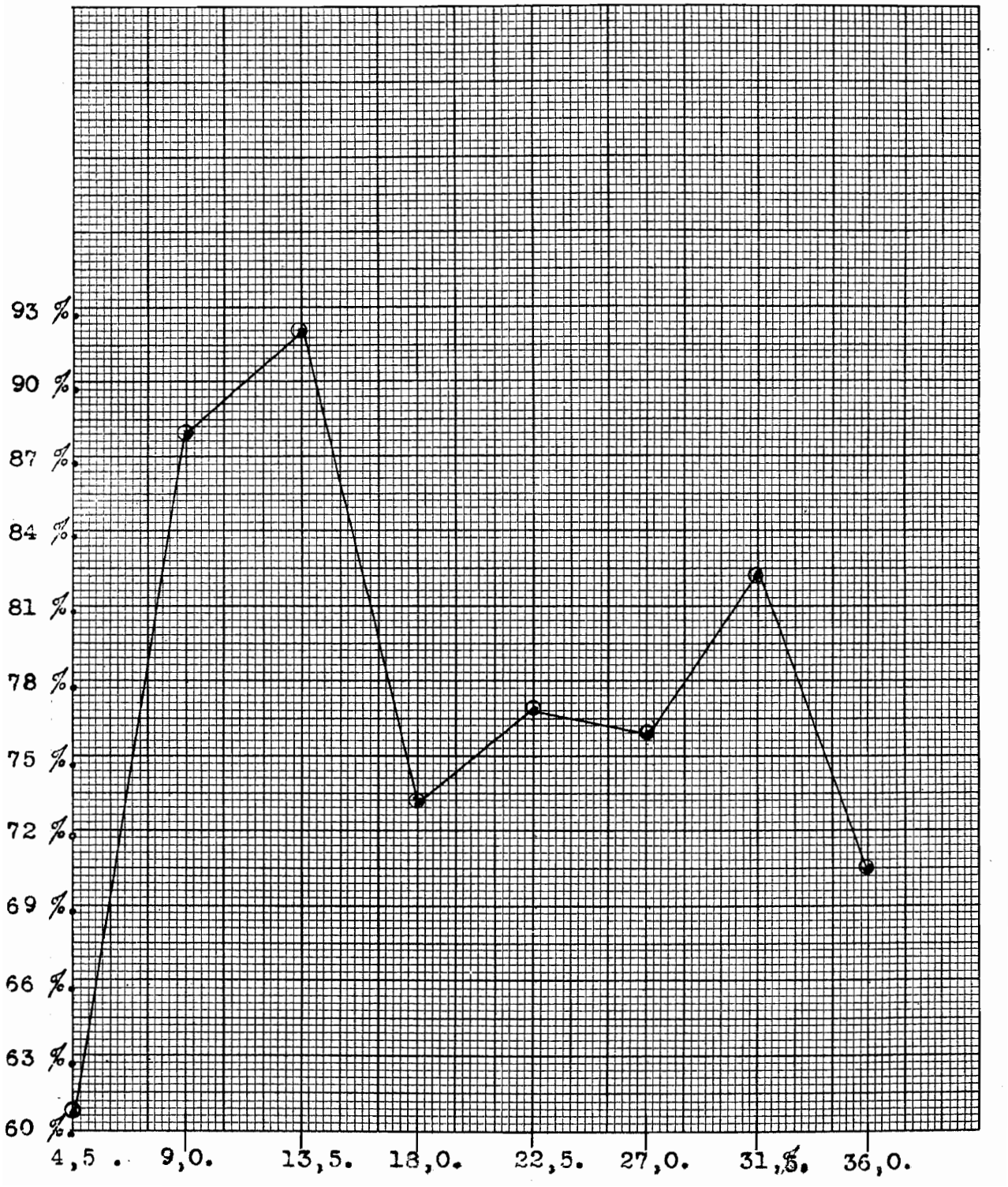
Vertical column:-Effe. Horizontal column:-Amp.pr sq/ft.



Efficiency-current density curve.

Strength of solution:-7,5 % $ZnSO_4$.

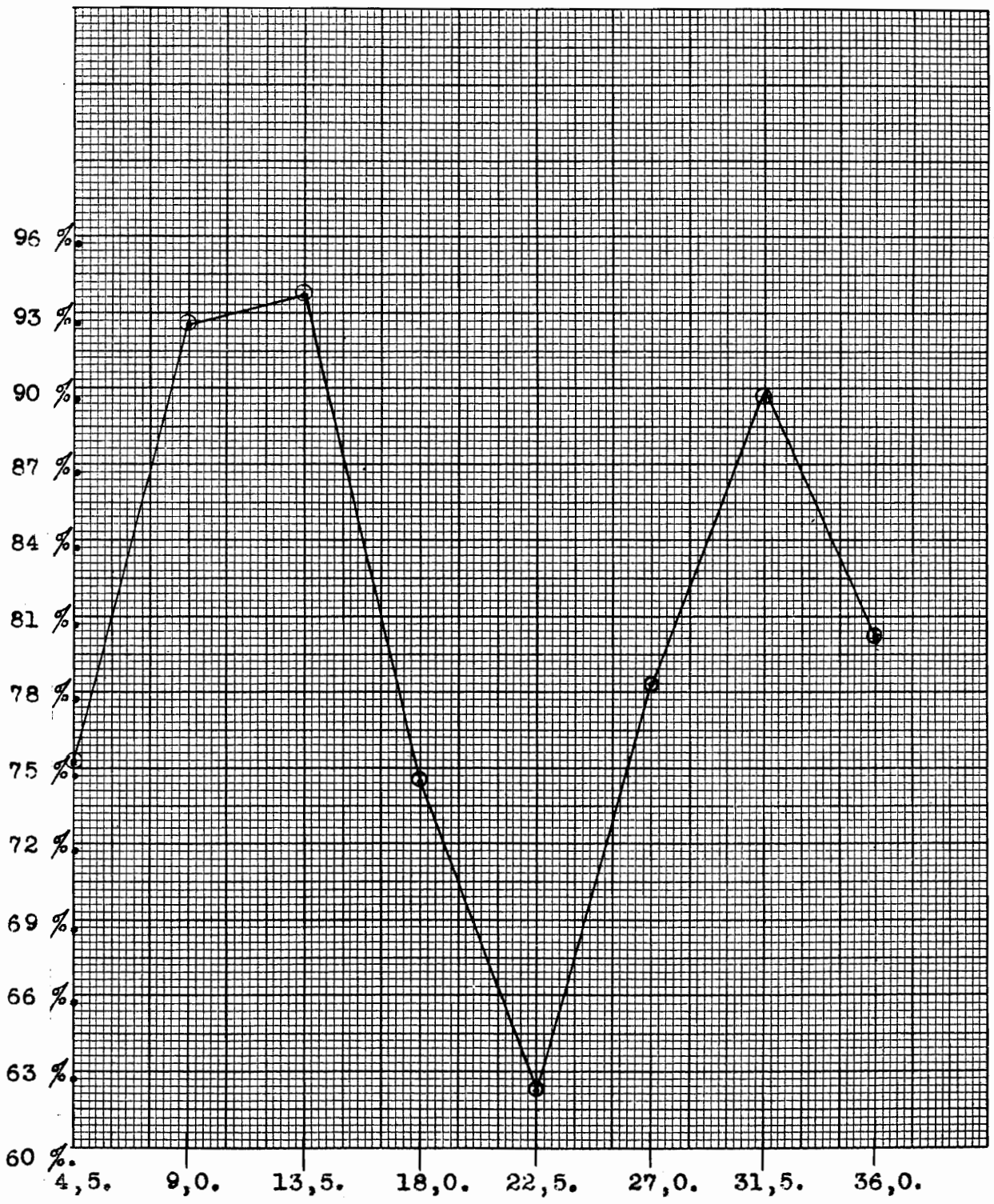
Vertical column:-Effe. Horizontal column:-Amp.pr sq/ft.



Efficiency-current density curve.

Strength of solution:-10 % $ZnSO_4$.

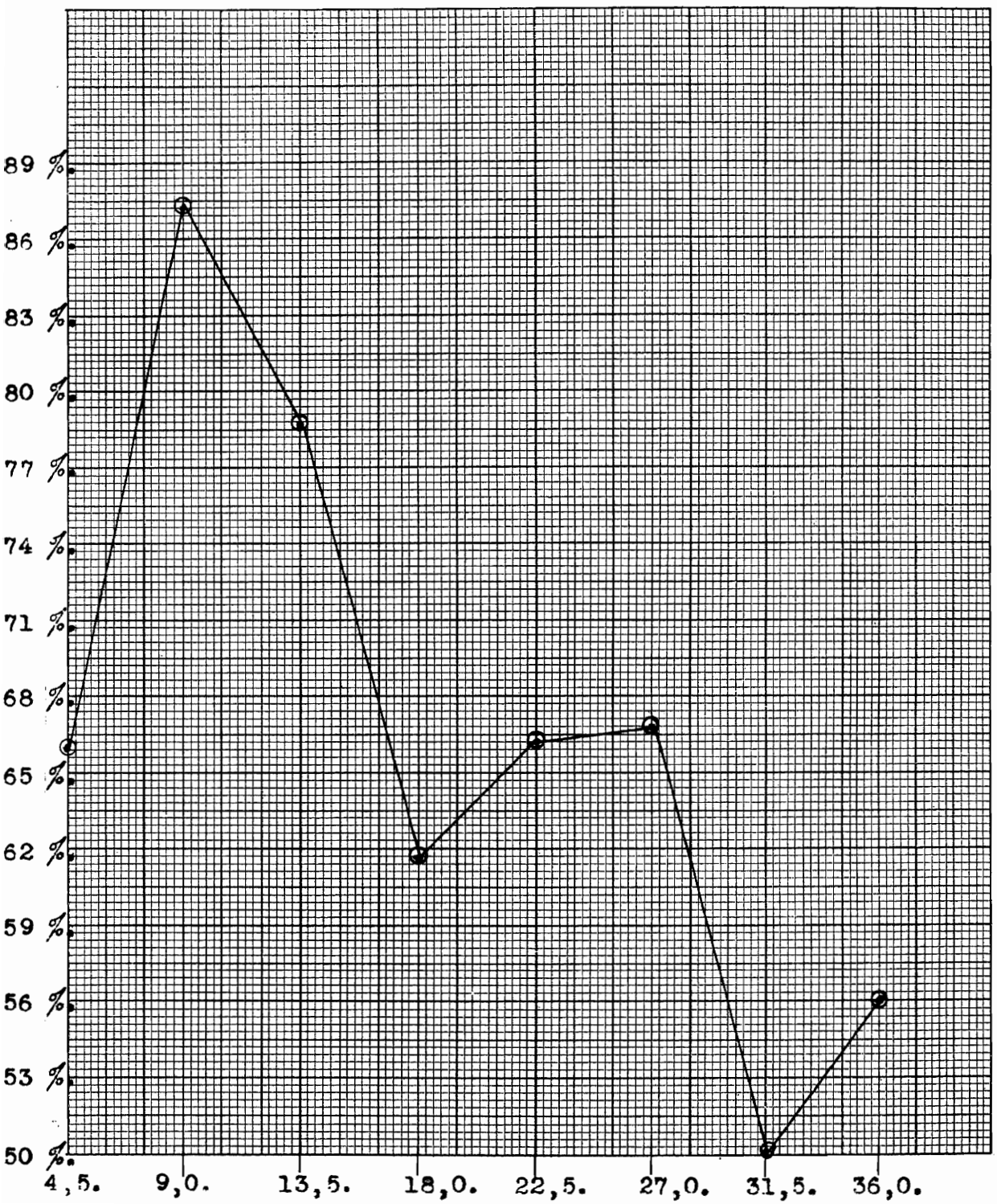
Vertical column:-Effc. Horizontal column:-Amp.pr sq/ft.



Efficiency-current density curve.

Strength of solution:-12,5 % $ZnSO_4$.

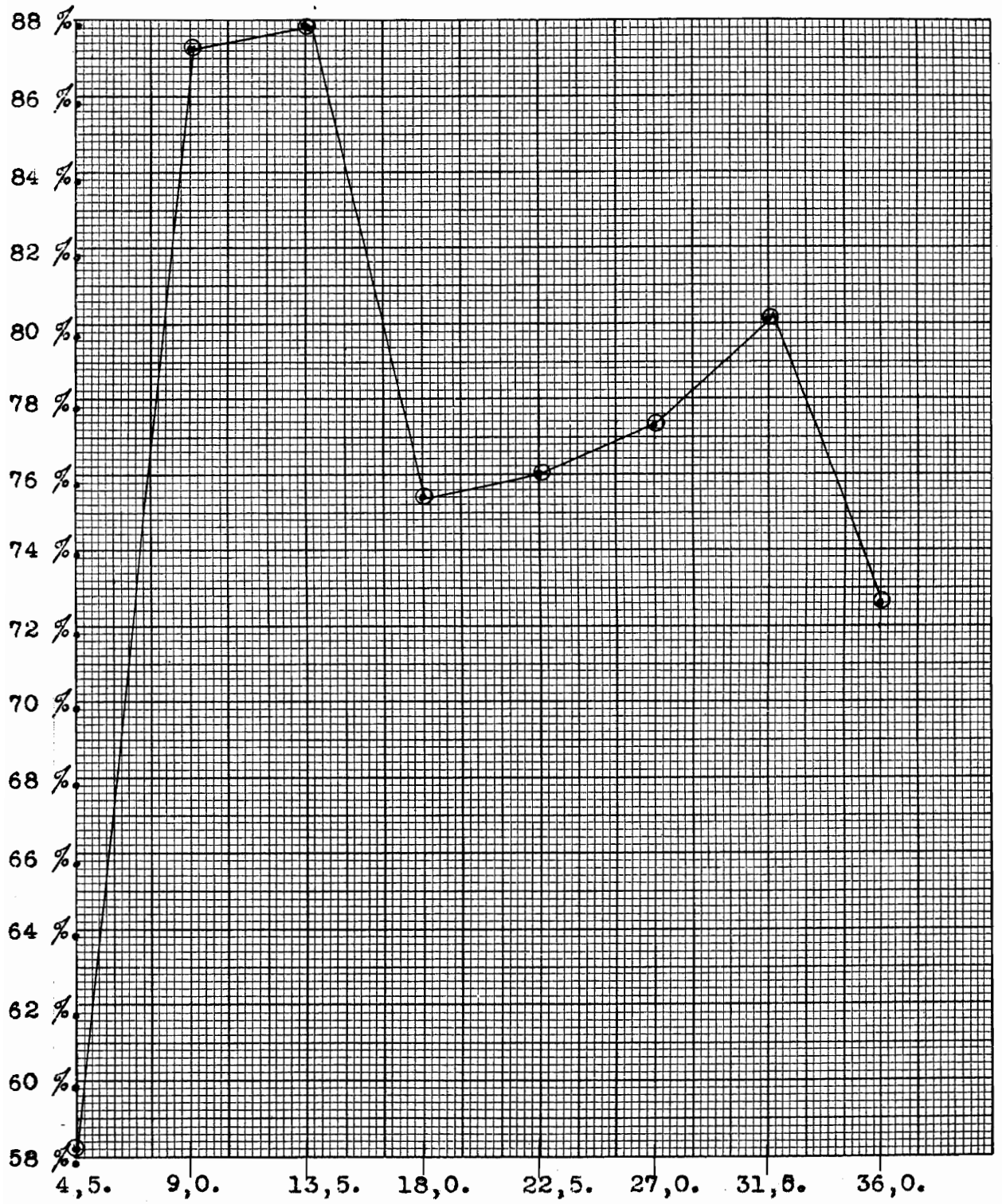
Vertical column:-Effe. Horizontal column:-Amp.pr sq/ft.



Efficiency-current density curve.

Strength of solution:-15 % $ZnSO_4$.

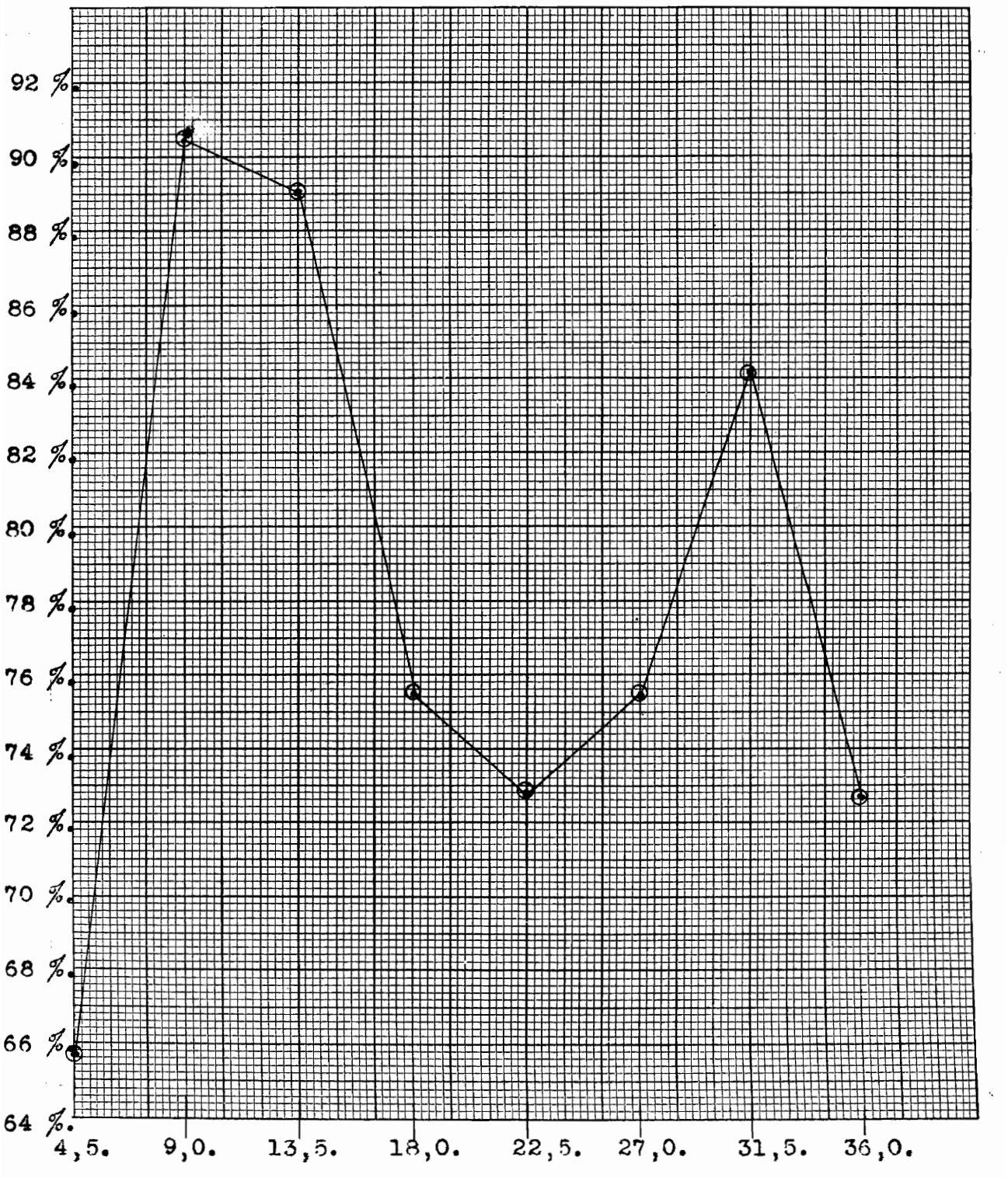
Vertical column:-Effc. Horizontal column:-Amp.pr sq/ft.



Efficiency-current density curve.

Strength of solution:)20 % $ZnSO_4$.

Vertical column:-Effe. Horizontal column:-Amp.pr sq/ft.



Conclusions and Remarks.

It will be noticed that in six cases out of eight the maximum efficiency is obtained with a 10 % $ZnSO_4$. solution. The highest efficiency(93,67 %) is gotten by using a current density of 13,5 and a 10 % $ZnSO_4$ solution. The lowest efficiency is in all cases but one obtained with a 1/4 % solution. It is an almost universal rule that the efficiency increases steadily from 1/4 to 10 % solutions. In every case a drop in the efficiency is found when using a 12,5 % solution. With still stronger solutions the efficiency again increases.

The very weak solutions(1/4 to 1 %)all give the best extractions with a current density of 4,5 amp. In regard to these solutions we notice a markable decrease in efficiency with a current density of 9,0 amp. Then follows an increase, and with still stronger currents the efficiency decreases correspondingly in almost every case. Concerning the weak solutions with much sprouting it should be kept in mind that the sprouts adhere so loosely that with exactly the same conditions probably not two results could be made to check each other exactly. The curves show, however, a remarkable similarity.

With solutions of 2 % $ZnSO_4$ and stronger we obtain a different set of curves. It is an almost universal rule that peaks are obtained on the curves with current densities ranging from 9,0 to 18 amps. In every case but one an increase in efficiency is obtained with a current density of 13,5 amp. With still higher current densities the efficiency again decreases.

In concluding, it should be repeated that the results given are at the best close approximations. The conditions were such that absolute accuracy could not be obtained. The chief difficulty was, as already stated, found in the fact that the current fluctuated. An accurate value for the current used was not obtained. In spite of the above mentioned difficulties it is the sincere belief of the author that results obtained under ideal conditions will vary only slightly from those given in the previous pages.