1935

The effect of electrical lubrication on the transmission of pressure in dry pressed bodies

Oliver William Kamper

Department: Materials Science and Engineering

THE EFFECT OF ELECTRICAL LUBRICATION ON THE TRANSMISSION OF PRESSURE IN DRY PRESSED BODIES.

BY

OLIVER W. KAMPER

A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required of the

Degree of

BACHELOR OF SCIENCE IN CERAMIC ENGINEERING

Rolla, Missouri

1935

Approved by ______________________________

Professor of Ceramic Engineering

TABLE OF CONTENTS

ACKNOWLEGMENT

The writer wishes to express gratitude to Professor Dodd for his helpful suggestions in regard to this thesis; to Professor Frame for his helpful suggestions as to the electrical equipment and hookup; and to Dr. Monroe for his helpful advice pertaining to the chemistry concerned.

INTRODUCTION

One of the great problems facing the Ceramic industry today is the production of perfect brick by the dry press process. This problem has been of vital importance because of the physical defects obtained in the dry pressing operation due to the ununiform transmission of pressure in the ware produced. As a result of this ununiform transmission of pressure, strains, cracks, differential shrinkage, low strength, and laminations have been accentuated after the firing of the body.

Pressure transmission is influenced by several factors: the size and shape of grog and clay grain,[1] the time and duration of pressure application,[2] the physical character of the mix,[3] the occluded air,[4,5] and the lubrication of the mold box.[6] These factors

---

(1) H.R. Herron, Thesis:"The Transmission of Pressure In The Dry Pressing of Building Brick and Fire Brick Mixes As Effected By The Variation In Grog Size." 1931
(2) R.E.Lee?Thesis:"The Effect of The Time of Pressure Applicatinn On Dry Pressed Ware." 1931
(3) "A Study Of The Dry Press Process," Dodd, Page, Netzband, Brick and Clay Record LXXVIII,6,'31
(4) W.P.Powell, Thesis: Occluded Air In Dry Press Mixes." 1930
(5) "Entrapped Air" - Rueckel, "Research in Dry Press-Refractories." J.A.C.S. XIV, 10, 1931
(6) "The Effect of Various Factors On Pressure Transmission In Dry Pressing." Dodd, A.R.I. Techanical Bulletin No. 33, March 1932

have all been investigated and their effects noted. Lubrication of the mold box has been attempted with various lubricants including oils, emulsions, and water itself, buf a survey of the literature fails to reveal any published information regarding the electrical lubrication of the dry press.

In 1913 Dawkins[1] found that if metal in contact with clay is made cathode and a current is passed, the clay no longer tends to adhere and all of the effects of lubrication are obtained. We can see from this that the fundamental principle of electro-lubrication is not new. During the last few years electrically lubricated dies for stiff mud and soft mud machines have been developed and used successfully,[2] but to the present date no information has been revealed regarding the electrical lubricaion of the dry-press machine.

It is believed by authorities[3,4] that the phenomenon of electrical lubrication is due to the action of "cataphoresis" (migration of the particles in sus-

---

(1) Dawkins: British Clayworker: 22,91,92, (1913)
Clayworker: 57,426 (1912)
(2) "Electrical Lubrication of Stiff Mud Dies" J.O. Everhart, J.A.C.S. Vol. 17, Sept. 1934.
"Electrical Lubrication of Hand-Molded Refractory Shapes," J.O.Everhart J.A.C.S. Vol. 17, Oct. 1934.

(3) Alexander: Collid Chemistry, Vol. 1, p.821.
(4) T.R.Briggs, "Electrical Endosmosis and Cataphoresis," 2nd Report On Collid Chemistry, 1918, p.26-47.

pension to the positive electrode when subjected to an electrical potential) and "endosmosis" (travel of a liquid through a porous medium to the negative electrode when subject to an electrical potential). In the body of stiff mud consistency endosmosis is probably most effective; in the body of soft mud consistency both endosmosis and cataphoresis take place; in the body in the slip cataphoresis is effective; and in the body of dry press consistency endosmosis is in all probabilities most effective, if the moisture is sufficient to be attracted to the surface. It is planned to determine in this investigation just what effect the application of current will have on the lubrication of the dry-press mold box.

OBJECT OF INVESTIGATION

The object of this investigation is to study the effect of the application of electricity as a means of lubricating the dry press machine or, of obtaining a uniform transmission of pressure in the dry press process.

MATERIALS USED

The materials used in this investigation were clays of widely different physical properties, the reason for this being to cover the entire range of clays which are used in the manufacture of brick by the dry press process. The clays consist of the following: St. Louis Surface clay, North Mo. Semi-Flint clay, Missouri No.1 Flint clay, and also some fire brick grog. The following mixes were made from the above clays:

1. St. Louis Surface Clay
2. North Missouri Semi-Flint 85.7% - St. Louis Surface Clay 14.3%
3. North Missouri Semi-Flint 92% - Fire Brick Grog 8%
4. Missouri No.1 Flint Clay 75% - North Missouri Semi-Flint 25%

TYPE OF PRESS[1]

The dry press machine used in this investigation was obtained from the Hydraulic Press Manufacturing Company of Mount Gilead, Ohio. It has a total capacity of 135 tons, and a mold box 20 by 9-$\frac{3}{4}$ by 4-$\frac{3}{4}$ inches in size. The lower ram travel is 22 inches, and the mold box travel is 1-$\frac{1}{4}$ inches. The deep mold box makes it possible to press blocks as large as ten inches in depth. This proved a decided advantage since it permitted a block to be made of several one to two inch layers suitable for examination. The press is actuated by a motor driven plunger which draws water from a closed reservoir and forces it into the cylinder at a maximum pressure of 6000 pounds per square inch.

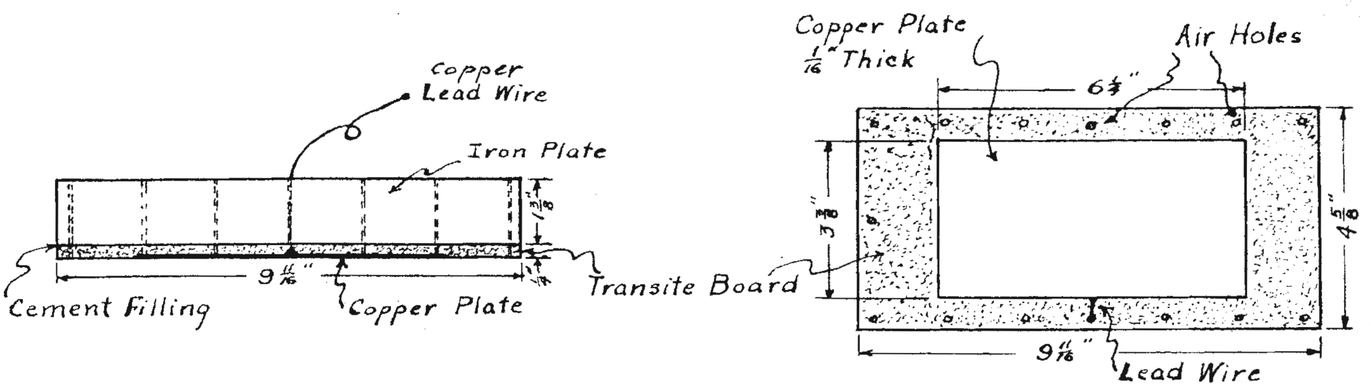
In operation, the hydraulic cylinder moves the ram upward through the bottom of the mold box. A removable ram block forms the stationary top for the mold. Because the movement is applied to the bottom of the mix, the lower layers are the first to become compressed. They, in turn, transmit the pressure upward to the layers above, and outward to the sides

(1) "Rate of Ram Travel On Dry Press Bodies," F.J.Zvanut, Thesis for B.S. in Ceramic Engineering (1932) Missouri School of Mines and Metallurgy.

of the mold obx. A point in the operation is reached at which the pressure outward becomes great enough to create sufficient friction between the grains of the mix and the sides of the mold box to raise the mold box through a maximum distance of 1-$\frac{1}{4}$ inches. During this period, the stationary ram in the top of the box transmits pressure to the upper layers of the block. As a result of this type of action, the lower layers are the most dense, the middle layers are the most porous, and the top layers are moderately dense. When the mold box is lubricated so that there is less friction at the side-wall the press acts as though all the compression was effected from the lower end.

ELECTRICAL EQUIPMENT

The electrical equipment used in this investigation consisted of an ammeter, voltmeter, rheostat for regulating the current, and copper electrodes at the top and bottom of mold box which acted as positive poles. A diagram of these electrodes is shown on the following page (Fig.1) A diagram (Fig.2) is also shown of the dividers used between the layers which also acted as conductors being made of tinfoil surrounded by wax paper.



Section View

Plan View

Figure 1 - Positive Electrode

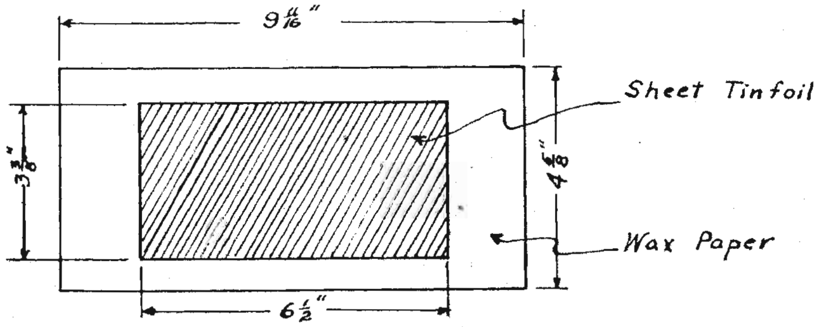


Figure 2 - Divider

The positive electrode as shown in the Fig.1 on the previous page consists of a sheet of one-sixteenth inch thick copper, 6-¼ inches long, and 3-3/8 inches wide. This copper plate was countersunk in a piece of 1/4 inch transite board. The transite board was of the same dimensions as the movable iron plate fitting under the upper ram, and was fastened to this iron plate by the use of cement. The transite board served as an insulator between the electrode and the iron plate. A lead wire was put through one of the air holes in the iron plate and fastened to the copper plate serving to supply positive current to the top of the clay.

The negative wire was fastened to the mold box so that the sides of the mold box served to supply the negative current.

The dividers as shown in Fig.2 on the previous page consist of sheets of tinfoil 6-¼ inches long and 3-3/8 inches wide surrounded by wax paper the size of the mold box. This divider, with the tinfoil, served as a conductor for the current and also as a means of separating the layers from each other.

PROCEDURE

Milling and Screening

The clays were ground by passing through rolls. After passing through the rolls they were screened through a Great Western Manufacturing Company gyratory riddle screen. The St. Louis Surface clay was ground to pass a 10-mesh screen, while the Semi-Flint, Flint, and Grog were passed through an 8-mesh screen. In each case the oversize was reground until the entire sample passed through the screen.

Tempering

After grinding, each clay and mix was tempered by hand in a large tub. A moisture determination was made of each clay before the tempering water was added so that from eight to ten percent moisture was added to each mix, that is by weight. After adding the necessary water the mix was kneaded by hand and then passed through a screen to break up the lumps that had formed. The tempered mix then was allowed to stand under cover for twenty-four hours before forming,to insure uniform moisture distribution.

Forming

The mix was introduced into the mold box by hand; a two inch layer was put in and covered with a separator made of tinfoil and wax paper. The weight of this layer was determined and all of the following layers weighed the same to insure uniformity. All of the clays or mixes took different amounts for the block. The average was approximately four pounds.

After charging the mold box with eight 2 inch layers the pump was turned on and the press run until 2000 pounds per square inch final pressure was attained. This was held for three seconds by the manipulation of valves.

During the pressing,direct current was applied in varying amounts, as alternating current could not be used because of its directional change. Any concentration of moisture at the mold surface would be destroyed by the reversal of the direction of flow. The current was applied as soon as the ram began to move upward and remained on until the block was removed.

In the first part of the investigation just one positive electrode was placed at the top on the movable ram block but later it was found necessary to place another positive electrode on the lower ram.

The positive current was applied through these electrodes and the mold box acted as the negative pole. In this way the water was drawn to the mold box surface and acted as a lubricant. Little current flowed during the start of the application of pressure, but as the clay became compressed the current flow also increased and had to be regulated so that the desired flow could be obtained. This limit was between five and fifteen amperes.

In the latter part of the investigation and electrolyte, ammonium chloride, one-tenth normal solution, was used as the tempering medium to determine effect as a conductor for the current and to determine its action as a lubricant.

A block was also formed in which no current was applied so that a comparison could be made with respect to those in which the current had been applied.

Sampling and Drying

After forming, the blocks were removed from the mold box and the layers separated and samples obtained as shown by the dotted lines in the Fig. 3 on the following page. Each layer was divided into eight squares and squares (a) and (b), as shown in Fig. 3 were used for determinations of porosity. These samples were dried at room temperature for twenty-four

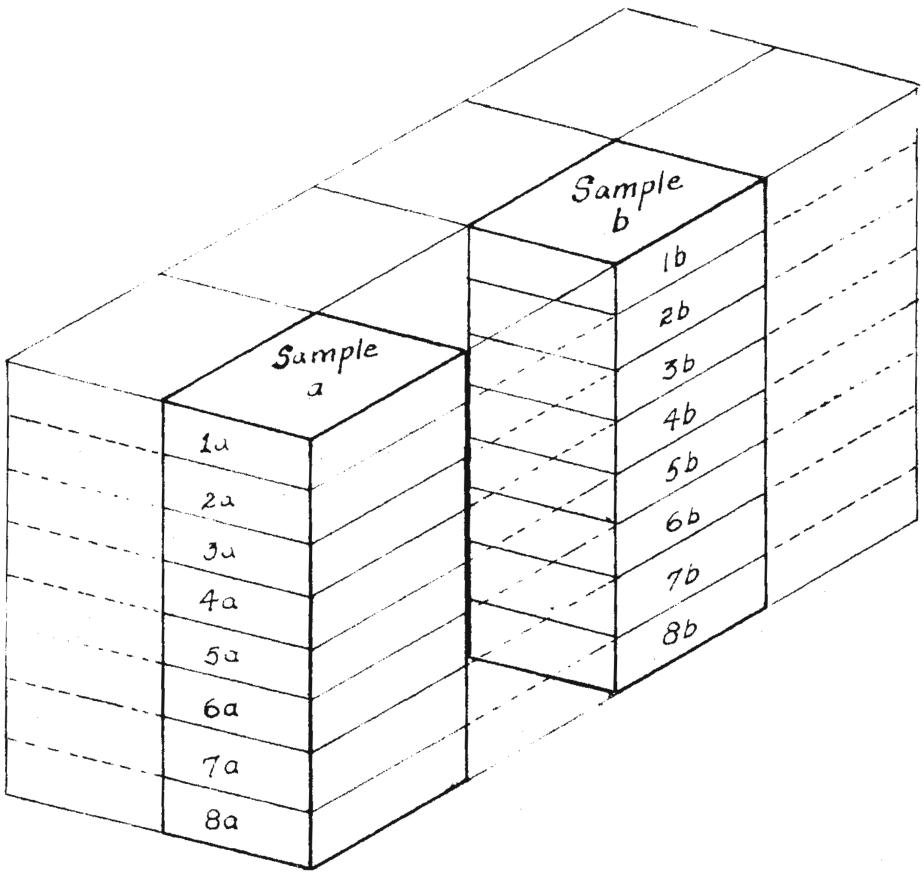


Figure 3

hours, and then completely dried for twenty-four hours at 235°F.

Apparent Porosity Determinations

The two pieces or squares from each layer, which were completely dried, were allowed to cool in a dessicator. After cooling they were brushed to remove the loose particles and weighed to the nearest 0.1 gram. The samples were then immersed in kerosene and put under a vacuum of 20 inches for three hours, after which the weights saturated and the weights suspended in kerosene were determined and recorded.

The apparent porosities were calculated for each of the samples by use of the following formula:

$$\text{Apparent Porosity} = \frac{\text{Weight Saturated} - \text{Weight Dry}}{\text{Weight Saturated} - \text{Weight Suspended}}$$

The average of the two samples of each layer was obtained and plotted against the layer number to obtain the curves shown in the graphs.

DATA

The data was obtained as outlined in the porosity determination after which the porosity was calculated and an average made of each layer of each block. The porosity was then plotted against the layer number of each block and a comparison made of each of the runs.

Table I - Plot I - These data show the porosities obtained when no current was supplied to the St.Louis Surface Clay.

Table II - Plot I - These data and the plot show the porosity of the St.Louis Surface Clay when 5 amperes current is supplied with a positive electrode at the top of the clay.

Table III - Plot I - These data and the plot show the porosity of the St.Louis, Surface Clay when 6-½ amperes current is supplied with a positive electrode at the top and bottom.

Table IV - Plot I - These data and the plot show the porosity of the St.Louis Surface Clay when 7 amperes current is supplied with a positive electrode at the top and bottom and when the tempering water was a 0.1 normal solution of ammonium chloride.

Table V - Plot I - These data and the plot show the porosity of the St. Louis Surface Clay when no current was supplied and a 0.1 normal solution of ammonium chloride served as the tempering medium.

Table VI - Plot II - These data and the plot show the porosity obtained with a mix of North Missouri Semi-Flint 85.7% and St.Louis Surface Clay 14.3% when 5 amperes current is supplied with a positive electrode at the top.

Table VII - Plot II - These data and the plot show the porosity of A North Missouri Semi-flint 85.7% and St.Louis Surface Clay 14.3% mixture when no current is supplied.

Table VIII - Plot II - These data and the plot show the porosity of a mix of North Missouri Semi-Flint 85.7% and St.Louis Surface Clay 14.3% when subjected to a 6-½ ampere current with a positive electrode at the top and bottom.

Table IX - Plot III - These data and the plot show the porosity obtained by a mix of North Missouri Semi-Flint 92% and Fire Brick Grog 8% when subject to no current.

Table X - Plot III - These data and the plot show the porosity of a mix of North Missouri Semi-

Flint 92% and Fire Brick Grog 8% when subject to a current of 14 amperes with a positive electrode at the top of the clay.

Table XI - Plot III - These data and the plot show the porosity of a mix of North Missouri Semi-Flint 92% and Fire Brick Grog 8% when subjected to a current of 6 amperes with a positive electrode at the top and bottom.

Table XII - Plot III- These data and the plot show the porosity obtained by a mix of North Missouri Semi-Flint 92% and Fire Brick Grog 8% when subjected at a current of 7 amperes with a positive electrode at the top and bottom and a 0.1 normal solution of ammonium chloride added as the tempering water.

Table XIII - Plot IV - These data and the plot show the porosity obtained by a mix of North Missouri Semi-Flint 25% and Missouri No. 1 Flint 75% when subjected to no current.

Table XIV - Plot IV - These data and the plot show the porosity obtained by a mix of North Missouri Semi-Flint 25% and Missouri No.1 Flint when subjected to a current of 7-½ amperes with an electrode at the top of the clay.

Table XV - Plot IV - These data and the plot show the porosity obtained by a mix of North Missouri Semi-Flint 25% and Missouri No.1 Flint 75%

when subjected to a current of 7 amperes and with a 0.1 normal solution of ammonium chloride added as the tempering water.

TABLE I

St. Louis Surface Clay

Pressure	2000 lbs/sq. in.
Current	none
Moisture	10%
Weight per layer	Approximately 4 lbs.

Percent Apparent Porosity

Layer	Sample(a)	Sample (b)	Average of Two
1	27.58	26.35	26.97
2	27.56	27.30	27.43
3	28.48	28.08	28.28
4	28.10	27.89	28.00
5	25.91	25.65	25.78
6	25.83	25.50	25.68
7	23.98	25.10	24.54
8	23.05	25.19	24.12

TABLE II

St. Louis Surface Clay

Pressure	2000 lbs/sq.in.
Current	5 amperes-one electrode
Moisture	10%
Weight per layer	Approximately 4 lbs.

Percent Apparent Porosity

Layer	Sample(a)	Sample(b)	Average of Two
1	26.85	26.80	26.83
2	26.80	26.95	26.88
3	26.72	27.38	27.05
4	26.50	26.42	26.46
5	26.35	26.32	26.34
6	24.20	25.53	24.87
7	24.00	24.48	24.28
8	23.40	24.52	23.96

TABLE III

St. Louis Surface Clay

Pressure	2000 lbs/sq.in.
Current	6½ amperes-two electrodes
Moisture	10%
Weight per layer	Approximately 4 lbs.

Percent Apparent Porosity

Layer	Sample(a)	Sample(b)	Average of Two
1	25.95	25.72	25.88
2	25.92	26.08	26.00
3	26.18	25.66	25.92
4	25.75	25.28	25.52
5	25.08	24.38	24.73
6	24.49	24.34	24.42
7	23.31	24.08	23.69
8	23.21	23.88	23.55

TABLE IV

St. Louis Surface Clay

Pressure	2000 lbs/sq.in.
Current	7 amperes-two electrodes
Moisture	10%
Electrolyte	Ammonium chloride
Weight per layer	Approximately 4 lbs.

Percent Apparent Porosity

Layer	Sample(a)	Sample(b)	Average of two
1	26.48	26.45	26.47
2	26.44	25.60	26.02
3	26.12	25.52	25.82
4	25.54	25.35	25.44
5	24.88	24.91	24.90
6	24.40	25.23	24.81
7	23.74	23.95	23.86
8	22.72	24.45	23.59

TABLE V

St. Louis Surface Clay

Pressure	2000 lbs/sq.in.
Current	none
Electrolyte	Ammonium chloride
Moisture	10%
Weight per layer	4 lbs. Approximately

Percent Apparent Porosity

Layer	Sample(a)	Sample(b)	Average of two
1	26.40	25.86	26.13
2	26.12	25.92	26.02
3	26.85	26.01	26.43
4	26.74	25.68	26.21
5	26.12	25.35	25.90
6	25.26	25.38	25.32
7	24.57	24.68	24.62
8	23.51	23.78	23.64

TABLE VI

North Missouri Semi-Flint 85.7%
St. Louis Surface Clay 14.3%

Pressure	2000 lbs/sq.in.
Current	5 amperes-one electrode
Moisture	9.4%
Weight per layer	Approximately 3-$\frac{3}{4}$ lbs.

Percent Apparent Porosity

Layer	Sample(a)	Sample(b)	Average of two
1	19.24	18.79	19.01
2	19.44	18.32	18.88
3	18.35	18.83	18.59
4	18.14	18.74	18.44
5	18.11	18.56	18.34
6	17.78	17.93	17.85
7	17.16	17.46	17.85
8	16.60	16.36	16.48

TABLE VII

North Missouri Semi-Flint 85.7%
St. Louis Surface Clay 14.3%

Pressure	2000 lbs/sq.in.
Current	None
Moisture	9.4%
Weight per layer	Approximately 3-$\frac{3}{4}$ lbs.

Percent Apparent Porosity

Layer	Sample(a)	Sample(b)	Average of two
1	18.40	18.46	18.43
2	18.90	18.55	18.72
3	18.53	18.72	18.63
4	17.67	17.27	17.47
5	17.88	17.94	17.91
6	17.86	17.91	17.88
7	16.92	17.76	17.34
8	17.20	17.82	17.51

TABLE VIII

North Missouri Semi-Flint	85.7%
St. Louis Surface Clay	14.3%

Pressure	2000 lbs/sq.in.
Current	6-½ amperes-two electrodes
Moisture	9.5%
Weight per layer	Approximately 3-¾ lbs.

Percent Apparent Porosity

Layer	Sample(a)	Sample(b)	Average of two
1	18.01	17.65	17.83
2	18.46	16.50	17.48
3	16.87	16.65	16.86
4	17.05	16.44	16.74
5	16.12	17.05	16.59
6	16.62	16.38	16.50
7	15.86	16.79	16.33
8	15.58	16.39	15.99

TABLE IX

North Missouri Semi-Flint 92%
Fire Brick Grog 8%

Pressure	2000 lbs/sq.in.
Current	none
Moisture	8%
Weight per layer	Approximately 4 lbs.

Percent Apparent Porosity

Layer	Sample(a)	Sample(b)	Average of two
1	17.41	16.87	17.14
2	17.24	17.76	17.50
3	16.56	16.82	16.69
4	16.14	15.86	16.00
5	16.14	16.03	16.08
6	15.07	15.18	15.13
7	14.94	15.39	15.16
8	15.04	14.94	14.54

TABLE X

North Missouri Semi-Flint 92%
Fire Brick Grog 8%

Pressure	2000 lbs/sq.in.
Current	14 amperes-one electrode
Moisture	8%
Weight per layer	Approximately 4 lbs.

Percent Apparent Porosity

Layer	Sample(a)	Sample(b)	Average of two
1	16.13	16.41	16.27
2	16.67	16.65	16.66
3	16.97	15.97	16.47
4	16.25	15.94	16.10
5	15.76	15.83	15.79
6	15.44	15.83	15.64
7	15.43	15.62	15.52
8	14.81	14.72	14.77

TABLE XI

North Missouri Semi-Flint 92%
Fire Brick Grog 8%

Pressure	2000 lbs/sq.in.
Current	6 amperes-two electrodes
Moisture	8%
Weight per layer	Approximately 4 lbs.

Percent Apparent Porosity

Layer	Sample(a)	Sample(b)	Average of two
1	16.67	16.94	16.80
2	16.63	16.27	16.45
3	16.06	15.84	15.95
4	16.17	15.50	15.83
5	15.74	15.50	15.62
6	15.26	15.66	15.46
7	15.05	15.86	15.45
8	14.94	14.75	14.85

TABLE XII

North Missouri Semi-Flint 92%
Fire Brick Grog 8%

Pressure	2000 lbs/sq.in.
Current	7 amperes-twp electrodes
Electrolyte	Ammonium chloride
Moisture	9%
Weight per layer	Approximately 4 lbs.

Percent Apparent Porosity

Layer	Sample(a)	Sample(b)	Average of two
1	16.67	17.16	16.92
2	17.59	17.34	17.46
3	17.01	17.22	17.17
4	17.45	17.23	17.34
5	16.47	17.51	16.99
6	16.72	17.08	16.90
7	16.94	17.36	17.15
8	16.77	17.53	17.15

TABLE XIII

North Missouri Semi-Flint 25%
Missouri No. 1 Flint 75%

Pressure	2000 lbs/sq.in.
Current	none
Moisture	8%
Weight per layer	Approximately 3-$\frac{3}{4}$ lbs.

Percent Apparent Porosity

Layer	Sample(a)	Sample(b)	Average of two
1	22.75	22.78	22.77
2	22.68	22.65	22.67
3	23.02	23.14	23.08
4	22.42	22.61	22.52
5	21.72	21.35	21.54
6	21.55	21.88	21.72
7	20.95	21.68	21.32
8	21.04	21.15	21.08

TABLE XIV

North Missouri Semi-Flint 25%
Missouri No. 1 Flint 75%

Pressure	2000 lbs/sq.in.
Current	7-$\frac{1}{2}$ amperes-one electrode
Moisture	8%
Weight per layer	Approximately 3-$\frac{3}{4}$ lbs.

Percent Apparent Porosity

Layer	Sample(a)	Sample(b)	Average of two
1	23.08	22.68	22.88
2	23.28	22.50	22.89
3	22.82	21.94	22.38
4	22.52	22.05	22.29
5	21.72	22.12	21.92
6	21.21	21.48	21.34
7	21.08	21.62	21.35
8	21.11	21.24	21.17

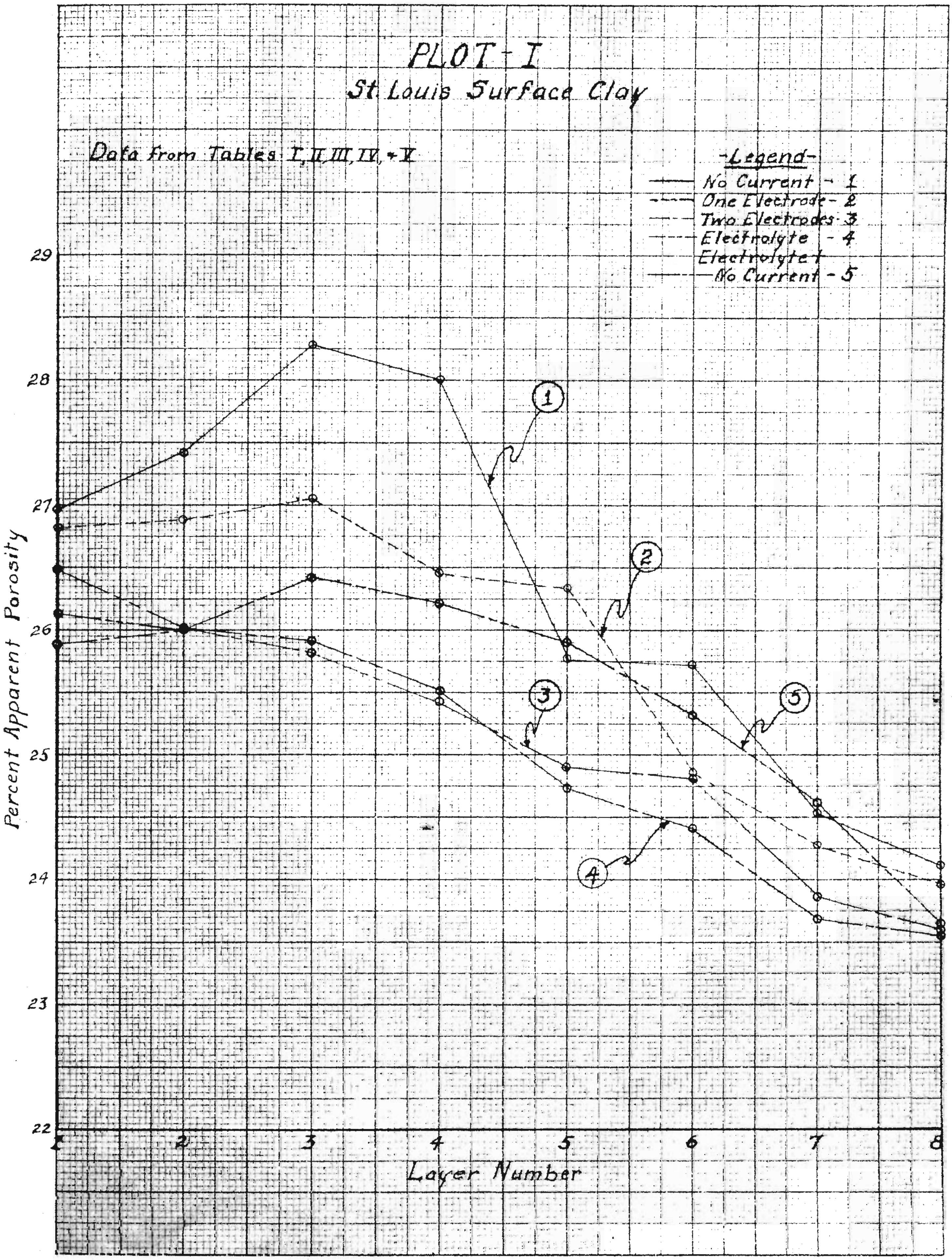
TABLE XV

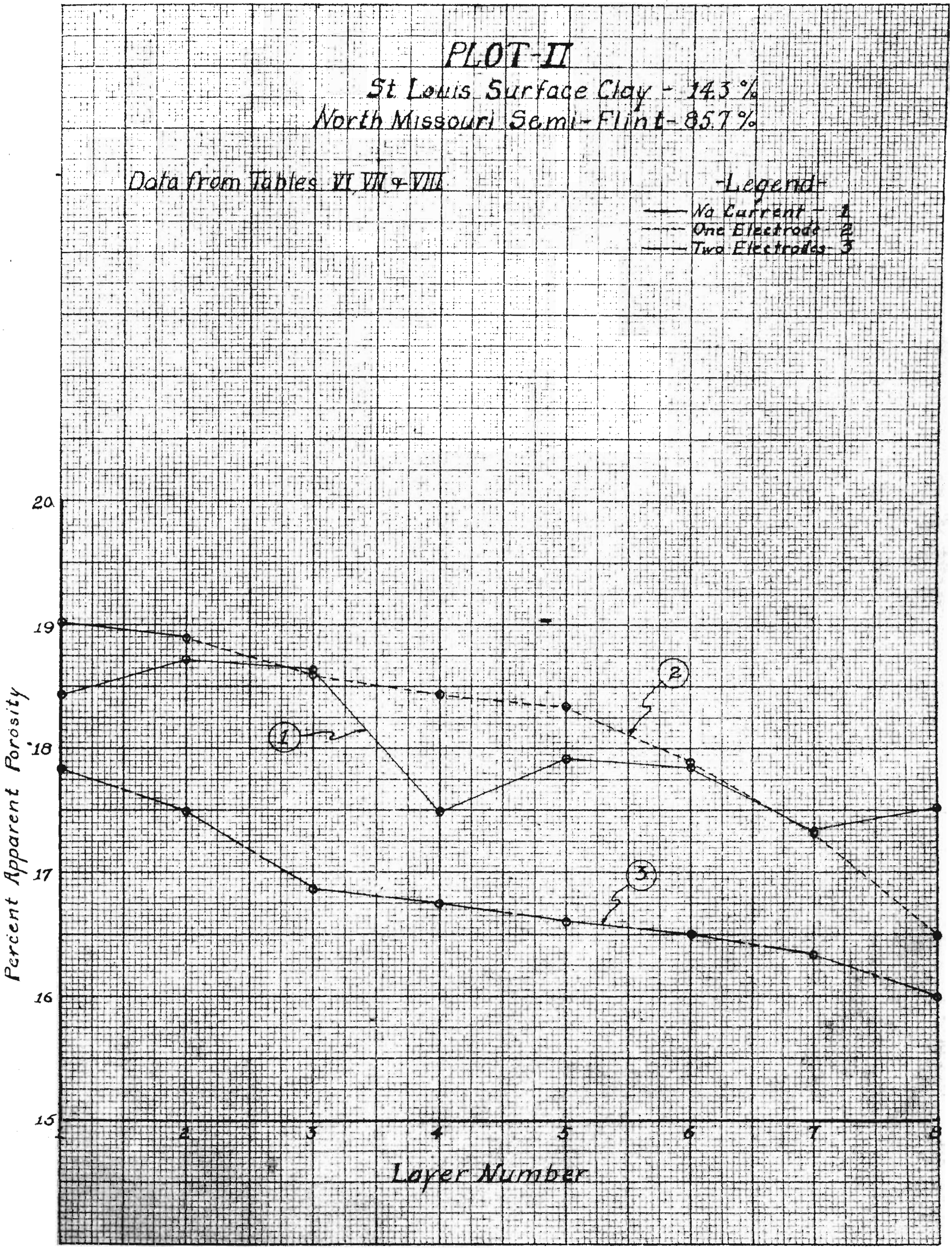
North Missouri Semi-Flint	25%
Missouri No.1 Flint	75%

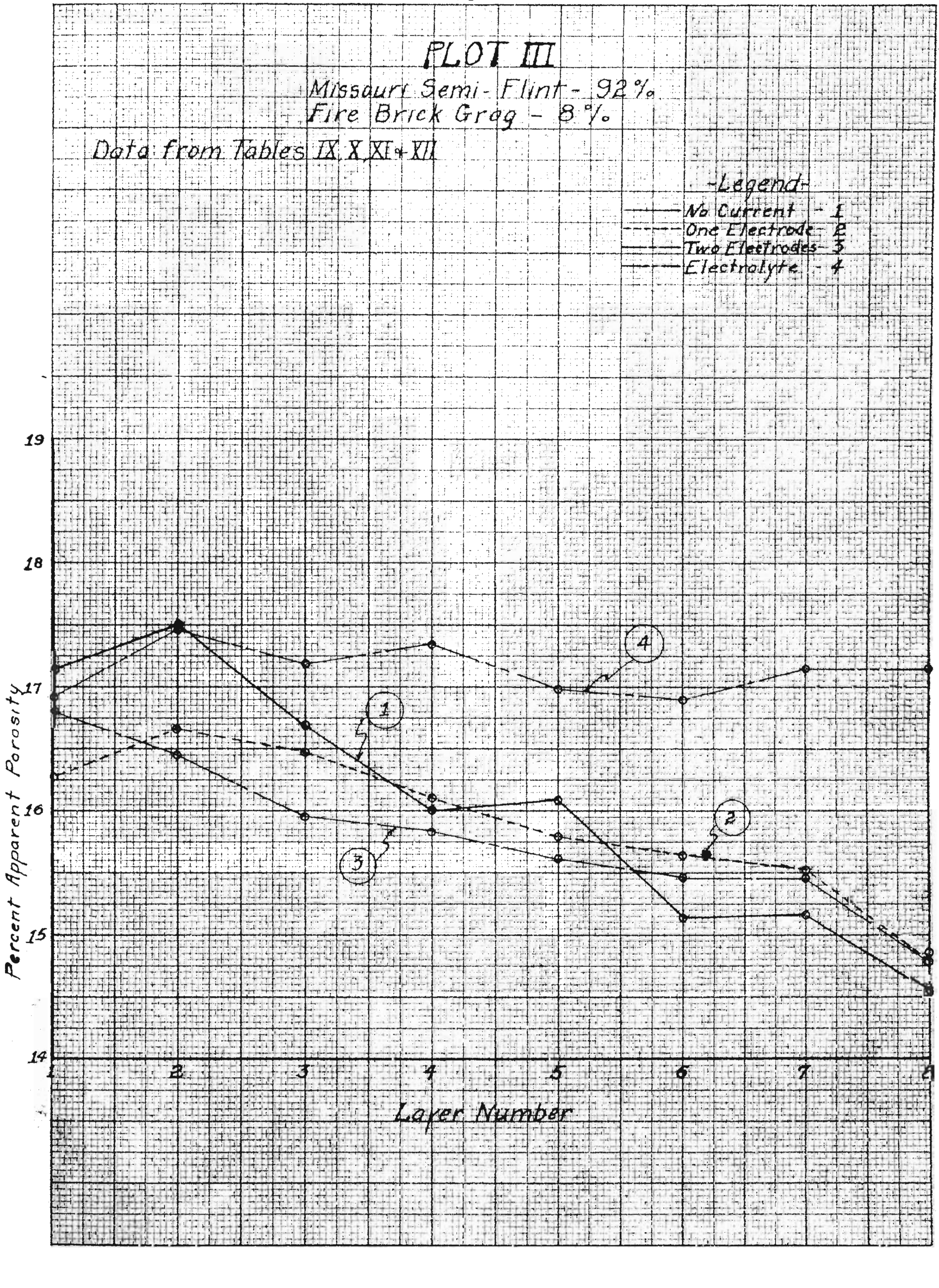
Pressure	2000 lbs./sq.in.
Current	7 amperes-two electrodes
Electrolyte	Ammonium chloride
Moisture	10%
Weight per layer	Approximately 3-¾ lbs.

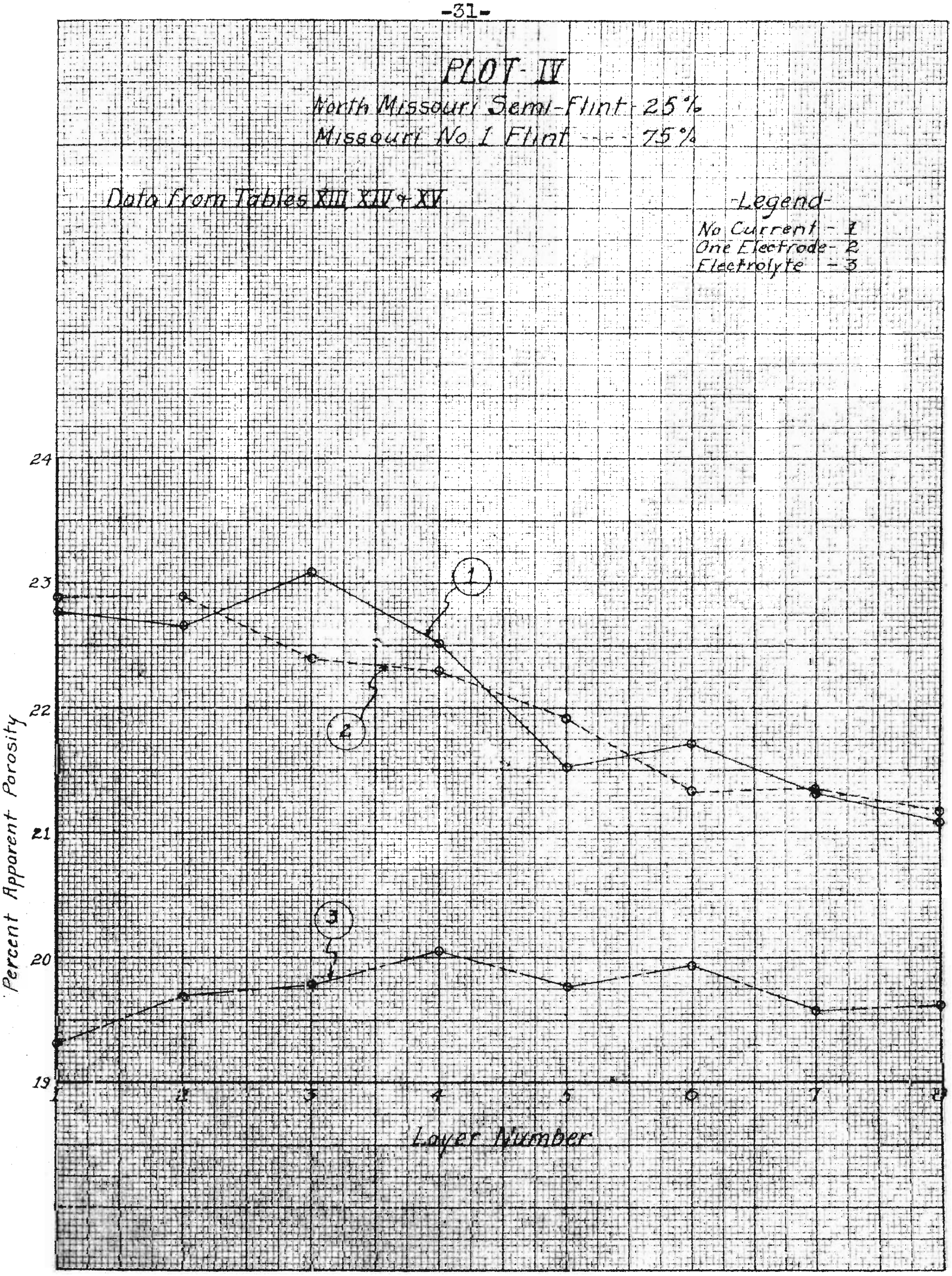
Percent Apparent Porosity

Layer	Sample(a)	Sample(b)	Average of two
1	19.31	19.30	19.31
2	19.35	20.02	19.69
3	19.75	19.81	19.78
4	20.12	19.98	20.05
5	19.68	19.83	19.76
6	19.91	19.97	19.94
7	19.65	19.58	19.62
8	19.67	19.65	19.66


PLOT - I
St. Louis Surface Clay
Data from Tables I, II, III, IV, + V
-Legend-
No Current - 1
One Electrode - 2
Two Electrodes - 3
Electrolyte - 4
Electrolyte + No Current - 5
Percent Apparent Porosity
22
23
24
25
26
27
28
29
1
2
3
4
5
6
7
8
Layer Number


PLOT-II
St Louis Surface Clay - 14.3 %
North Missouri Semi-Flint - 85.7 %
Data from Tables VI VII & VIII
-Legend-
No Current - 1
One Electrode - 2
Two Electrodes - 3
Percent Apparent Porosity
20
19
18
17
16
15
1
2
3
4
5
6
7
8
Layer Number


PLOT III
Missouri Semi-Flint - 92%
Fire Brick Grog - 8%
Data from Tables IX, X, XI + XII
-Legend-
No Current - 1
One Electrode - 2
Two Electrodes - 3
Electrolyte - 4
Percent Apparent Porosity
14
15
16
17
18
19
Layer Number
1
2
3
4
5
6
7
8


PLOT IV
North Missouri Semi-Flint 25%
Missouri No 1 Flint ---- 75%
Data from Tables XIII, XIV + XV
-Legend-
No Current - 1
One Electrode - 2
Electrolyte - 3
Percent Apparent Porosity
24
23
22
21
20
19
1
2
3
4
5
6
7
8
Layer Number

DISCUSSION OF DATA

St. Louis Surface Clay - If we make a comparison of the plotted curves as obtained by each of the different runs with this surface clay it can be seen that there is a great variation. In the case where no current was applied the curve shows an increase in porosity in the center layers which should be, as explained in the theory, and drops off rapidly in the lower layers which are more compressed. Where current was applied with one electrode at the top the first five layers show a rather smooth level curve, but it drops off readily with the last three layers, showing that some lubrication was obtained for the first five which show approximately the same porosity but greater compression in the last three. In the run where two positive electrodes were used, with and without the electrolyte, the curve shows a gradual decrease from the top layer to the lower layer. This is as we would expect since the compression begins at the bottom where the grains are compressed much closer together. In the case where the electrolyte was added without the addition of current a curve is obtained much the same as with that mix tempered with water and no current supplied except, that it does not reach as high a peak for the center layers.

North Missouri Semi-Flint 85.7% - St.Louis Surface Clay 14.3%. - With this mix, the curve obtained without the use of current reaches a peak or greatest porosity in the center layers as we would expect. When current was added with a positive electrode at the top the curve is level for the first five layers and then shows a decided drop. With an electrode at the top and the bottom a smooth curve, with a gradual decrease, was obtained and should be expected as explained previously.

North Missouri Semi-Flint 92% - Fire Brick Grog 8% - This mix showed the same characreristic curves as those obtained with the other mixes, except where the electrolyte was added and current applied with the two electrodes. This curve showed a rather constant porosity, not varying more than .5 percent but it did have two points which were a little high. This characteristic is difficult to explain unless it could be said to be due to other properties such as grain size, entrapped air, etc..

<u>North Missouri Semi-Flint 25% - Missouri No.1 Flint 75%</u>

This plot of curves showed about the same characteristics as that of plot III. The addition of the electrolyte and current gave porosities not varying more than .7 percent but it showed uneven points on the curve at various layers. This can probably be explained as was done with those of plot III.

In the first attempts to supply current, with just the one positive electrode at the top, difficulty was encountered. Because of the resistance of the clay to the passage of current, heat developed in the layer under the electrode and steam was generated which in one case when the top ram had been removed caused the electrode to be blown off and cracked the top layer. This heat generated also caused a drying effect on the top layer which resulted in laminations. To overcome this a second positive electrode was placed on the bottom ram and better results were obtained as shown by the curves. The addition of the electrolyte produced even better results allowing more current to be conducted through the clay mix.

SUMMARY OF RESULTS

In summarizing the results obtained we may readily say that the addition of current is satisfactory for the lubrication of the mold box. While the application of current with one positive electrode at the top of the clay did not bring the results hoped for it did have an effect on the first five layers, giving substantially equal porosity. When two positive electrodes were used, one at the top and one at the bottom, results were obtained as was expected, showing a practically straight line porosity decreasing gradually with each lower layer. The addition of the electrolyte and the application of current showed even more conclusive results as to the lubrication of the mold box. It showed a straight line porosity curve decreasing gradually with each lower layer. This decrease would be expected as the application of pressure from the bottom would cause each successive upper layer to be compressed much less than the one underneath and would therefore give greater porosity.

CONCLUSION

In conclusion, it may be said that, the application of current as a means of lubricating the dry-press mold box is a very satisfactory method, but positive current must be supplied from the top and bottom and the mold box must act as the negative electrode; the addition of an electrolyte gives much better results as shown by the porosity curves due to the more uniform passage of current throughout the mix.

APPLICATION TO INDUSTRY

The results of this experiment show that the application of current as a lubricant is satisfactory so that these findings may be very beneficial to the industry in several ways. In the first place, by lubricating the dry press mold box with current will in all probability dispence with many of the variations in physical characteristics and produce more nearly perfect dry pressed ware. Mold box friction may be overcome and this will do away with many laminations obtained before.

In practically all plants today the branding plate for their refractories is lubricated with oil or heat of some character and it is my belief that this plate could be lubricated with current and do away with other methods of lubrication.

RECOMMENDATIONS FOR FURTHER RESEARCH

This problem of electrical lubrication can be further investigated along the following steps:

1. To find the exact current necessary to obtain the optimum lubrication and do away with the cost of excess current.