PART 1

CORROSION OF NICKEL ANODES

PART 2

DISTRIBUTION OF ELECTROLYTIC NICKEL ON A CATHODE

THESIS FOR THE DEGREE OF M. S.

GAYLORD C. SMITH

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Part I

Corrosion of Nickel Anodes

Part II

Distribution of Electrolytic Nickel

on a Cathode

A Thesis

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This research work was done in the Physical Chemical Laboratories at Michigan State College, under the direction of Dr. Dwight T. Ewing.

PART I

Anodic Corrosion Of Nickel Anodes

Aside from the work of Hogaboon (Metal Industry (New York) 27, 172, (1929), the literature does not seem to contain any systematic work on the study of the various factors effecting the electrolytic corrosion of nickel anodes. Hogaboon's work was confined largely to the study of various kinds of electrodes, especially as regards their crystal structure and other factors effected by the method of formation.

It is the purpose of this investigation to study the effects of the various factors, such as current density; addition agents; temperature and concentration. The addition agents were boric acid, sodium fluoride; sodium chloride; sodium citrate; magnesium sulfate and nickel chloride. Two different temperatures, two concentrations and five different current densities were used in this work.

The experimental procedure in this study was as follows: The anode was placed between two cathodes in the nickel solution. The current passed was measured with an ammeter and a timepiece. From this, the theoretical loss in weight of the anode was calculated. This was checked by comparison with the loss in weight of the nickel anode.

This method has several objections, some of which are: 1. The necessity to dry the anode after each run. This tends to oxidize or make passive the anode and so reduce the anodic efficiency of the process.

2. Considerable time is lost in waiting for the anode to dry.

3. The possibility of mechanical removal of particles from the anode by handling it.

The method of calculating the theoretical loss was as follows:

One coulomb of electricity is a current of one ampere flowing for one second.

96,500 coulombs are one Faraday.

One Faraday of current will liberate one equivalent weight in grams of a metal.

1 ampere hour is 1 X 60 X 60 = 3600 coulombs.

$96,500 \div 3600 = 26.805$

The equivalent weight of two valent nickel ions is the molecular weight divided by two $\frac{58.68}{2}$

Thus, 1 ampere hour $\frac{1}{26.805}$ of $\frac{58.68}{2} = 1.0948$ grams of nickel.

Thus a current of 1 ampere for 30 min = 1/2 X 1.0948 grams = .5474 grams of nickel.

The actual loss X 100 divided by the theoretical loss is recorded as the percent loss.

Data:

TABLE I

Solution, 125 g. $NiSO_4.7H_2O$ per liter

Addition Agent	Amt. of add. gms 1 liter	Temp.	Current density amp/dm²	% loss	Remarks
None	--	Room	.2	88.1	
"	"	"	.3	75.2	Some gassing at anode
"	"	"	.4	75.0	at anode
"	"	"	.5	72.4	
".	"	"	.6	85.6	Solution became acid

TABLE II

Solution, 125 g. $NiSO_4.7H_2O$ per liter

$NiCl_2.6H_2O$	15	"	.2	110.0	
"	"	"	.3	113.0	
"	"	."	.4	117.0	
"	"	"	.5		Solution
"	"	"	.6		Very acid
"	"	"	1.5	145.0	Ph - 5
"	28	"	.2	130.0	
"	"	"	.3	107.0	
"	"	"	.4	116.0	
"	"	"	.5	89.0	
"	"	"	.6	114.0	
"	"	"	1.0	93.0	
"	42.5	"	.2	98.0	
			.3	105.0	
			.4	110.0	Ph - 6
			.5	88.0	
			.6	93.0	

TABLE II (continued)

Addition Agent	Wt. of add. gms 1 liter	Temp	Current density amp/dm²	% loss	Remarks
$NiCl_2 \cdot 6H_2O$	[illegible]	Room	.2	102.0	
"	"	"	.3	114.0	
"	"	"	.4	112.0	
"	"	"	.5	105.0	
"	"	"	.6	111.0	
"	"	"	1.0	95.0	
"	97.8	"	.2	120.0	
"	"	"	.3	102.0	
"	"	"	.4	139.0	
"	"	"	.5	97.0	
"	"	"	.6	113.0	
"	"	"	1.0	119.0	

TABLE III

Solution, 125 g. 1 liter $NiSO_4.7H_2O$

Addition Agent	Amt. of add. gms 1 liter	Temp	Current Density amp/dm²	% loss	Remarks
NaF	1	Room	.2	98.0	
"	"	"	.3	116.0	
"	"	"	.4	103.0	
"	"	"	.5	109.0	
"	"	"	.6	99.0	
"	2	"	.2	108.0	
"	"	"	.3	131.0	
"	"	"	.4	93.0	
"	"	"	.5	97.0	
"	"	"	.6	93.0	
"	3	"	.2	110.0	
"	"	"	.3	108.0	
"	"	"	.4	100.0	
"	3	"	.5	98.0	
"	"	"	.6	83.0	
"	5	"	.2	94.0	
"	"	"	.3	87.0	Could not destroy oxide film. O_2 given off.
"	"	"	.4	16.0	
"	"	"	.5	73.0	
"	"	"	.6	10.0	
"	10	"	.2	16.0	
"	"	"	.3	5.0	O_2 given off
"	"	"	.4	14.0	
"	"	"	.5	13.0	
"	"	"	.6	--	

TABLE IV

Solution 125 g. 1 liter $NiSO_4.7H_2O$

Addition Agent	Amt. of add. gms 1 liter	Temp	Current density amp/dm²	% loss	Remarks
H_3BO_3	15	Room	.2	37.1	
"	"	100°F	.2	71.6	
"	"	Room	.3	11.6	
"	"	100°F	.3	51.0	
"	"	Room	.4	21.0	
"	"	100°F	.4	44.0	
"	"	Room	.5	1.0	
"	"	100°F	.5	44.0	Solutions were acid
"	"	Room	.6	9.0	
"	"	100°F	.6	29.0	
"	20	Room	.2	92.0	
"	"	100°F	.2	91.0	
"	"	Room	.3	8.0	
		100°F	.3	13.0	
		Room	.4	33.0	Anode dipped in HCl
		100°F	.4	31.0	
		Room	.5	15.0	
		100°F	.5	17.0	
		Room	1.0	8.0	
		100°F	1.0	4.0	
	30	Room	.2	108.0	
		100°F	.2	108.0	
		Room	.4	11.0	
		100°F	.4	21.0	
		Room	1.0	9.0	
		100°F	1.0	8.0	

TABLE V

Solution 125 g. 1 liter $NiSO_4.7H_2O$

Addition Agent	Amt. of add. gms 1 liter	Temp	Current density amp/dm²	% lost	Remarks
NaCl	5	Room	.2	115.0	
		100°F	.2	115.0	
		Room	.3	111.0	
		100°F	.3	111.0	
		Room	.4	95.0	
		100°F	.4	96.0	
		Room	.5	124.0	
		100°F	.5	117.0	
		Room	.6	112.0	
		100°F	.6	115.0	
NaCl	5	Room	1.0	110.0	
		100°F	1.0	108.0	
	10	Room	.2	129.0	
		100°F	.2	136.0	
		Room	.4	97.0	
		100°F	.4	103.0	
		Room	.5	105.0	
		100°F	.5	106.0	
		Room	.6	100.0	
		100°F	.6	103.0	
	15	Room	.2	108.0	
		100°F	.2	119.0	
		Room	.4	109.0	
		100°F	.4	110.0	
		Room	.5	-	
		100°F	.5	-	

TABLE V (continued)

Addition Agent	Amt. of add. gms 1 liter	Temp	Current density amp/dm²	% loss	Remarks
		Room	.8	107.0	
		100°F	.8	101.0	
		Room	1.0	144.0	
		100°F	1.0	107.0	
	20	Room	.2	96.0	
		100°F	.2	106.0	
		Room	.5	95.0	
		100°F	.5	105.0	
		Room	.6	92.8	
		100°F	.6	93.1	

TABLE VI

Solution 125 g. 1 liter $NiSO_4.7H_2O$

$MgSO_4$	5	Room	.2	81.0	
		100°F	.2	95.0	
		Room	.3	70.0	
		100°F	.3	97.0	
		Room	.4	67.0	
		100°F	.4	100.0	
		Room	.5	52.0	
		100°F	.5	106.0	
		Room	.6	45.0	
		100°F	.6	111.0	
	10	Room	.2	86.0	
		100°F	.2	98.0	
		Room	.4	76.0	
		100°F	.4	90.0	
		Room	.5	28.0	
		100°F	.5	69.0	
		Room	1.0	12.0	
		100°F	1.0	64.0	

TABLE VI (continued)

Addition Agent	Wt. of add. gms 1 liter	Temp	Current density amp/dm²	% loss	Remarks
	20	Room	.5	82.0	
		100°F	.3	95.0	
		Room	.4	26.0	
		100°F	.4	88.0	
		Room	.6	35.0	
		100°F	.6	68.0	
		Room	1.0	15.0	
		100°F	1.0	76.0	
$MgSO_4$	25	Room	.2	95.0	
		100°F	.2	112.0	
		Room	.3	56.0	
		100°F	.3	97.0	
		Room	.4	38.0	
		100°F	.4	60.0	
		Room	.5	59.0	
		100°F	.5	88.0	
		Room	.6	52.0	
		100°F	.6	53.0	
		Room	1.0	10.0	
		100°F	1.0	35.0	
$MgSO_4$	30	Room	.3	100.0	
		100°F	.3	85.0	
		Room	.4	7.0	
		100°F	.4	79.0	
		Room	.5	10.0	
		100°F	.5	25.0	
		Room	.6	14.0	

TABLE VII

Solution 125 g. 1 liter $NiSO_4 . 7H_2O$

Addition Agent	Amt. of add. gms 1 liter	Temp	Current density amp/dm²	% loss	Remarks
Na citrate $2Na_3C_6H_5O_7 . 11H_2O$	10	Room	.2	52.0	
		100°F	.2	71.0	
		Room	.3	18.0	
		100°F	.3	73.0	
		Room	.4	17.0	
		100°F	.4	66.0	
		Room	.5	6.0	
		100°F	.5	68.0	
		Room	1.0	5.0	
		100°F	1.0	18.0	
	20	Room	.2	39.0	
		100°F	.2	62.0	
		Room	.4	17.0	
		100°F	.4	53.0	
		Room	.5	13.0	
		100°F	.5	57.0	
		Room	.6	16.0	
		100°F	.6	65.0	
		Room	1.0	9.0	
		100°F	1.0	39.0	
	30	Room	.3	35.0	
		100°F	.3	46.0	
		Room	.5	13.0	
		100°F	.5	44.0	
		Room	.6	19.0	
		100°F	.6	48.0	

TABLE VII (continued)

Addition Agent	Amt. of addn. gms 1 liter	Temp	Current density amp/dm²	% loss	Remarks
		Room	1.0	6.0	
		100°F	1.0	49.0	
		Room			
		100°F			
		Room			
		100°F			

It was desired to keep out all double nickel salts so that no test of NH_4Cl was run. It would probably be as efficient as $NaCl$ and $NiCl_2 \cdot 6H_2O$, as it seems to be the anion that effects the corrosion.

It was noticed that even though a concentration of fluorine ions did not appreciably aid the corrosion, that they did tend to keep sludge from settling out of the bath. This and the interest in high temperature nickel deposition lead to some experiments on the anodic corrosion in hot nickel baths containing both chlorine and fluorine in an endeavor to obtain good anodic corrosion and at the same time to keep a clear solution. Upon trying this, it was noted that a brighter deposit of nickel was obtained.

A higher concentration of nickel was used because of the high current densities that were to be used at the higher temperatures.

TABLE VIII

Solution 250 g. 1 liter $NiSO_4.7H_2O$

Addition Agent	Amt. of add. gms 1 liter	Temp	C.D. amps/dm²	Gloss	Remarks
-	-	120°	1	[illegible]	
		120°	2	7.0	
NaF	2.5	120°	1	120.0	
			2	117.0	
			3	76.0	
			4	81.0	
			6	79.0	
			8	75.0	
		150°T	5	125.0	Corrosion
			10	100.0	Uneven
NaF	15	120°	2	115.0	
		120	3	83.0	O_2 given off anode turned black
		120	4	82.0	
		150°T	5	107.0	
		150°	6	111.0	
		150°	8	97.0	
		150°	10	91.0	
NaF	22.5	150°	2	111.0	
		150°	4	86.0	
		150°	5	70.0	
		150°	10	90.0	
NaF	30	150°	2	116.0	
		150°	3	82.0	
		150°	4	85.0	
		150°	5	50.0	
		150°	10	57.0	

TABLE VIII (continued)

Addition Agent	Amt. of add. gms 1 liter	Temp	C.D. amps/dm²	% Loss	Remarks
$NiCl_2 \cdot 6H_2O$ NaF	15 5	130°	10	100	
"	"	1[illegible]0	15	100	
$NiCl_2 \cdot 6H_2O$ NaF	15 10	120°	10	good	
$NiCl_2 \cdot 6H_2O$ NaF	22.5 10	150°	5	"	corroded under film
		150°	10	"	
$NiCl_2 \cdot 6H_2O$ NaF H_3BO_3	22.5 10 7.5	150°	10	"	corroded uneven with discoloration but not as much film as without boric acid.

CONCLUSIONS

The chlorine ion when used alone is the only addition agent tested that materially aids anodic corrosion. Small concentrations of the fluoride ion is advantageous, but looses it's beneficial properties as the concentration is increased. It also aids in keeping a clear solution and has a tendency to give a brighter deposit on the cathode. Increase of temperature aids anodic corrosion. Corrosion is better at low than at high current densities.

It is not efficient to use nickel anodes at a higher current density than two amperes per square decimeter because of the waste of metal due to mechanical losses caused by uneven corrosion. There was in many cases a noticeable loss due to this effect not shown in these results because of careful handling.

Magnesium sulfate, sodium citrate and boric acid did not seem to effect the anode corrosion.

Good results can be obtained by using both chlorine and fluorine in the solution if too much fluorine is not used.

PART II

Distribution of Electrolytic Nickel on a Cathode

It is known that under ordinary plating conditions the deposited metal is not exactly uniform in thickness. The plate has a decided tendency to be thickest near the edges. Upon observing an anode of rolled nickel it is also apparent that the corrosion is fastest near the bottom and at the edges. These conditions indicate that the current does not exactly follow the resistance rule, but that it seems to go largely from the edges to the edges.

The object of this study is to determine the magnitude of this effect and the factors which cause it. To do this it was necessary to obtain a method by which the plate could be studied. The only satisfactory method for this is to remove the deposit of nickel as a sheet from the plate upon which it was formed. Considerable difficulty was encountered in doing this.

Several Government patents have been taken out for this process, but none seemed entirely satisfactory. Most called for a preliminary deposition of copper or some other metal which was then electrodeposited with nickel. The copper was then dissolved. These methods were not desirable because of the time element, and the fact that the solvents slightly attacked the nickel. A method of treating the surface for plating with selenious acid was not tried. It is well known that nickel will not adhere well to an oiled surface, or to a previous deposit of electrolytic nickel.

Due to the above facts it was decided to use an oiled panel to deposit the nickel onto. A small amount of sodium oleate was dissolved in benzene. The panel was then rubbed over with a cheese cloth, dampened with this solution and then allowed to dry. The deposits peeled well enough but were filled with pin holes, so that this method was discarded.

There was available in the laboratory several panels of sheet steel, eight inches by twelve inches which were nickel plated and polished last year by Mr. J. E. Archer. It was decided to use these. They were first cleaned for a few seconds in an alkaline electrolytic cleaner, then dipped into a dip of dilute hydrochloric acid, then back into the hot alkali, then rinsed in cold water and hung on the cathode bar of the nickel plating tank. Current was passed at the rate of thirty amperes for one hour. The panel was then removed, rinsed in cold and hot water and air dried. By taking a light hammer and tapping the edges of the plate it was found that the deposited nickel parted easily from the previous nickel deposit. By this method plates could be produced which were free from pin holes. Considerable care must be taken not to get the panel too clean or the deposit could not be removed. If too much oil or grease is left on the panel, the deposit would have pin holes or would crack and curl while still in the nickel tank. After a few trials one can judge the cleaning rather closely.

The first anodes used were hot rolled 98-99% nickel. Screen anodes were made by depositing electrolytic nickel on sixteen mesh copper screen. Copper screen was first chosen instead of steel screen because it was thought that the conductivity would be higher. This did not produce desirable results. The nickel corroded unevenly, holes developing into the plate and reaching the copper screen. The copper then went into solution much easier than the electrolytic nickel. Before this was noticed the copper was largely into the solution and the screen anodes crumbled to pieces. Two days were then spent in removing the copper from the bath by working it intermittently and leaving the cathodes in place. Copper would deposit the nickel cathodes by electromotive series displacement. Then another layer of nickel was deposited over the copper by electrolysis and the process repeated. The anodes were removed at night and the bars were hung full of nickel foil which had been made by peeling plate from the panels used in the experiment. The second night no copper was deposited onto the foils.

Because copper screen was not found satisfactory it was decided that steel screen should be used. Only steel screen protected with zinc was available. The zinc was removed by hydrochloric acid which at the same time cleaned the steel wires. The screen was then rinsed in cold water and hung on the cathode bar where it was plated for two days. This gave a very heavy deposit of nickel and was used for the remainder of the experiment. Any iron that found its way into solution would be of little harm because it would mostly hydrolyze and settle to the bottom of the tank in the mud.

The conditions most likely to effect the character of the deposit were believed to be the electrode distance, the shape of the anodes, and moving and still cathodes.

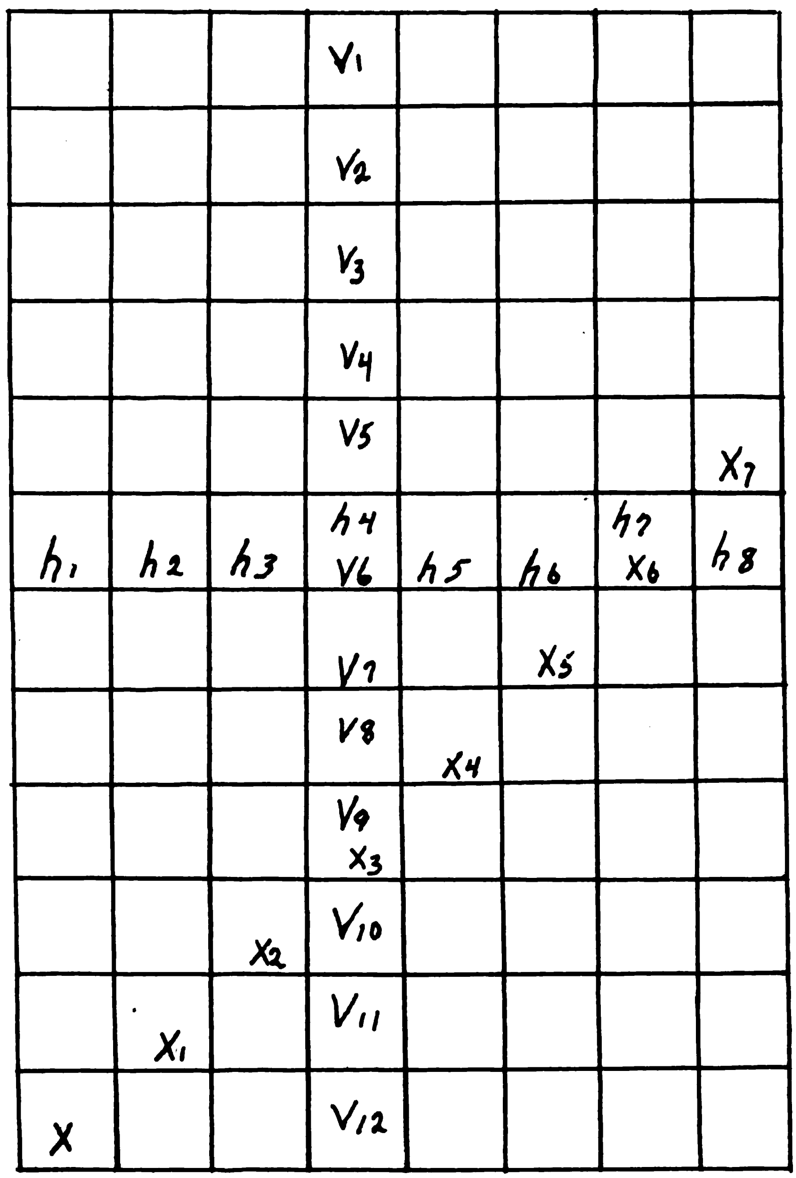
All runs were made at about the same current density on the cathode. Electrode distances of seven inches, four inches and one inch were used with both rolled and screen anodes.

The nickel solution used was one made up by Mr. J. L. Archer last year. It contained single nickel salts,- $NiSO_4.7H_2O$ - about 40 oz. per gallon; nickel chloride, - $NiCl_2.6H_2O$ - about 6 oz. per gal.; and boric acid,- H_3BO_3 - 3-5 oz. per gallon. This was found to work best at a temperature of 110°F - 120°F and at a pH of 6.0. The cathode current density was [illegible].5 amperes/sq.ft.

It was found to work well with the rolled anodes but frequent small additions of concentrated NH_4OH solution were found necessary when the electrolytic nickel screen anodes were used.

When the deposits were produced and pickled as above described they were marked off into square inches and lettered as shown in the diagram.

The lettered sections were cut out with shears


V1
V2
V3
V4
V5
X7
h4
h7
h1
h2
h3
V6
h5
h6
X6
h8
V7
X5
V8
X4
V9
X3
V10
X2
V11
X1
V12
X

as carefully as possible and weighed. The thickness of these sections was measured with micrometers reading in thousandths of inches. Four panels were run as a check in most cases. The weights are in grams, and the thickness in inches.

DATA TABULATED

TABLE I

Anodes: hot rolled 98-99% nickel Amperes: 50
Temperature: 110°-120°F pH: 6.0
Voltage: 3.4 volts Time: 1 hour

Electrode distance 7 inches

Section	Panel No.1 Weight	Panel No.1 Thickness	Panel No.2 Weight	Panel No.2 Thickness	Panel No.3 Weight	Panel No.3 Thickness	Panel No. 4 Weight	Panel No. 4 Thickness	Average Wt.	Average Thick
H	.379	.002-.005	.417	.002-.005	.345	.0015-.005	.419	.005-.0015	.390	.002-.005
H1	.140	.0012-.0015	.150	.0015	.134	.0014	.164	.0014	.147	.0014
H2	.118	.001	.122	.001	.105	.0008	.126	.001	.119	.001
H3	.113	.001	.116	.001	.096	.0008	.127	.001	.114	.001
H4	.113	.001	.116	.001	.096	.0008	.124	.001	.114	.001
H5	.113	.001	.118	.001	.105	.0008	.133	.001	.117	.001
H6	.133	.0015	.134	.0015	.114	.001	.144	.0014	.132	.0012
H7	.230	.0015-.005	.230	.0015-.005	.211	.002	.275	.0015-.005	.246	.005.-.0015
h1	.250	.005-.0015	.249	.005-.0015	.238	.005-.0015	.238	.005-.0015	.247	.005-.0015
h2	.136	.0015	.137	.0015	.122	.0014	.143	.0014	.137	.0015
h3	.112	.0012	.120	.001	.112	.001	.126	.001	.117	.001
h4	.112	.001	.115	.001	.100	.0008	.122	.001	.112	.001
h5	.112	.001	.115	.001	.100	.0008	.123	.001	.112	.001
h6	.119	.001	.118	.001	.103	.0008	.128	.001	.117	.001
h7	.133	.0015	.134	.0013	.114	.001	.144	.0015	.131	.0015
h8	.243	.0015-.005	.235	.0015-.005	.211	.002	.275	.0015-.005	.243	.0015-.005
V1	.224	.005-.0015	.220	.005-.0015	.196	.001-.005 (212)		.0015-.005	.220	.005.-
V2	.124	.0012	.120	.0012	.115	.001	.139	.0013	.123	.0012
V3	.119	.001	.117	.001	.100	.0008	.129	.001	.116	.001
V4	.118	.001	.118	.001	.096	.0008	.127	.001	.115	.001
V5	.115	.001	.113	.001	.092	.0008	.124	.001	.115	.001
V6	.118	.001	.117	.001	.100	.0008	.124	.001	.115	.001
V7	.112	.001	.115	.001	.098	.0008	.122	.001	.112	.001
V8	.112	.001	.115	.001	.098	.0008	.126	.001	.112	.001
V9	.113	.001	.113	.001	.096	.0008	.124	.001	.115	.001
V10	.127	.001	.119	.001	.097	.0008	.126	.001	.118	.001
V11	.133	.0012	.139	.0012	.117	.001	.141	.0015	.136	.0012
V12	.222	.0015-.005	.220	.0015-.005	.197	.001-.005	.243	.002-.005	.222	.0015-.005

DATA TABULATED

TABLE II

Anodes: electrolytic nickel screen
Temperature: 110°-120°F
Voltage: 5.4 volts

Amperes: 30
pH: 6.0
Time: 1 hour

Electrode distance 7 inches

Section	Panel No. 1 Weight	Panel No. 1 Thickness	Panel No. 2 Weight	Panel No. 2 Thickness	Panel No. 3 Weight	Panel No. 3 Thickness	Panel No. 4 Weight	Panel No. 4 Thickness	Average Wt.	Average Thickness
X	.276	.005-.0015	.224	.005-.001	.302	.005-.001	.315	.005-.0015	.278	.005-.001+
X_1	.118	.001	.101	.001	.119	.001	.143	.001	.120	.001
X_2	.090	.0008	.090	.0008	.082	.0008	.109	.001-	.092	.0008
X_3	.088	.0008	.080	.0006	.088	.0008	.091	.0008	.087	.0008
X_4	.090	.0008	.080	.0006	.088	.0008	.088	.0008	.087	.0008
X_5	.092	.0008	.085	.0006	.088	.0008	.090	.0008	.088	.0008
X_6	.107	.001	.090	.0008	.110	.001	.103	.0008	.102	.0009
X_7	.185	.0012-.004	.169	.001-.004	.200	.001-.004	.203	.001-.004	.188	.001-.004
h_1	.184	.004-.001	.173	.004-.001-	(.230)	.003-.001	.180		.179	.003-.001
h_2	.101	.001	.089	.0008	.110	.001-	.091	.0008	.098	.001-
h_3	.092	.0008	.08	.0006	.089	.0008	.085	.0008	.088	.0008
h_4	.092	.0008	.08	.0006	.088	.0008	.085	.0008	.086	.0008
h_5	.089	.0008	.081	.0006	.088	.0008	.085	.0008	.086	.0008
h_6	.092	.0008	.085	.0006	.088	.0008	.090	.0008	.088	.0008
h_7	.107	.001-	.090	.0008	.110	.001-	.104	.001-	.102	.001-
h_8	.183	.001-.005	lost		lost		lost		.180	.001-.005
V_1			.136	.004-.0008	.173	.004-.001			.154	.004-.001
V_2	.094	.0008	.085	.0008	.091	.0008	.090	.0008	.089	.0008
V_3	.090	.0008	.080	.0006	.089	.0008	.086	.0008	.086	.0008
V_4	.089	.0008	.080	.0006	.088	.0008	.083	.0006	.085	.0008
V_5	.088	.0008	.080	.0006	.088	.0008	.083	.0006	.085	.0008
V_6	.092	.0008	.080	.0006	.088	.0008	.083	.0006	.086	.0008
V_7	.090	.0008	.081	.0006	.088	.0008	.084	.0008	.086	.0008
V_8	.090	.0008	.080	.0006	.088	.0008	.088	.0008	.087	.0008
V_9	.088	.0008	.080	.0008	.096	.0008	.091	.0008	.088	.0008
V_{10}	.090	.0008	.092	.0008	.112	.001	.105	.001-	.099	.0008
V_{11}	.105	.001-	.094	.0008	.122	.001	.119	.001	.110	.001
V_{12}	.135	.001-.004	.189	.001-.004	.222	.001-.005	.208	.001-.005	.189	.001-.004+

DATA TABULATED

TABLE III

Anodes: hot rolled - 98-99% nickel
Temperature: 110°-120°F
Voltage: 3.2 volts

Amperes: 30-40
pH: 6.0
Time: 1 hour

Electrode distance: 4 inches

Section	Panel No. 1 Weight	Panel No. 1 Thickness	Panel No. 2 Weight	Panel No. 2 Thickness	Panel No. 3 Weight	Panel No. 3 Thickness	Average Weight	Average Thickness
X	.410	.003-.0015	[illegible]	.003-.0015	.404	.003-.002	[illegible]	.003-.002
X_1	.170	.0014	.143	.0012	.133	.0015	.157	.0015
X_2	.141	.0012	.122	.001	.135	.0012	.133	.0012
X_3	.135	.0012	.110	.0008	.136	.0012	.136	.0012
X_4	.135	.0012	.106	.0008	.135	.0012	.135	.0012
X_5	.133	.0012	.108	.0008	.136	.0012	.136	.0012
X_6	.130	.0012	.125	.001	.140	.0012+	.145	.0015
X_7	.270	.0015-.005	.200	.001-.004	.223	.0015-.005	.247	.0015-.005
h_1	.286	.003-.0015	.211	.003-.001	.271	.003-.0015	.278	.003-.0015
h_2	.130	.0015	.120	.001	.132	.0015	.136	.0015
h_3	.133	.0012	.108	.0008	.132	.0012	.134	.0012
h_4	.134	.0012	.102	.0008	.131	.0012	.133	.0012
h_5	.135	.0012	.107	.0008	.132	.0012	.133	.0012
h_6	.136	.0012	.105	.0008	.134	.0012	.133	.0012
h_7	.132	.0015	.123	.001	.140	.0014	.143	.0014
h_8	.272	.0015-.005	.200	.001-.004	.223	.0015-.005	.247	.0015-.005
V_1	.218	.003±-.0015					.218?	.003-.0015
V_2	.130	.0015	.120	.001	.134	.0015	.132	.0015
V_3	.136	.0012	.100	.0008	.135	.0012	.136	.0012
V_4	.134	.0012	.102	.0008	.135	.0012	.135	.0012
V_5	.135	.0012	.104	.0008	.135	.0012	.133	.0012
V_6	.135	.0012	.102	.0008	.131	.0012	.133	.0012
V_7	.134	.0012	.102	.0008	.132	.0012	.133	.0012
V_8	.133	.0012	.106	.0008	.135	.0012	.135	.0012
V_9	.135	.0012	.110	.0008	.133	.0012	.135	.0012
V_{10}	.136	.0012	.109	.0008	.135	.0012	.135	.0012
V_{11}	.140	.0014	.124	.001	.130	.0015	.130	.0015
V_{12}	.237	.0015-.005	.192	.001-.004	.228	.0015-.005	.247	.0015-.005

DATA TABULATED

TABLE IV

Anodes: electrolytic nickel on copper screen
Temperature: 110°-120°F
Amperes: 30

Voltage: 3 volts
pH: 6.0
Time: 1 hour

Electrode distance : 4 inches

Section	Panel No. 1 Weight	Panel No. 1 Thickness	Panel No. 2 Weight	Panel No. 2 Thickness	Panel No. 3 Weight	Panel No. 3 Thickness	Panel No. 4 Weight	Panel No. 4 Thickness	Average Wt.	Average Thickness
X	.302	.007-.0015	.250	.005-.0012	.277	.005-.0015	.244	.005-.0015	.251	.005-.0015
X_1	.132	.0015	.124	.001	.143	.0014	.134	.001	.133	.001
X_2	.131	.001	.095	.0006	.122	.001	.117	.001	.116	.001-
X_3	.135	.001	.094	.0006	.115	.0008	.110	.0008	.113	.0008
X_4	.135	.001	.095	.0006	.118	.0008	.110	.0008	.114	.0008
X_5	.135	.001	.095	.0006	.130	.001	.104	.0008	.116	.001-
X_6	.130	.001+	.115	.0008	.150	.0015	.121	.001	.134	.001
X_7	.240	.001+-.005	.193	.001-.004	.240	.0015-.005	.221	.001-.005	.223	.001-.005
H_1	.233	.005-.0012	.187	.004-.001	.242	.005-.001	.222	.004-.001	.226	.0045-.001
H_2	.140	.001	.109	.0008	.151	.0015	.121	.001	.130	.001
H_3	.135	.001	.095	.0008	.130	.001	.104	.0008	.116	.0008
H_4	.137	.001	.095	.0008	.126	.001	.106	.0008	.116	.0008
H_5	.135	.001	.095	.0008	.126	.001	.108	.0008	.116	.0008
H_6	.135	.001	.095	.0008	.127	.001	.115	.0008	.113	.0008
H_7	.130	.0015	.119	.0008	..146	.0014	.126	.001	.135	.001
H_8	.238	.0015-.005	.193	.001-.004	.246	.0015-.005	.219	.001-.004	.224	.001-.0045
V_1	.240	.005-.001								
V_2	.140	.001								
V_3	.135	.001	.095	.0008	.125	.001	.111	.0008	.116	.0008
V_4	.135	.001	.095	.0008	.125	.001	.110	.0008	.116	.0008
V_5	.135	.001	.095	.0008	(.118)	.0009	.107	.0008	(114)	.0008
V_6	.135	.001	.095	.0008	.126	.001	.108	.0008	.116	.0008
V_7	.137	.001	.095	.0008	.126	.001	.108	.0008	.116	.0008
V_8	.133	.001	.095	.0008	.125	.001	.110	.0008	.116	.0008
V_9	.135	.001	.095	.0008	.126	.001	.109	.0008	.116	.0008
V_{10}	.135	.001	.095	.0008	.127	.001	.118	.0008	.118	.0008
V_{11}	.137	.001	.114	.0008	.133	.001	.124	.001	.127	.001
V_{12}	.220	.001-.005	.183	.001-.004	.215	.001-.005	.209	.001-.004	.212	.001-.0045

DATA TABULATED

TABLE V

Anodes: hot rolled 98-99% nickel
Temperature: 110°-120°F
Amperes: 30-40

Voltage: 1.8 volts
pH: 6.0
Time: 1 hour

Electrode distance: 1 inch.

Section	Panel No. 1 Weight	Panel No. 1 Thickness	Panel No. 2 Weight	Panel No. 2 Thickness	Panel No. 3 Weight	Panel No. 3 Thickness	Panel No. 4 Weight	Panel No. 4 Thickness	Average Wt.	Average Thickness
X	[illegible]	.005-.0015	.311	.005-.002	[illegible]	.005-.002	.221	.004-.001	.207	.005-.0015
H_1	.175	.0015	.245	.0018	.310	.002	.133	.001	.198	.0018
H_2	.177	.0015	.223	.0018	.285	.002	.135	.001	.203	.0018
H_3	.189	.0015	.227	.0018	.270	.002	.150	.001	.204	.0018
H_4	.173	.0015	.220	.0018	.260	.002	.150	.001	.201	.0018
H_5	.175	.0015	.215	.0018	.250	.0018	.149	.001	.197	.0018
H_6	.195	.0015	.222	.0018	.249	.0018	.131	.001	.204	.0018
H_7	.270	.0018-.005	.343	.0018-.005	.330	.0018-.005	.212	.001-.004	.293	.0018-.005
h_1	.275	.005-.0018	.345	.005-.0015	.355	.005-.002	.212	.004-.001	.295	.005-.0018
h_2	.193	.0018	.220	.0018	.230	.002	.131	.001	.203	.0018
h_3	.170	.0018	.213	.0018	.250	.002	.149	.001	.193	.0018
h_4	.169	.0018	.203	.0018	.257	.002	.133	.001	.185	.0018
h_5	.164	.0018	.212	.0018	.242	.002	.135	.001	.183	.0018
h_6	.179	.0018	.213	.0018	.230	.002	.123	.001	.183	.0018
h_7	.193	.0018	.222	.0018	.249	.002	.121	.001	.193	.0018
h_8	.270	.0018-.005	.345	.0018-.005	.377	.002-.005	.170	.001-.004	.260	.0018-.005
V_1										
V_2										
V_3	.159	.0018	.211	.0018	.235	.002	.119	.001	.183	.0018
V_4	.169	.0018	.209	.0018	.235	.002	.117	.001	.182	.0018
V_5	.173	.0018	.208	.0018	.235	.002	.124	.001	.186	.0018
V_6	.175	.0018	.200	.0018	.235	.002	.124	.001	.188	.0018
V_7	.175	.0018	.208	.0018	.257	.002	.135	.001	.184	.0018
V_8	.175	.0018	.203	.0018	.271	.002	.145	.0014	.186	.0018
V_9	.175	.0018	.227	.0018	.270	.002	.150	.0014	.204	.0018
V_{10}	.170	.0018	.222	.0018	.297	.0024	.154	.0015	.210	.0018
V_{11}	.195	.0018	.244	.002	.313	.0024	.159	.0015	.227	.0018
V_{12}	.270	.0018-.005	.340	.002-.005	.412	.0024-.005	.222	.0015-.004	.311	.0018-.005

DATA TABULATED

TABLE VI

Anodes: electrolytic nickel on copper screen.
Temperature: 110°-120°F
Amperes: 30-40

Voltage: 2 volts
pH: 6.0
Time: 1 hour

Electrode distance: 1 inch

Section	Panel No. 1		Panel No. 2		Panel No. 3		Average	
	Weight	Thickness	Weight	Thickness	Weight	Thickness	Weight	Thickness
[illegible]	.370	.0008-.001	.272	.0008-.0014	.304	.0008-.0015	.242	.0008-.0015
X_1	.133	.001	.143	.0014	.159	.0015	.150	.0015
X_2	.122	.001	.117	.001	.163	.001	.134	.001
X_3	.118	.0008	.100	.0008	.151	.0014	.123	.001
X_4	.113	.0008	.100	.0008	.143	.0014	.119	.0008
X_5	.113	.0008	.100	.0008	.152	.0015	.122	.001
X_6	.123	.001	.118	.0008	.163	.0015	.134	.001
X_7	.204	.001-.004	.183	.0008-.004	.250	.0015-.004	.213	.001-.004
h_1	.194	.004-.001	.192	.004-.0008	.249	.004-.0015	.212	.004-.001
h_2	.117	.0008	.117	.0008	.163	.0015	.132	.001
h_3	.113	.0008	.104	.0008	.152	.0015	.123	.001
h_4	.112	.0008	.100	.0008	.142	.0014	.118	.0008
h_5	.112	.0008	.100	.0008	.143	.0014	.118	.0008
h_6	.113	.0008	.103	.0008	.152	.0015	.122	.001
h_7	.123	.001	.112	.0008	.163	.0015	.133	.001
h_8	.204	.001-.004	.182	.0008-.004	.254	.0015-.004	.213	.001-.004
V_1								
V_2								
V_3	.114	.0008	.100	.0008	.156	.0015	.123	.001
V_4	.114	.0008	.100	.0008	.147	.0015	.120	.001
V_5	.111	.0008	.100	.0008	.138	.001	.116	.0008
V_6	.112	.0008	.100	.0008	.138	.001	.116	.0008
V_7	.112	.0008	.100	.0008	.143	.0014	.118	.0008
V_8	.113	.0008	.100	.0008	.143	.0014	.118	.0008
V_9	.118	.0008	.100	.0008	.144	.0014	.120	.0008
V_{10}	.124	.0008	.108	.0008	.158	.0015	.130	.001
V_{11}	.129	.001	.118	.0008	.173	.0016	.140	.001
V_{12}	.202	.001-.004	.181	.001-.004	.280	.0016-.004	.221	.0012-.004

DATA TABULATED

TABLE VII

Anodes: electrolytic nickel deposited on steel screen - 14 mesh.
Temperature: 110°F
Voltage: 2.2 volts
Amperes: 30
pH: 6.0
Time: 1 hour
Electrode distance: 1 inch.

Section	Panel No. 1 Weight	Panel No. 1 Thickness	Panel No. 2 Weight	Panel No. 2 Thickness	Panel No. 3 Weight	Panel No. 3 Thickness	Average Weight	Average Thickness
X	.240	.004-.0015	.237	.004-.0012	.236	.004-.001	.247	.004-.001
X_1	.161	.0015	.142	.0012	.105	.0008	.136	.001
X_2	.169	.0015	.151	.0014	.102	.0008	.140	.001
X_3	.161	.0015	.161	.0015	.108	.0008	.145	.001
X_4	.155	.0015	.151	.0015	.120	.001	.145	.0012
X_5	.157	.0015	.173	.0016	.140	.001	.153	.0015
X_6	.160	.0015	.217	.0018	.174	.0016	.188	.0016
X_7	.192	.0018-.003	.210	.0018-.004	.285	.0016-.005	.251	.0016-.004
h_1	.196	.004-.0015	.222	.004-.0016	.171	.004-.001	.193	.004-.001
h_2	.150	.0015	.173	.0016	.114	.0008	.149	.0015
h_3	.157	.0015	.151	.0015	.121	.001	.146	.0015
h_4	.153	.0015	.155	.0015	.130	.001	.151	.0015
h_5	.154	.0015	.180	.0016	.145	.0014	.159	.0015
h_6	.174	.0015	.200	.0018	.166	.0015	.180	.0016
h_7	.193	.0015	.217	.0018	.174	.0016	.193	.0018
h_8	.230	.0018-.004	.270	.0018-.005	.285	.0015-.006	.271	.0016-.005
V_1								
V_2								
V_3	.188	.0015	.193	.0017	.145	.0014	.168	.0015
V_4	.184	.0016	.214	.002	.151	.0015	.183	.0015
V_5	.199	.0015	.150	.0017	.146	.0014	.165	.0015
V_6	.154	.0015	.155	.0015	.121	.001	.150	.0015
V_7	.152	.0015	.157	.0015	.121	.001	.143	.0012
V_8	.150	.0015	.154	.0015	.115	.001	.140	.0012
V_9	.161	.0015	.161	.0015	.108	.0008	.143	.0012
V_{10}	.150	.0015	.155	.0015	.105	.0008	.140	.0012
V_{11}	.158	.0015	.152	.0015	.117	.0008	.142	.0012
V_{12}	.188	.0016-.004	.200	.0015-.004	.196	.0008-.004	.193	.0016

DATA TABULATED

TABLE VIII

Anodes: Hot rolled 98-99% nickel.
Temperature: 110°F
Voltage: 1.8 volts
Electrode distance: 1 inch.

Amperes: 30
pH: 6.0
Time: 1 hour

Section	Panel No. 1 Weight	Panel No. 1 Thickness	Panel No. 2 Weight	Panel No. 2 Thickness	Panel No. 3 Weight	Panel No. 3 Thickness	Average Weight	Average Thickness
X	.303	.003-.0015	.255	.003-.0015	.272	.003-.0015	.250	.003-.0015
X_1	.130	.0015	.149	.0015	.145	.0012	.151	.0015
X_2	.148	.0012	.150	.001	.141	.001	.140	.001
X_3	.143	.001	.156	.001	.142	.0012	.140	.001
X_4	.137	.001	.144	.0012	.149	.0014	.143	.001+
X_5	.142	.0012	.147	.0014	.144	.0012	.144	.0014
X_6	.145	.0012	.151	.0015	.155	.0015	.150	.0015
X_7	.222	.001-.004	.195	.0015-.004	.196	.0015-.004	.205	.0015-.004
h_1	.215	.004-.0015	.197	.004-.0012	.200	.004-.0012	.204	.004-.0012
h_2	.148	.0015	.142	.0012	.140	.0012	.143	.0012
h_3	.140	.001	.141	.001	.141	.0012	.141	.0012
h_4	.140	.001	.135	.001	.137	.001	.137	.001
h_5	.137	.001	.144	.0012	.143	.0012	.141	.0012
h_6	.139	.001	.147	.0012	.150	.0015	.145	.0014
h_7	.145	.0014	.151	.0015	.156	.0015	.151	.0015
h_8	.222	.001-.004	.195	.0015-.004	.198	.004	.205	.0015-.004
V_1								
V_2								
V_3	.151	.001	.145	.0014	.144	.0012	.140	.001
V_4	.130	.001	.142	.0012	.143	.0012	.138	.001
V_5	.141	.0012	.136	.001	.140	.001	.139	.001
V_6	.140	.001	.134	.001	.137	.001	.137	.001
V_7	.142	.0012	.135	.001	.139	.001	.138	.001
V_8	.142	.0012	.131	.001	.140	.001	.137	.001
V_9	.143	.0012	.136	.001	.142	.0012	.140	.001
V_{10}	.135	.001	.131	.001	.143	.0014	.138	.001
V_{11}	.142	.0012	.145	.0014	.150	.0015	.146	.0015
V_{12}	.232	.001-.004	.200	.0014-.004	.222	.0015-.004	.220	.0015-.004

DATA TABULATION

TABLE IX

Summary of Results   Weights only.

Section	Rolled Knots 7" distance	Screen Knots 7" distance	Rolled Knots 4" distance	Screen Knots 4" distance	Rolled Knots 1" distance	Screen Knots 1" distance
h_1	.247	.179	.278	.226	.204	.212
h_2	.137	.098	.156	.130	.143	.132
h_3	.117	.086	.134	.116	.141	.123
h_4	.112	.086	.133	.116	.137	.118
h_5	.112	.086	.133	.113	.141	.118
h_6	.117	.088	.135	.113	.145	.122
h_7	.131	.102	.146	.135	.151	.133
h_8	.248	.180	.247	.224	.205	.213
V_1	.220	.154	.218			
V_2	.123	.089	.152			
V_3	.116	.086	.136	.116	.140	.123
V_4	.115	.085	.135	.116	.138	.120
V_5	.115	.085	.136	.114	.139	.113
V_6	.115	.086	.133	.116	.137	.116
V_7	.112	.086	.133	.116	.138	.118
V_8	.112	.087	.135	.116	.137	.118
V_9	.115	.088	.136	.116	.140	.120
V_{10}	.118	.099	.135	.118	.138	.130
V_{11}	.128	.110	.150	.127	.146	.140
V_{12}	.222	.189	.247	.212	.220	.221

These values cannot be directly compared by observation with ease. But when plotted the curves can easily be compared as to slope, which means metal distribution and thus current distribution.

There are two methods of plotting available. The thickness of the deposit as measured with the micrometers can be plotted against the sections, or the weights of the sections can be plotted against the sections. The thicknesses show better the variations close to the edges, but are less exact than the weights, because of the difficulty of making measurements at the edge due to small irregularities in the surface at the edge.

TABLE X

Seven Inch Electrode Distance

Rolled anodes - eight inch direction of panel

Slope of line between 1 - 2 = 5.5

Slope of line between 7 - 8 = 5.85

Average slope = 5.67

twelve inch direction of panel

Slope of line between 1 - 2 = 4.85

Slope of line between 11-12 = 4.7

Average slope = 4.77

Screen anodes - eight inch direction of panel

Slope of line between 1 - 2 = 4.05

Slope of line between 7 - 8 = 3.9

Average slope = 3.97

twelve inch direction of panel

Slope of line between 1 - 2 = 3.25

Slope of line between 11-12 = 3.95

Average slope = 3.6

Direction	Screen Anodes	Rolled Anodes	Diff.
8 inch	slope of graph = 3.97	slope of graph = 5.67	1.7
12 inch	" " " = 3.6	" " " = 4.77	1.17

These figures show that there is a slightly less tendency for the deposit to go to the edge of the panel when screen anodes are used.

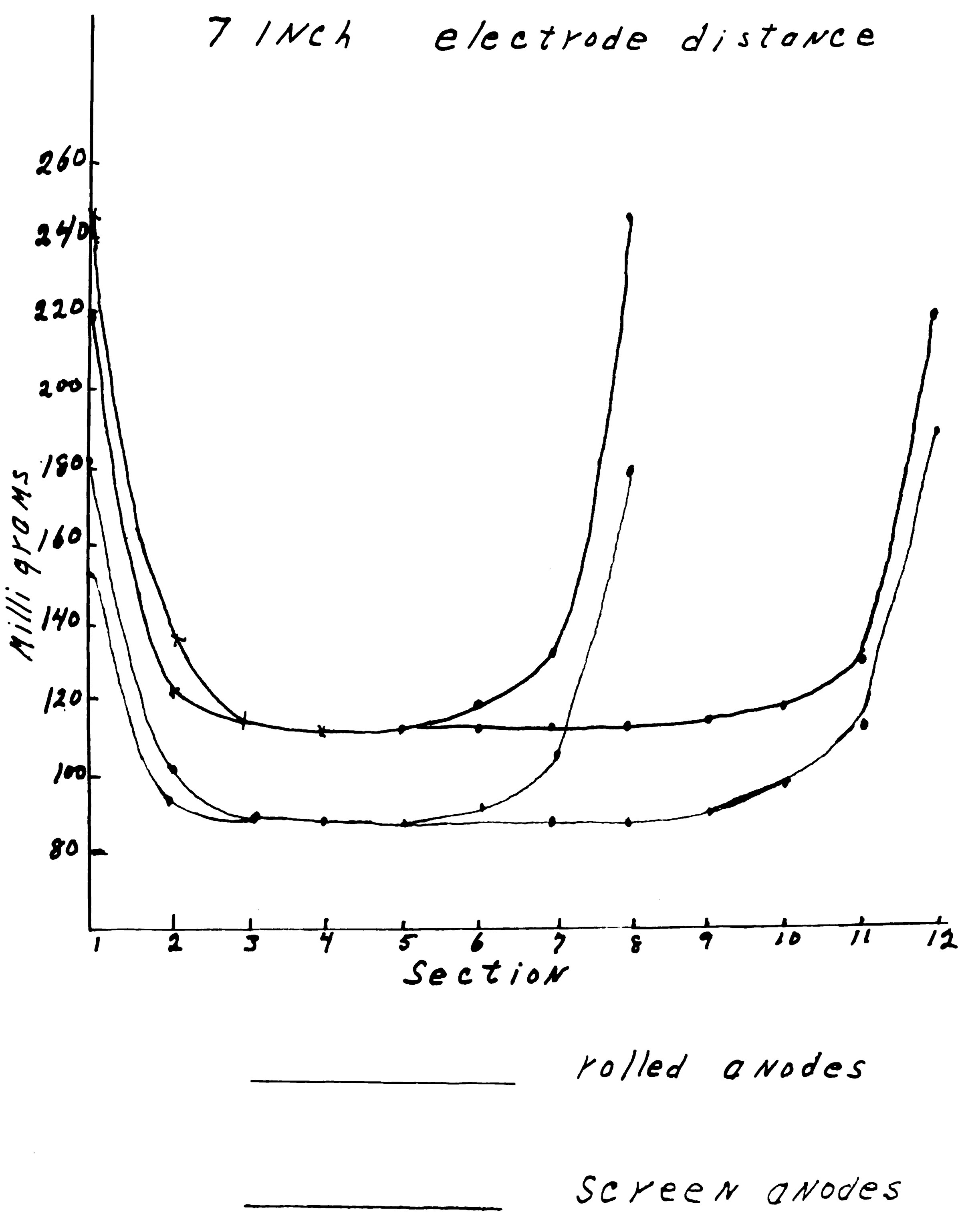

7 INCH electrode distance
260
240
220
200
180
160
140
120
100
80
Milligrams
1
2
3
4
5
6
7
8
9
10
11
12
Section
rolled anodes
screen anodes

Table XI

Four Inch Electrode Direction

Rolled anodes - eight inch direction

Slope in line from 1 - 2 = 6.1

Slope in line from 7 - 8 = 5.05

Average slope = 5.57

twelve inch direction

Slope in line from 11-12 = 4.85

Screen anodes - eight inch direction

Slope in line from 1 - 2 = 4.8

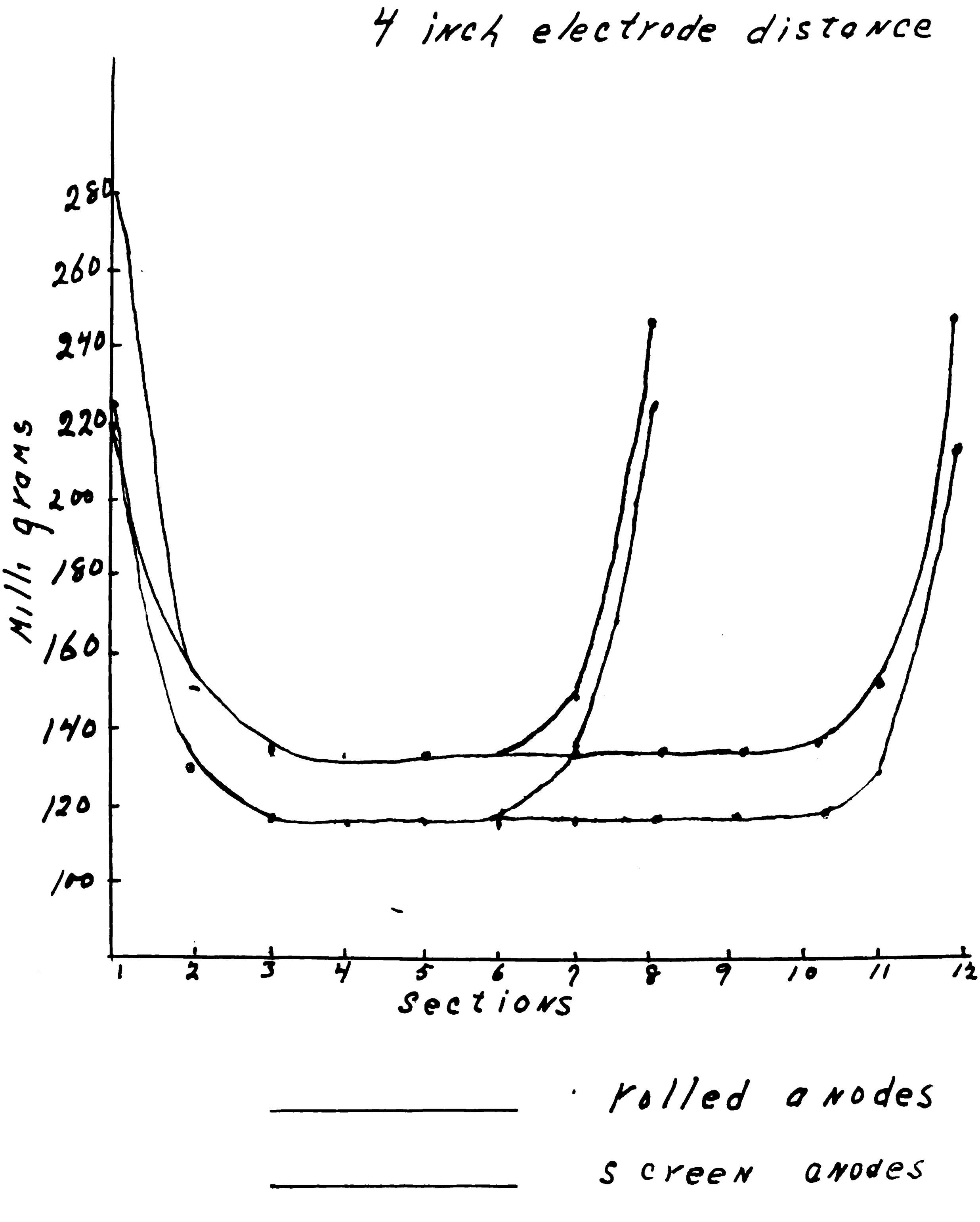
Slope in line from 7 - 8 = 4.55

Average slope = 4.67

twelve inch direction

Slope in line from 11-12 = 4.25

Direction	Screen Anode	Rolled Anode	Diff.
8 inch	slope of graph = 4.67	slope of graph = 5.57	.90
12 "	" " " = 4.25	" " " = 4.85	.60



4 inch electrode distance
Milli grams
280
260
240
220
200
180
160
140
120
100
1
2
3
4
5
6
7
8
9
10
11
12
Sections
rolled anodes
screen anodes

TABLE XII

One Inch Electrode Distance

Rolled anodes - eight inch direction

Slope of graph from 1 - 2 = 3.05

Slope of graph from 7 - 8 = 2.7

Average slope = 2.87

twelve inch direction

Slope of graph from 11-12 = 3.7

Screen anodes - eight inch direction

Slope of graph from 1 - 2 = 4.0

Slope of graph from 7 - 8 = 4.0

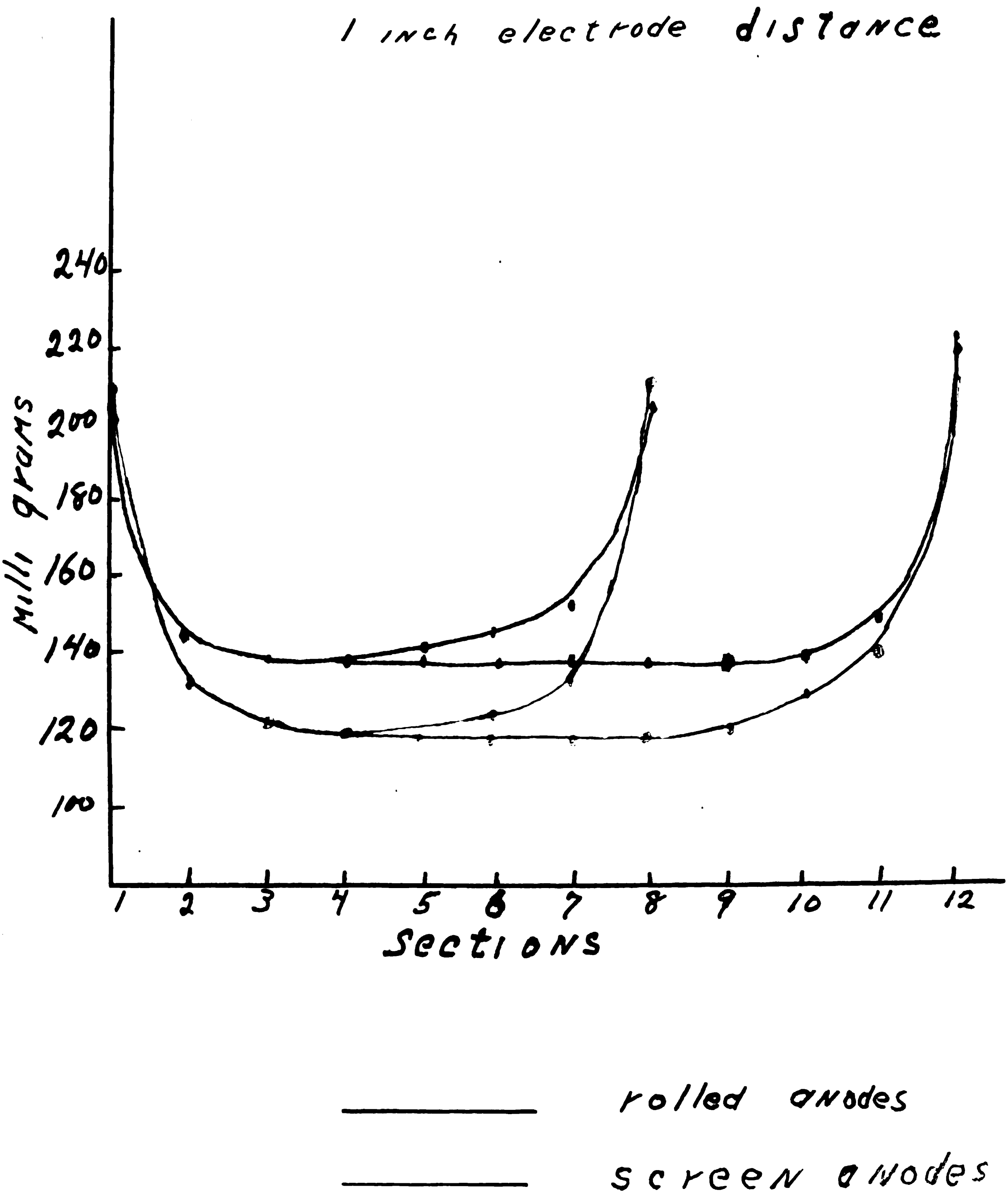
Average slope = 4.0

twelve inch direction

Slope of graph from 11-12 = 4.5

Direction	Screen Anodes	Rolled Anodes	Diff.
8 inch	slope of graph = 4	slope of graph = 2.87	-1.13
12 "	" " " = 4.5	" " " = 3.7	- .8

These indicate that the screen anodes increase the effect of the deposit at the edge.



1 inch electrode distance
240
220
200
180
160
140
120
100
Milli grams
1
2
3
4
5
6
7
8
9
10
11
12
Sections
rolled anodes
screen anodes

TABLE XIII

Direction	Electrode Distance	Screen Anodes		Rolled Anodes		Diff.
8 inch	7 inches	slope	3.97	slope	5.67	1.7
12 "	7 "	"	3.6	"	4.77	1.17
8 "	4 "	"	4.67	"	5.57	.9
12 "	4 "	"	4.25	"	4.85	.6
8 "	1 inch	"	4	"	2.87	-1.13
12 "	1 "	"	4.5	"	3.7	- .8

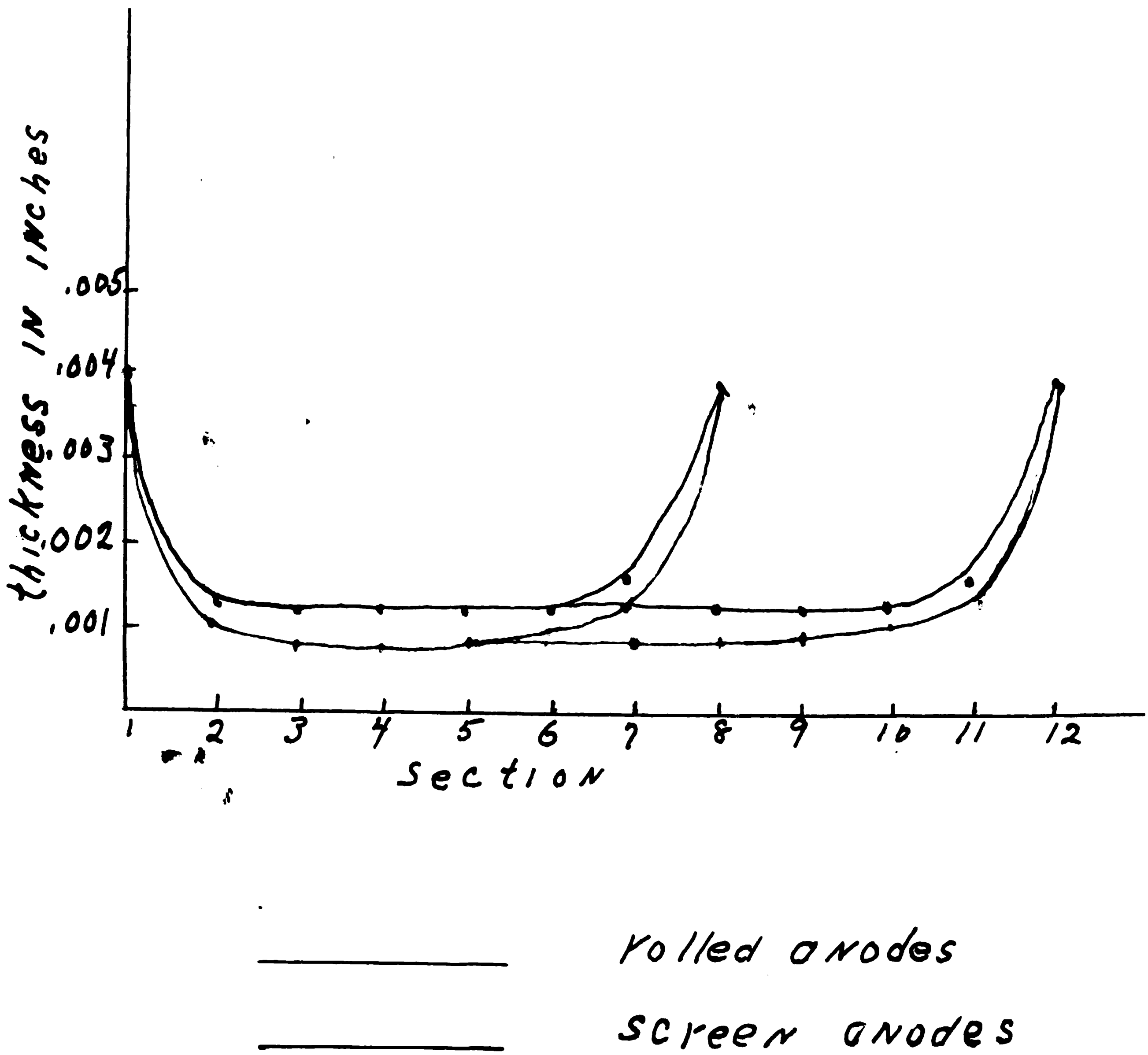
It is obvious that the rolled anodes give steeper slopes than the screen anodes do in the first two cases. This would indicate that screen anodes decreaed the tendency for the deposit to become heavy on the edges. However, when the electrodes are brought closer together this effect is reversed.

Rather different results are found when the thickness of the deposit as measured by the micrometer is examined. This shows that instead of going to the very edge of the panel the deposit is thickened further back from the edge; thus giving a more symetrical curve. With rolled anodes the edge is thick but drops rapidly to or nearly to the thickness of the center of the deposit. With screen anodes the edge is not so thick, but it does not drop so rapidly as shown in the following table.

TABLE XIV

Section	1" electrode distance Rolled Anodes		1" electrode distance Screen Anodes	
	Weight	Thickness	Weight	Thickness
h_1	.204	.004-.0012	.212	.004-.001
h_2	.143	.0012	.132	.001
h_3	.141	.0012	.123	$.001^-$
h_4	.137	$.001^+$	.118	.0008
h_5	.141	.0012	.118	.0008
h_6	.145	.0012	.122	$.001^-$
h_7	.151	.0015	.133	.001
h_8	.205	.0015-.004	.213	.001-.004
V_3	.140	.0012	.123	$.001^-$
V_4	.138	.0011	.120	$.001^-$
V_5	.139	.0012	.116	.0008
V_6	.137	$.001^+$	.118	.0008
V_7	.138	.0011	.118	.0008
V_8	.137	$.001^+$	.118	.0008
V_9	.140	.0012	.120	$.001^-$
V_{10}	.138	.0011	.130	.001
V_{11}	.146	.0015	.140	$.001^+$
V_{12}	.220	.0015-.004	.221	.0012-.004

1 inch electrode distance



These curves show that in the case of screen anodes the effect of increasing thickness at the edge is noticeable for a distance of from three to four inches from the edge while in the case of the rolled anodes the effect of the edge is shown only about half as far from the edge. This makes the edge much more noticeable on the panels plotted with rolled anodes.

These phenomena are more noticeable when the electrode distance is closed in.

Conclusions

1. The shape of the anode materially effects the distribution of metallic nickel on a sheet metal cathode.

2. The distance between the anodes and the cathode effect the distribution of metallic nickel on a sheet metal cathode.

3. With high purity hot rolled nickel anodes the tendency to thicken the deposit at the edge is lessened as the anodes are brought closer toward the cathode.

4. With electrolytic nickel screen anodes the tendency to have a thickened edge is lower than with rolled anodes.

5. At small distances between electrodes, screen anodes broaden out the thickened band near the edges to at least twice as wide as with rolled anodes. This makes the edges appear not to be as much thicker than the center as they actually are. That is, the edge effect covers more of the panel.

After the above data was taken to determine the effect of the electrode distance and the shape of the anode, it was decided to carry out some determinations on the effect of moving the cathode. Both types of anodes were used and an electrode distance of four inches was used.

DATA TABULATED

TABLE XV

Anodes: hot rolled - 98-99% nickel.
Temperature: 110°F
Volts: 3.5-3.6 moving cathode
3.4 still cathode

Amperes: 30
Time: 1 hour
pH: 6.0
Electrode distance: 4 inches

Section	Moving Cathode Panel No. 1		Moving Cathode Panel No. 2		Still Cathode Panel No. 3		Still Cathode Panel No. 4	
	Weight	Thickness	Weight	Thickness	Weight	Thickness	Weight	Thickness
X	.404	.003-.0015	.330	.003-.0016	.392	.003-.0015		
X_1	.134	.0015	.134	.0013	.137	.0015	.134	.0016
X_2	.132	.001	.130	.001	.143	.0012	.134	.001
X_3	.124	.001	.121	.001-	.124	.001	.125	.001-
X_4	.122	.001-	.119	.001-	.129	.001	.119	.001-
X_5	.124	.001	.127	.001	.121	.001	.126	.001
X_6	.137	.001	.143	.0012	.143	.0012	.123	.001
X_7	.232	.001-.005	.272	.0012-.005	.210	.0012-.005	.232	.001-.005
h_1	.243	.005-.0012	.256	.005-.0014	.255	.005-.0015	.160	.004-.0015
h_2	.143	.0012	.143	.0014	.145	.0015	.149	.0015
h_3	.126	.001	.125	.001	.129	.001	.120	.001
h_4	.125	.001	.121	.001	.122	.001	.120	.0008
h_5	.126	.001	.121	.001	.125	.001	.119	.0008
h_6	.128	.001	.127	.001-	.121	.001	.121	.001
h_7	.137	.001	.143	.0012	.141	.0012	.128	.001
h_8	.232	.001-.004	.272	.0012-.004	.210	.001-.004	.218	.001-.004+
V_1								
V_2								
V_3	.125	.001	.122	.001	.124	.001	.122	.001
V_4	.125	.001	.122	.001	.125	.001	.124	.001
V_5	.124	.001	.125	.001	.121	.001	.123	.001
V_6	.125	.001	.120	.001	.122	.001	.120	.001-
V_7	.124	.001-	.121	.001	.123	.001	.122	.001
V_8	.122	.001-	.120	.001	.125	.001	.120	.001-
V_9	.124	.001	.121	.001	.124	.001	.123	.001
V_{10}	.124	.001	.123	.001	.134	.001	.128	.001
V_{11}	.139	.0012	.140	.0012	.150	.0015	.138	.001
V_{12}	.245	.001-.004	.248	.0012-.004	.245	.0015-.004	.232	.001-.004

DATA TABULATED

TABLE XVI

Anodes: electrolytic nickel screen
Temperature: 110°F
Voltage: 3.6 moving cathode
3.5 still cathode

Amperes: 30
pH: 6.0
Time:
Electrode distance: 4 inches.

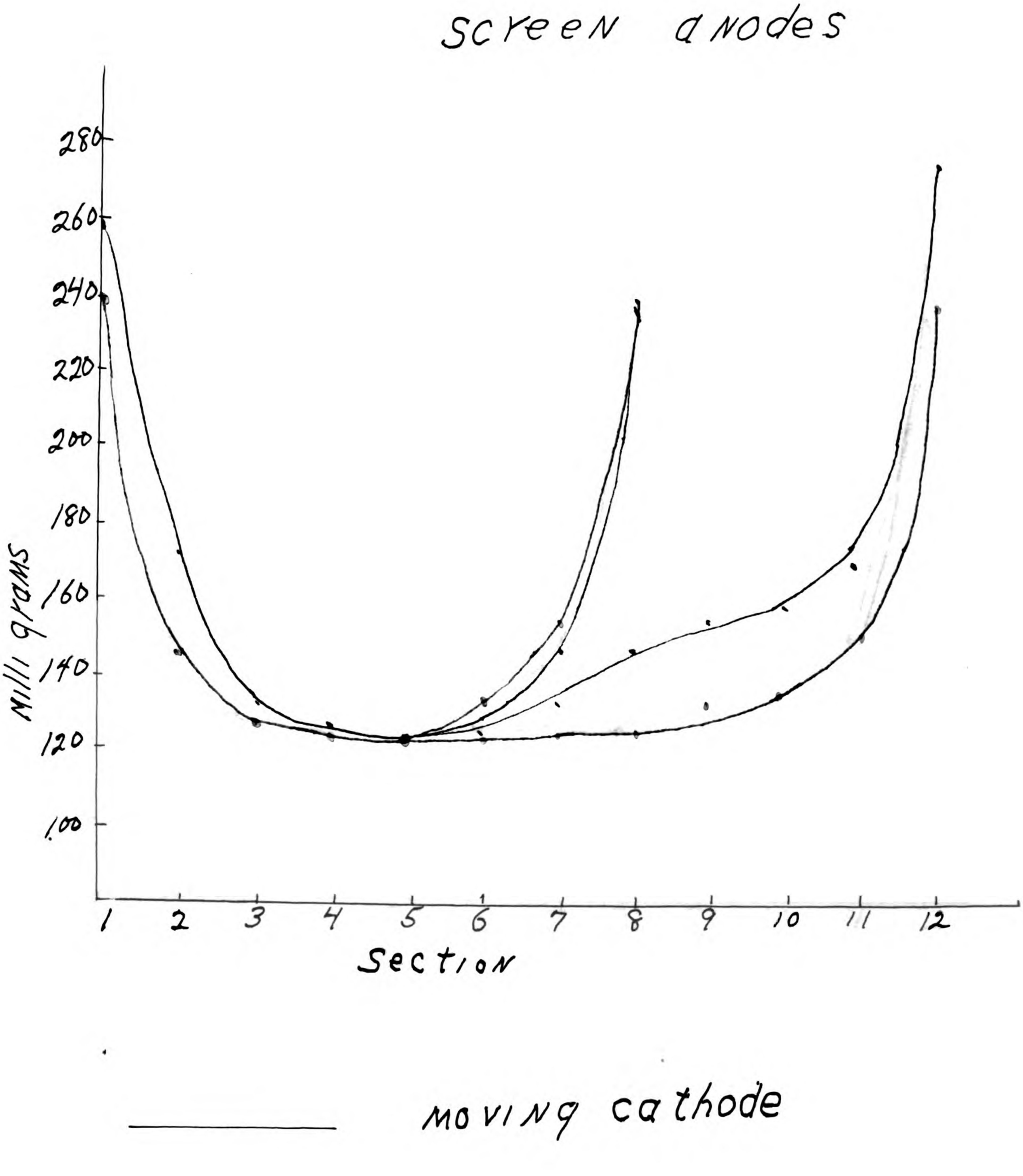
Section	Moving Cathode Panel No. 1		Moving Cathode Panel No. 2		Still Cathode Panel No. 3		Still Cathode Panel No. 4	
	Weight	Thickness	Weight	Thickness	Weight	Thickness	Weight	Thickness
X	.430	.003-.002			[illegible]	.003-.0015	[illegible]	.003-.0015
X_1	.134	.0016	.199	.0018	.175	.0016	.138	.0016
X_2	.134	.0015	.130	.0015	.137	.001	.133	.001
X_3	.143	.0015	.145	.0014	.133	.001	.129	.001
X_4	.148	.0015	.143	.0014	.127	.001	.123	.001
X_5	.132	.001	.133	.001	.132	.001	.132	.001
X_6	.138	.001	.144	.0014	.150	.0015	.143	.0015
X_7	.204	.001-.004	.234	.0015-.005	.231	.0015-.005	.245	.0015-.005
h_1	.246	.005-.0014	.239	.005-.0015	.235	.005-.0015	.249	.005-.0014
h_2	.142	.0012	.134	.0018	.146	.0014	.147	.0014
h_3	.123	.001	.140	.001+	.123	.001	.129	.001
h_4	.117	.0008	.132	.001	.124	.001	.123	.001
h_5	.123	.001−	.135	.001	.123	.001	.122	.001
h_6	.121	.001−	.133	.001	.132	.001	.132	.001
h_7	.138	.001−	.150	.0013	.143	.0012	.143	.0015
h_8	.204	.001-.004	.234	.0015-.005	.231	.0012-.005	.243	.0015-.005
V_1								
V_2								
V_3	.103	.0008	.105	.0008	.126	.001	.121	.001
V_4	.103	.0008	.110	.0008	.121	.001−	.126	.001
V_5	.104	.0008	.124	.001	.122	.001−	.122	.001
V_6	.117	.001−	.133	.001	.121	.001−	.120	.001
V_7	.130	.001	.132	.001	.124	.001−	.121	.001
V_8	.111	.001*	.143	.0012	.123	.001	.124	.001
V_9	.140	.0015	.145	.0012	.133	.001	.129	.001
V_{10}	.153	.0015	.155	.0015	.137	.001	.130	.001
V_{11}	.164	.0016	.171	.0016	.134	.0015	.147	.0015
V_{12}	.230	.0016-.005	.267	.0016-.005	.267	.0015-.005	.240	.0015-.005

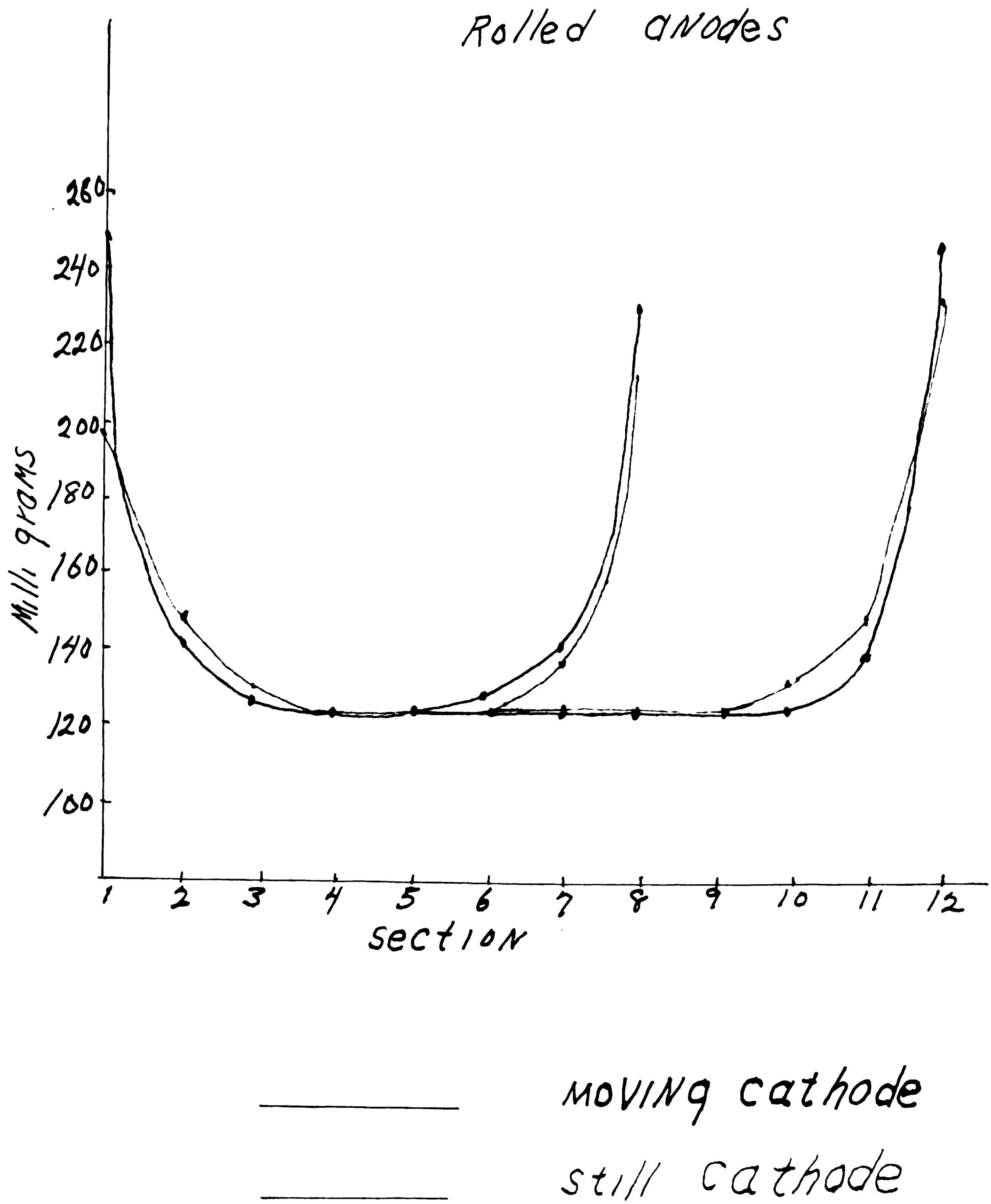
DATA TABULATED

TABLE XVII

Averages

Section	Rolled Anodes Moving		Rolled Anodes Still		Screen Anodes Moving		Screen Anodes Still	
	Weight	Thickness	Weight	Thickness	Weight	Thickness	Weight	Thickness
X	.397	.006-.0015	.392	.006-.0015	.450	.006-.002	.364	.005-.0016
X_1	.159	.0015	.165	.0015	.196	.0018	.170	.0016
X_2	.131	.001	.138	.001	.132	.0015	.135	.001
X_3	.122	.001-	.123	.001	.147	.0014	.131	.001
X_4	.120	.0008	.124	.001	.147	.0014	.125	.001
X_5	.125	.001	.123	.001	.133	.001	[illegible]	.001
X_6	.140	.0012	.135	.001	.141	.0012	.149	.0015
X_7	.252	.0012-.005	.221	.001-.005	.217	.0012-.004	.237	.0015-.005
h_1	.249	.005-.0012	.207	.0045-.0015	.257	.005-.0015	.242	.005-.0014
h_2	.144	.0012	.148	.0015	.153	.0015	.145	.0014
h_3	.125	.001	.129	.001	.130	.001	.127	.001
h_4	.123	.001	.121	.001	.124	.001	.123	.001
h_5	.123	.001	.122	.001-	.129	.001	.122	.001
h_6	.127	.001	.121	.001	.127	.001	[illegible]	.001
h_7	.140	.001	.134	.001	.144	.0014	.146	.0014
h_8	.252	.001-.005	.214	.001-.004+	[illegible]	.0014-.005	.237	.0014-.005
V_3	.128	.001	.123	.001	.106	.0008	.123	.001
V_4	.125	.001	.124	.001	.105	.0008	.12[illegible]	.001
V_5	.125	.001	.122	.001	.114	.0008	.122	.001
V_6	.122	.001	.121	.001	.125	.001	.122	.001
V_7	.122	.001	.122	.001	.131	.001	.122	.001
V_8	.121	.001	.122	.001	.143	.0012	.125	.001
V_9	.122	.001	.123	.001	.147	.0015	.121	.001
V_{10}	.123	.001	.131	.001	.135	.0015	.133	.001
V_{11}	.139	.0012	.144	.0012	.137	.0015	.136	.0015
V_{12}	.245	.001-.004	.255	.001-.004	.275	.0015-.005	.253	.0015-.005


Screen anodes
280
260
240
220
200
180
160
140
120
100
Milli grams
1
2
3
4
5
6
7
8
9
10
11
12
Section
moving cathode



Rolled anodes
Milli grams
260
240
220
200
180
160
140
120
100
1
2
3
4
5
6
7
8
9
10
11
12
section
moving cathode
still cathode

TABLE XVIII

Rolled anodes moving - eight inch direction

Slope from 1 - 2 = 5.25

Slope from 7 - 8 = 5.6

Average slope = 5.42

twelve inch direction

Slope from 11-12 = 5.35

Rolled anodes still - eight inch direction

Slope from 1 - 2 = 2.95

Slope from 7 - 8 = 4.

Average slope = 3.47

twelve inch direction

Slope from 11-12 = 4.7

Direction	Moving	Still	Diff.
8 inch	slope of graph = 5.42	slope of gfaph = 3.47	1.95
12 "	" " " = 5.35	" " " = 4.7	.65

This indicates that the tendency to deposit at the edge is aided by moving the cathode.

TABLE XIX

Screen anodes moving - eight inch direction

Slope of line from 1 - 2 = 5.2

Slope of line from 7 - 8 = 4.25

Average slope = 4.72

twelve inch direction

Slope of line from 11-12 = 5.3

Screen anodes still - eight inch direction

Slope of line from 1 - 2 = 4.8

Slope of line from 7 - 8 = 4.05

Average slope = 4.42

twelve inch direction

Slope of line from 11-12 = 4.4

Direction	Moving	Still	Diff.
8 inch	slope of graph = 4.72	slope of graph = 4.42	.3
12 "	" " " = 5.3	" " " = 4.4	.9

TABLE XX

Combination of Tables of Slopes

Direction	Moving Screen anodes	Moving Rolled Anodes	Still Screen	Still Rolled
8 inch	4.72	5.42	4.42	3.47
12 "	5.3	5.35	4.4	4.7

In the light of these results, one must conclude that moving the cathode tends to cause heavy deposit on the edge. It was also noted that a higher voltage was necessary to force thirty amperes through the solution when the cathode was moving than when it was still. These combined facts indicate that by moving the cathode and thus agitating the solution, the polarization is disturbed. This disturbing of the polarization causes the current to come closer to the theoretical distribution. That is, the current coming from places on the anode where the cathode is not directly at right angles to it will cause metal to be deposited on the edge. When the cathode is still the polarization is greatest where the current density tends to be greatest and thus causes a more even distribution of current.

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