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A STUDY OF THE POSSIBILITY OF IMPROVING
GEORGIA OCHER BY ELECTROPHORESIS

Submitted to the
A THESIS

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by

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TABLE OF CONTENTS

1.	Abstract.	Page 1
2.	Introduction.	2
3.	Chemical and Microscopic Analysis.	
	Procedure	10
	Results	12
4.	Selection of the Electrolyte to Stabilize Suspension of Ocher in Water.	
	Procedure	14
	Results	15
5.	The Electrophoresis Cell.	
	Apparatus	18
	Pictures	20
	Procedure	22
	Results	24
6.	Electrophoresis with different Electrodes.	
	Apparatus	25
	Procedure	25
	Results	26
7.	Redesign of Cell.	29
8.	Miscellaneous.	30
9.	Conclusions.	31
10.	Recommended Procedure.	32
11.	Drawings and Sketches.	33

ABSTRACT

A chemical analysis of Georgia ocher is shown. The design of a revolving anode type of electrophoresis machine is included, with data obtained from its operation. Settling tests with different electrolytes used to stabilize a suspension of ocher in water are included. A study concerning the best metal to use as the anode and cathode in the construction of a cell for the electrophoresis of ocher is shown. A re-designed cell incorporating the materials contained in the above work is also included.

INTRODUCTION

Ocher or ochery earth is a natural mineral pigment composed largely of clay permeated with hydrated iron (Ferric Oxide). (1) Its color ranges from yellow through orange to reddish brown, depending largely on the amount of iron present.

Georgia leads this nation in its production with a yearly output estimated at over 15,000 tons. (2) Even though Georgia ocher compares favorably with the domestic supply, that produced in France is worth from three to five times as much per ton owing to its better grade of color. Therefore, it was deemed advisable that the State Engineering Experiment Station undertake the work of studying this ocher and finding some means to improve its quality; that is, mainly, its color.

Electrical endosmosis is the migration of colloidal particles in a stiff paste under the influence of an unidirectional current. Reuss of Moscow observed this phenomenon in 1808. (3)

- (1) United States Tariff Commission, Tariff Information Survey; Par. 35, Act of 1913; A-15.
- (2) Information Circular, U. S. Bureau of Mines; No. 6132; May 1929; "Ocher and Ochery Earths" by Santmyers.
- (3) Alexander, Colloidal Chemistry. Vol. 3, Pg. 673.

Two glass tubes were inserted vertically in a lump of moist clay, the tubes were filled with water, and by means of electrodes an electric current was sent through the apparatus. The water level in one of the tubes rose while the water level in the other tube fell and at the same time the latter tube became cloudy. Reuss thus discovered that under the influence of a direct electromotive force the water migrated through the somewhat porous clay diaphragm towards one electrode while loose particles of solid clay migrated to the opposite electrode.

This phenomenon has attracted the attention of many investigators, especially in the field of physical chemistry and colloidal chemistry, who have given considerable time to the study of the electrical behavior of various suspensions and liquids.

It has been found that many liquids, under the influence of an unidirectional electromotive force, may be forced through stationary diaphragms. The term "Electro-osmosis" has been proposed by O. C. Ralston (4) to replace a number of other names which have been given to this phenomenon. Likewise, it has been found that most solid materials, when suspended as fine particles in certain liquids, acquire an electric charge.

- (4) O. C. Ralston, "Electrophoresis and Electro-osmosis" Chemical and Metallurgical Engineering, No. 27, 778, 1932.

Under the influence of an unidirectional electromotive force, these particles can be made to travel toward one of the electrodes. Ralston has proposed that this traveling of solid particles through a liquid due to electrical forces shall be called "Electrophoresis".

However, other workers seem to favor the terms endosmosis and cataphoresis for these two phenomena and in the literature these seem to be interchangeable.

The present development of electrophoresis or cataphoresis as applied to clays can, in a large part, be ascribed to Count Bothro von Schverin. (5) Between 1901 and 1918, he obtained nineteen patents in this country on cataphoretic and endosmotic equipment and on processes for both peat and clay. It might be of interest to add that he first studied law and philosophy receiving the degree of Doctor of Jurisprudence. Later deciding chemistry was his field, he studied under Emil Fisher at the University of Berlin and under Professor Bayer, inventor of the indigo synthesis, in Munich. After this he undertook the dewatering of peat by endosmosis which led to his later work on the endosmosis and cataphoresis of kaolin. His theory and equipment are still used in industry at the plant of the Carlsbad Electromose Company at Chodan, Czechoslovakia and other plants located in Saxony and East Prussia.

- (5) American Ceramic Society Journal, No. 14, 1931, Pg. 219 "The Electrical Dewatering of Clay Suspensions" by C. E. Curtis.

His United States patents were taken over by this country during the time of the World War. A plant in North Carolina has recently been reported to be using his processes.

Schverin's drum-anode electrophoresis machine was patented in this country in 1915. (U.S. 1,133,967). Schverin's machine gave the ideas for the machine constructed by H. S. Davis (5) whose work was incorporated in the construction of the machine used for this present work. This machine will be described a little later in this thesis.

A rather complete treatise on the Chodan plant is reported by Curtis. (5) The results seem to indicate that little purification of the Kaolin took place during electrophoresis but the machine seems to give more effective results in dewatering clays.

A. V. Bleininger (6) conducted some experiments on electrophoresis at the U. S. Bureau of Standards in 1912. Preliminary tests with the revolving anode type of machine showed that the best electrolyte for general purposes was sodium hydroxide, and that the amount of reagent necessary never exceeded 0.2% of the weight of dry clay. Sodium oxalate proved to be slightly superior in some cases. Sodium silicate was not tried.

- (6) American Ceramics Society No. 15, 1913, Pg. 338.
A. V. Bleininger, "Electrical Separation of Clay".

It was also noted that the velocity of migration of the clay particles seemed to be independent of their size and shape within certain limits. A potential difference of 220 volts was impressed and a clay was obtained with only 25% water. It is interesting to note that good separation of flint and feldspar from clay was obtained but no separation of ferric oxide from clay took place.

L. G. Hall (7) working with cement slurries gave the following facts:

1. The opposite charges on the liquid and solid are probably due to the "electrical double layer," which is purely a surface effect; hence the efficiency of the process depends on the amount of surface exposed.
2. The velocity of the particles approximates that of ions and increases with the voltage.
3. The degree of dehydration is a function of the voltage.
4. The amount of material moved is proportional to the amperage.
5. The efficiency of the process is directly proportional to the fluidity. (He used thick slurries.)

The completeness of dewatering was found to be dependent on the voltage only. With clay, a deposit was obtained which was very wet at 30 volts but at 1000 volts was very dry.

- (7) L. G. Hall, "Electrical Unwatering of Portland Cement Slurry", Cement Mill & Quarry (Now Pit & Quarry) 32, Nos. 9, 11, 12, 16, 1928.

There was an economic limit, however, to the voltage that could be used, due to the loss of current through electrolysis of the water at higher voltages.

The current consumption was dependent upon two factors. The first of these was the amount of electrolyte present. Some electrolyte was necessary to increase the yield, but the amount should be maintained as low as possible to prevent loss of current through electrolysis of the water. A second factor was the viscosity, which could be lowered by the use of electrolytes or by raising the temperature of the suspension.

Adsorbed air was also detrimental to efficiency of current use. However, adsorbed air could be released by the addition of electrolytes. In comparing cement slurries with clay suspensions, it was found that they differ in the fact that cement slurries contain two materials, clay and limestone, with opposite electrical tendencies. The clay would tend to go to the anode while limestone would tend to go towards the cathode. Since, however, mutually adsorptive materials tend to go to the same pole, both the limestone and clay would go to the anode unless the electric potential ruptured the adsorption bond. This was also shown in Bleining-er's experiments with clay and ocher. (8)

- (8) A. V. Bleininger, "Use of Sodium salts in Purification of Clays and in the Casting Process," U. S. Bureau of Standard Technical Paper No. 51, 1915.

A great deal of work was done in 1928, 1929, and 1930 (9) by Vance S. Cartwright, Howard S. Davis, and Carl E. Curtis at the Northwest Experiment Station, U. S. Bureau of Mines in cooperation with the University of Washington, as a part of a general program in investigating the dewatering of Pacific Northwest plastic kaolins. In their experiments they obtained the following results.

1. The concentration of electrolyte which gives the maximum dispersion as determined by settling tests agrees approximately with the concentration which gives the best results in electrophoresis.

2. A certain degree of dewatering can be obtained by using a suspension to which no deflocculent has been added but a deflocculent seems to be necessary for efficient dewatering. Of the deflocculents tested, sodium silicate gave better results than sodium hydroxide. The best results with sodium silicate were obtained when the concentration of dry silicate was below 0.6% of the weight of dry clay in suspension. Five percent sodium hydroxide produced coagulation.

3. In most cases cataphoresis raised the indicated hydrogen ion content of a dispersed suspension, but lowered the pH of the clay which collected on the anode to, or below neutrality.

4. The cost of electricity in terms of direct current at one cent per kilowatt hour, and with the maximum efficiency attained with the present machine, would be \$1.30 per ton of dry clay. With the efficiency attained at Carlsbad it is calculated that the cost would be between 65 and 80 cents per ton, depending on the particular authority.

5. While the experiments thus far seem to indicate that the process is, as Bleininger pointed out, a substitute for filter pressing, it should be noted that it might be more efficient than filter pressing in the case of a very fine grained or very plastic clay which is filter-pressed with difficulty. It likewise offers a continuous method for the partial dewatering of clays and allied semi-colloidal suspensions.

(9) American Ceramic Society Journal, No. 14, 1931, Pg. 219. "The Electrical Dewatering of Clay Suspensions," by C. E. Curtis.

Grange (10) states that if the iron is in the form of a silicate, it can be removed from clay but the carbonate, oxide, and hydroxide of iron migrate to the anode along with the clay.

(10) Ceramics Abstracts, 6, 1927, Pg. 35.
"Electro-osmosis and its Application to Purifying Clays."

CHEMICAL AND MICROSCOPIC ANALYSIS OF THE OCHER PROCEDURE

No definite information was available, but it was generally considered that the iron was present in Georgia ocher as the hydrated oxide. In light of previous work on kaolin, one could hardly expect to remove iron in this form from ocher. Therefore, it was necessary to determine the composition of Georgia ocher and proceed with the experimental refining according. If the iron was found to be present in the form of the oxide there was still the possibility of depending on a change of particle size as a means of beneficiation.

The ocher used in all this work was obtained from the New Riverside Ocher Company, Cartersville, Georgia. Samples of number 404 raw and number 404 refined were used. Moisture, loss on ignition, silica, ferric oxide, aluminum oxide, manganese dioxide, titania, barium oxide, magnesium oxide, calcium oxide, and the specific gravity were determined on both these ochers. All of the methods used for these analysis were taken from the rock analysis by Mahin (11) except that for manganese which was taken from the method of the American Society for Testing Materials (12) and that for titania which was taken from the cup-ferron method as developed by Hilderbrand and Lundell in their text. (13)

- (11) Mahin, Quantitative Analysis, 1932.
- (12) American Society for Testing Materials. C 18-35
- (13) Hilderbrand & Lundell, Applied Inorganic Analysis.

A microscopic examination of the ocher was made to try and determine the actual minerals present in the ocher. A Zeiss petrographic microscope and all of its accessories were used in this work. Glass slides were made by first making a very dilute suspension of the ocher in water, placing a few drops on the slide, and allowing to dry. Also slides were made of the heavy minerals in the ocher by the same method after these minerals had been separated by elutriation over a period of two weeks time.

The procedure for the identification of the minerals in the ocher was taken from the scheme from Rodgers and Kerr, (14) and Larsen's tables, (15) and U. S. Geological tables, (16) were used for their identification.

- (14) Rodgers & Kerr; "Thin-Section Mineralogy" McGraw-Hill, 1933.
- (15) Esper S. Larsen: "Microscopic Determination of Non Opaque Minerals" - 1927.
- (16) Bulletin 848 - U. S. Geological Survey - 1932.

RESULTS

The following table shows the results of the chemical analyses that were made in comparison with a published analyses of French ocher.

Table No. 1

Ocher	#404 Raw	#404 Refined	Prepared French (17)
Moisture	0.54	0.82	1.8
Loss on ignition	8.40	9.24	9.2
Silica	25.21	20.72	54.0
Ferric oxide	58.21	61.66	20.7
Alumina	4.56	5.60	13.8
Manganese dioxide	2.68	2.22	-
Titinia	0.89	0.54	-
Barium oxide	trace	trace	
Magnesium oxide	trace	trace	
Calcium oxide	trace	trace	
Specific gravity	3.0594	3.0084	

(17) Paints, Colors, Oils, and Varnishes,
C. H. Hurst.

The results of these analyses showed that the Georgia ocher has a very high iron content and a lower clay and silica content in comparison with the French ochers which are the accepted standards in regard to ochers used as paint pigments. This analysis also shows that by the process of refining the moisture, iron and alumina were increased, while the silica content was lowered. The specific gravity and the titinia and manganese contents remained approximately the same.

Unsatisfactory results were obtained with petrographic methods for the ocher seemed to consist entirely of opaque minerals. By the two methods used the only mineral definitely placed was limonite, ferric oxide with X waters of crystallization. The mineralogical forms in which the iron and manganese occur were not determinable due to the blanketing opacity effects produced by the ocherous constituents. Hence, no reliable conclusions could be reached as to their forms. However, one can tell the difference between French ocher and Georgia ocher under the microscope, for silica can be found in the French ocher but not in the Georgia ocher. This indicates that practically all the silica in the Georgia ocher exists in the form of a silicate instead of as a free silica.

The limonite was identified because it was of a yellow color, opaque and consisted of porous, massive, amorphous aggregates.

SELECTION OF THE ELECTROLYTE TO STABILIZE SUSPENSIONS OF OCHER IN WATER

PROCEDURE

Five percent suspensions of ocher by weight were used throughout these tests. The proper amount of ocher was placed in nessler tubes, the proper amount of water was added, followed by the proper amount of electrolyte. The nessler tubes were shaken thoroughly, the tubes were placed in racks, and the rate of settling was noted by watching the height of clear liquid left in the top of the tubes. A four-hour stabilization period was assumed to be sufficient for the purposes of this work. However, since most of the electrolytes tested did this, these settling tests were continued until some settling was noted in order to discriminate between the electrolyte as regards stabilizing properties. The concentration of electrolytes was based on a percentage of dry ocher used. The following percentages were run with each electrolyte: 0.1%, 0.2%, 0.3%, 0.6%, 1.5%, 3.0%, 6.0%. It was deemed best for comparative purposes to also express these percentages in gram equivalents of the positive ions and this is done in the table showing the results of this test. The following electrolytes were used: ammonium hydroxide, sodium hydroxide, sodium oxalate, sodium carbonate, sodium silicate, and a mixture (50-50) of sodium carbonate and silicate.

RESULTS

Table No. 2

1. Sodium Oxalate

%electrolyte by weight of ocher	0.1	0.2	0.3	0.6	1.5	3.0	6.0
Molality	.0009	.0019	.0028	.0056	.014	.028	.056
Time to settle in hours	30	24	4	2	1	$\frac{1}{2}$	$\frac{1}{2}$

2. Sodium Silicate

%electrolyte by weight of ocher	0.1	0.2	0.3	0.6	1.5	3.0	6.0
Molality	.00102	.002	.003	.006	.015	.03	.06
Time to settle in hours	36	40	56	36	30	24	18

3. Sodium Carbonate

% electrolyte by weight of ocher	0.1	0.2	0.3	0.6	1.5	3.0	6.0
Molality	.00118	.0024	.0035	.00708	.0177	.035	.0708
Time to settle in hours	36	48	30.	6	1	1	1

4. Sodium Hydroxide

% electrolyte by weight of ocher	0.1	0.2	0.3	0.6	1.5	3.0	6.0
Molality	.0063	.0024	.0035	.0071	.0177	.0354	.0708
Time to settle in hours	48	36	26	4	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$

5. Ammonium Hydroxide

% electrolyte	0.1	0.2	0.3	0.6	1.5	3.0	6.0
Molality	.007	.013	.019	.038	.094	.19	.37
Time in hours	3.0% was best but all took 90 or more hours to settle.						

6. Sodium Silcate & Carbonate

% electrolyte	0.1	0.2	0.3	0.6	1.5	3.0	6.0
Molality	.0011	.0022	.0033	.0066	.0165	.033	.066
Time in hours	36	48	30	16	12	6	$\frac{1}{2}$

Sodium silicate and ammonium hydroxide are shown by these tables to be the best electrolytes for this work for they both give a stable suspension for two or three days. In some respects the ammonium hydroxide was best but a comparison of costs seems to favor the use of the silicate for the electrophoretic work. The best concentration of silicate seems to be around 0.3% by weight of the ocher in suspension or around a molality of 0.003. This work, in the light of using the molalities, appears to be quite incomplete for the rate of settling with the molality under 0.02 for the sodium ion. The peptizing effect seems to be entirely dependent on the concentration of the sodium ion, and with the electrolytes of low molecular weight, the best concentration of the ions do not appear in the tables. However, the sodium oxalate seems to be by far the worst suspension electrolyte studied. It would be very interesting

to continue these studies with some other electrolytes such as ammonium carbonate or oxalate, to compare with the results already obtained. Also tests might be run using some organic substances such as gum arabic, gum tragacath and Bindex, the sulphite liquor extract of kraft paper manufacture. From such tables one could readily determine the effect of the different ions upon the suspensions. The electrolytes studied are used in making kaolin suspensions, and it was desired that the same apparatus be used to beneficiate both ocher and kaolin.

THE ELECTROPHORESIS CELL

APPARATUS

The design of the cell was the first phase of the work undertaken and actually consisted of assembling all the known data concerning the design of a cell for the electrophoresis of kaolin and simply applying these data to a revolving anode type cell. All of these data were taken from the work of Count Schverin (18) and the work of Hall (18) at the Northwest Experiment Station. It was already known that the machine would work with a very plastic kaolin. Therefore, even if it would not do what was expected with ocher it could still be used by the Ceramics Department for work with kaolin.

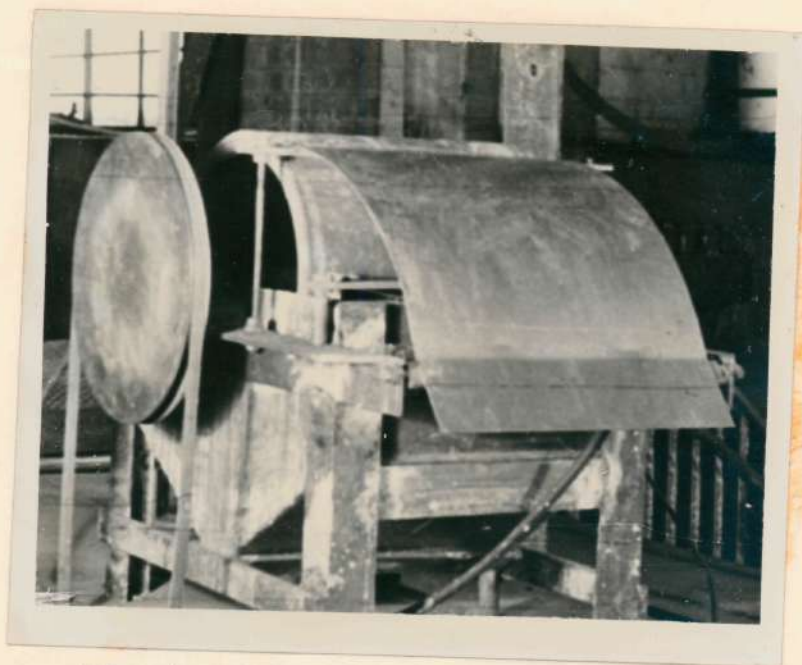
In view of the non-corrosive features of monel metal, it was decided to use this material for the tank and scrape of the machine since the introduction of iron in any form would influence the work of ocher. As the introduction of aluminum into the ocher would be beneficial because of its electrical and color properties, it was used in the construction of the cathode. As a surface was needed for the anode which would be inert to the current and the suspension and also would be hard enough to retain a polish to facilitate the removal of the product, a 15% alloy of antimony in lead was used.

(18) Ibid, Curtis.

This machine consisted of a supporting base, a monel metal tank, an aluminum grid cathode, a cast iron cylinder with a hard lead covering for the anode, and a scrape made of monel metal. The parts of the machine were well insulated to prevent short circuits. The current was fed out of the anode by means of copper strips sliding on a bronze ring. Details of the construction can be seen from the accompanying blue prints in the back of this thesis, and pictures, on the next page. Other details of interest concerning this machine were: the space between the anode and the cathode could be varied from 0 to $1\frac{1}{2}$ inches by raising or lowering the cathode and the scrape could be set by turning hand screw against a coil spring.

All of the machine work was done by W. P. A. mechanics and by Mr. Ray S. Leonard, machinist for the State Engineering Experiment Station. One pattern was made for the cast iron cylinder used in the construction of the anode. This piece was cast in the school foundry.

The complete unit was set up in the basement of the power house because of the availability of direct current. The unit was driven with a variable speed direct current motor provided with a rheostat connected in series with the armature circuit. The anode had to be revolved at such a low speed (3-6 Revolutions per Hour) that a 1000:1 gear reducer had to be used along with four pulleys and two V-belts with the ratio 25:1, yield-



Electrophoresis cell showing the scrape end.



Close up showing anode, scrape, inlet pipe, and shaft with electrical connection to anode.

ing an anode speed of approximately 4 RPH.

A reserve tank for the ocher slip was used provided with two inch pipe connection and valve to control the flow to the cell.

The voltage was read directly with a direct current voltmeter. A shunt was used with the ammeter, so this instrument had to be calibrated before it could be used.

Suspensions were mixed in ball mills in the Ceramic Engineering Department and transported to the electrophoresis equipment in the Power Plant.

A sketch of the apparatus as set up in the power house is shown in the blue prints.

PROCEDURE

Batch No. 1:

Eight kilograms of ocher, 24 grams of sodium silicate and 32 kilograms of water were put into a ball mill with 15 kilograms of rubber covered iron balls. The mill was run for an hour and a half to insure proper mixing of the suspension. This slip was taken in buckets and poured into the reserve tank.

The cell was filled with ocher slip, the anode was rotated, the scrap adjusted, and the current was turned on. It was immediately noticed that a gas was being formed on the cathode, obviously due to the electrolysis of the water. The cell was run for 20 minutes. The voltage stayed constant at 117, but the amperage gradually increased from 22 to 80. Also the temperature of the slip in the cell increased from 25 degrees centigrade to 90 degrees centigrade.

A coat of ocher was formed on the anode but it was filled with gas bubbles and really didn't contain much ocher. As the temperature increased less and less ocher was deposited.

The current was turned off and the cell and contents allowed to cool for an hour, then run again for 15 minutes. The voltage again remained constant at 117 but the starting amperage was 66 gradually increasing to 93. The temperature increased rapidly from 40 to 110 degrees. Some of the water started to boil.

Only about 100 grams of ocher was scraped off during the entire run and this contained a black deposit from the anode and was full of bubbles.

Batch No. 2

The same amount and form of suspension was used as in batch number 1 but the voltage was held constant at 30; the amperage varied from 3 to 12. The gap between the anode and the cathode was decreased but no appreciable electrophoresis was obtained. Only a thin coat of ocher was obtained which could not be scraped off the anode.

Batch No. 3

The suspension and voltage were the same as in the first batch but the suspension was only mixed for one hour in the ball mills and twice as much was made up. This slip was run through the cell at a faster rate to keep down the temperature and consequently the amperage; however, still no good coat was obtained although more ocher was scraped off than on any other run. The amperage varied from 34 to 50.

Batch No. 4

As electrolysis had been observed in all the preceding runs the voltage was decreased to 8 volts and the same procedure used as with batch No. 3. A thin coating of ocher was obtained but it could not be scraped off the anode.

RESULTS

From the four runs made, there were a number of interesting facts observed. First, in the electrophoresis of ocher, the amperage varied directly as the temperature and more ocher was deposited if the temperature and amperage was kept fairly low. Second, lead seemed to be a poor metal to be used as the anode for the ocher replaced either some of the antimony or lead and a fine black film was mixed with the ocher deposited. A qualitative analysis was made of this black powder and it was found to be a mixture consisting mainly of iron, with some antimony and lead. Some ocher was in the sample and possibly some of the lead anode itself. However, it seems possible that some of the iron from the ocher was being replaced by the lead from the anode, and this black film consisting principally of particles of free iron. Third, it was observed that even at 8 volts, electrolysis of the water took place to a minor extent and the bubbles coming off the cathode, which was below the anode, caused the discharge of the colloidal charge on the ocher particles and thus they settled in the cell rather than depositing on the anode.

However it might be stated here that two different runs were made with kaolin and a very good coat approximately $1/4$ inch to $1/2$ inch was obtained at 117 volts and 40 amperes. This kaolin contained 31% water on a dry clay basis, a considerable proportion silicious grit being removed.

ELECTROPHORESIS WITH DIFFERENT ELECTRODES

APPARATUS

A small 1/4 horsepower motor-generator unit was used to obtain the necessary direct current. Six hundred cc glass beakers were used as cells. A wooden rack was used to support two copper tubes from which the anode and cathode were suspended. This rack also had notches cut in it so that the rods could be set and thus the spacing between the anode and cathode could be varied. Two-inch by four-inch plates of copper, hard lead (15% antimony), aluminum, wrought iron, and monel metal were used both for anodes and cathodes. A small blunger was used to thoroughly mix the suspensions. A sketch of this apparatus as used is shown with the blue prints.

PROCEDURE

The concentrations of ocher in water were constant but the metals used for the cathode and anode were all varied to determine the best metal for the anode and the cathode. Five hundred grams of water, 125 grams of ocher, and 5 grams of sodium silicate were blunged together for a half hour. This suspension was placed in the beaker which served as the cell, until the metallic plates were just completely covered. Then the current was turned on. The voltage, amperage, temperature, and time by a stop watch were recorded.

Weighings were made of the plates and wet deposits, the plates and dry deposits, and the plates alone. Thus the dry weights and moisture contents of the deposits were determined.

RESULTS

Table No. 3

Data with Aluminum as Cathode

Anode	Voltage	Amperes	Time minutes	Thickness inches	Current density Amp. per sq. in.
Aluminum	96	1.2	5	1/8	0.2
Lead	90	1.6	5	1/16	0.266
Copper	94.5	1.5	5	1/16	0.166
Monel	118	.8	5	3/16	0.133
Iron	61.5	1.78	Ocher would not adhere.		

Anode	Watt Hour	Weight wet & dry		%water dry basis	grams per sq. in. per hr
Aluminum	9.6	42.5	23.5	81	0.12
Lead	12.0	25.5	15.7	65	20.4
Copper	9.5	13.6	7.3	86	31.6
Monel	7.9	44.3	28.0	58	51

It was found that any of these metals when used as the cathode would be attacked and some of it would be deposited with the ocher. As aluminum was the only one of these metals which would be beneficial when added to the ocher, only figures obtained by using aluminum as the cathodes are listed in the table of results. It should also be stated that with aluminum as the anode the product obtained was full of bubbles caused by the electrolysis of the water. With lead as the anode, electrolysis was also noticed and the same black film obtained as in the runs with the big cell. From these facts and figures it is easy to see that the only metal to be used for the anode should be monel and for the cathode, aluminum. Another difficulty was overcome in this part of the work as compared to work with the big cell because the gases coming off the cathode escaped into the air without passing across the anode. Thus less of the colloidal charges on the ocher were discharged by the gases.

Some of the ocher obtained electrophoretically using the aluminum, monel cell was compared to the French ocher and the original ochers by the tinting method of A. S. T. M. That is, 1 gram of ocher was rubbed with 0.55 grams of linseed oil and smeared on a white porcelain plate. The results obtained were:

Table No. 4

Ocher	French	404 Raw	404 Refined	Electrophoretic
Munsell Color (19)	YR-Y 6/10	YR-R 6/8	YR-R 6/8	YR 4/8
Dictionary Color (20)	10K7	11K8	11K8	12L8

The results as shown by this table may be a little misleading for the differences in the color of the ochers are more than the table shows but this is due to the fact that the colors in the tables do not cover the range of hue of the ocher very well and also the figures were obtained by comparisons by eye.

(19) Munsell-Book of Color. Munsell Color Company
1929

(20) A Dictionary of Color. A. Maerz & M. Rea Paul
McGraw-Hill, 1930

REDESIGN OF CELL

From the results of the work done with the small plates, it was decided to redesign the electrophoresis cell. This was done and a blue print is included in this thesis. The same base, tank and electrical connections were used as with the first cell. However, a monel disc was used for the anode and an aluminum sheet used for the cathode. The cell was designed where the gases from the cathode would not sweep past the anode due to the horizontal spacing arrangement between the anode and the cathode. The ocher should be deposited on the side of the disc and scraped off of the side instead of the periphery as with the previous cell. Machine work was started on this change. The anode and cathode were fabricated but the scrape was never completed. Thus the redesigned cell was never assembled and no experiments could be run with it.

MISCELLANEOUS

While this is not strictly on the subject of the electrophoresis of ocher, it is of interest to observe that there was a possibility of leaching part of the iron from this ocher by chemical means and thus improve its color. Consequently a test was made by boiling some ocher with concentrated sulphuric acid. The iron was dissolved after about two hours of treatment and a white residue left which settled out of suspensions. However, it was very difficult to filter this suspension on account of the residue caking on the filter paper. This residue was very white and consisted of very fine particles.

This possibility may be the method to pursue. The objective of such a method would be to leach out only part of the iron, leaving a light canary colored residue.

CONCLUSION

It is realized that this thesis represents as a whole a rather haphazard investigation into the beneficiation of Georgia Ocher. It is hoped that the results of this work will prove of benefit for a review of the problem as a whole.

The results do indicate that the electrophoresis of ocher would not be sufficiently beneficial to warrant the power and equipment costs involved. However, if such equipment were used for dewatering instead of filter pressing and drying, the cell as redesigned would do this very satisfactorily. For this process the suspension table No. 2 could be used to select the best electrolyte for deflocculation.

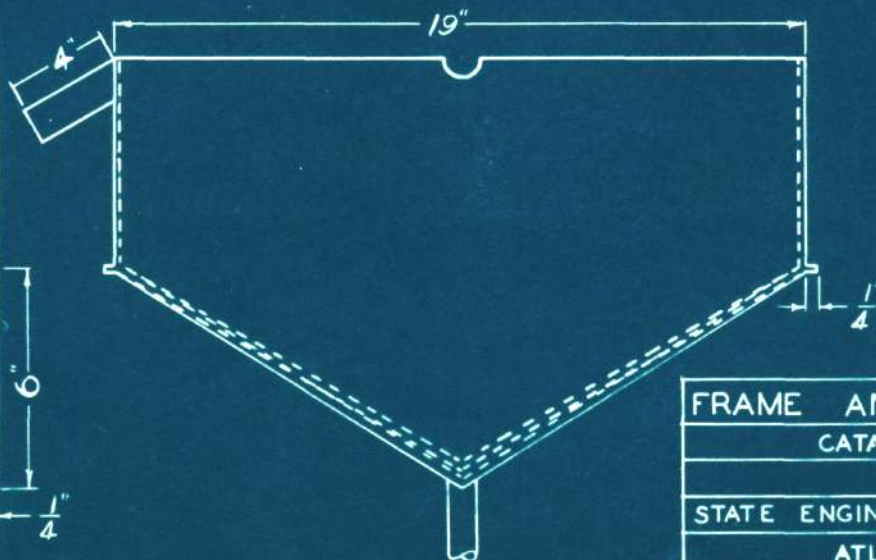
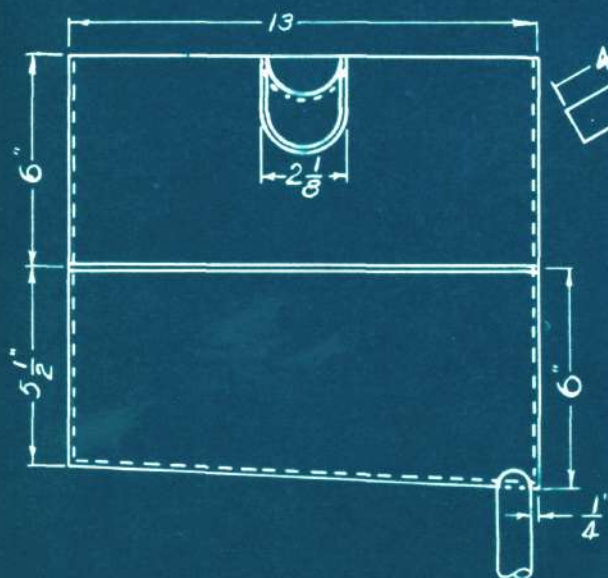
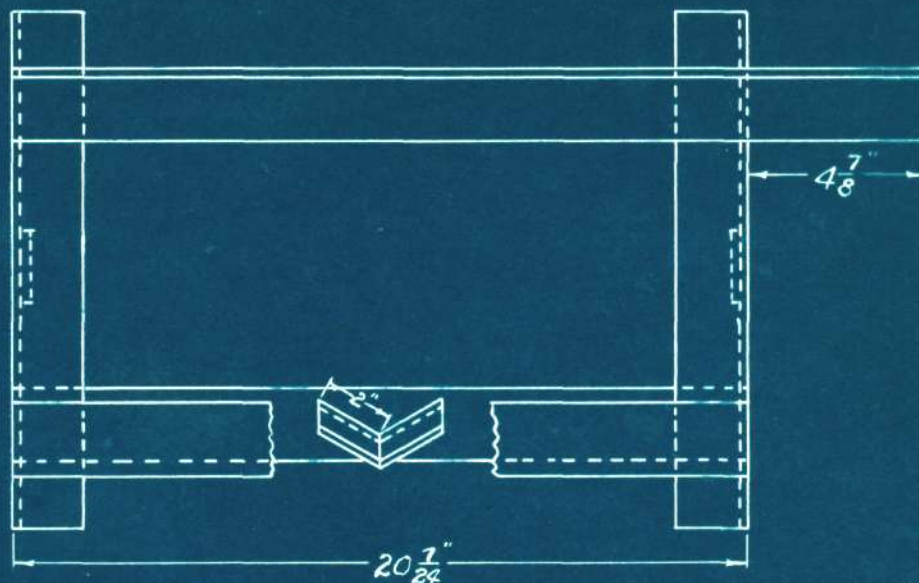
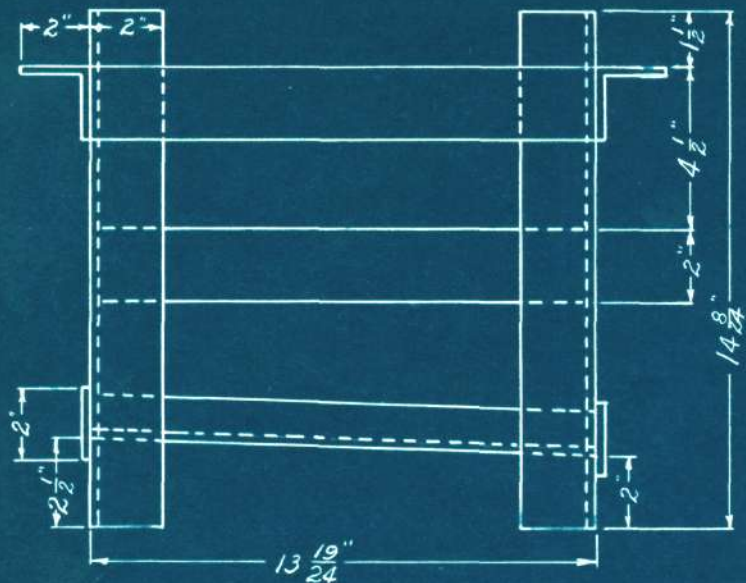
RECOMMENDED PROCEDURE

If a further investigation of this character is attempted, it is suggested that a small motor-generator unit be used in conjunction with rheostats so that the voltage and amperage could be varied over a wide range. Instead of this, a Thyron tube that was lately developed by the General Electric Company, might serve this purpose at a lower cost. Small plates could be used to better advantage than a continuous machine for investigative work. If the results warranted, a continuous electrophoresis cell could be constructed.

There is, as noted in this thesis, a possibility of changing the color of the ocher by chemical means and further work should be done along this line, bleaching or leaching the color-bearing minerals from the ocher.

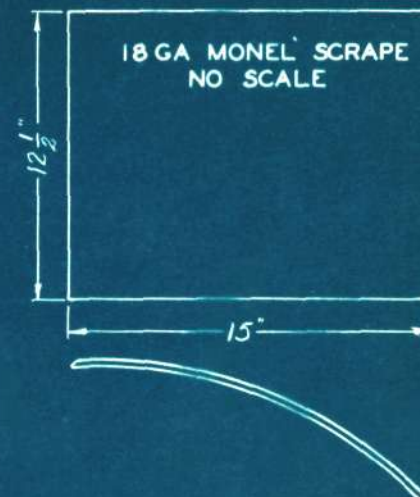
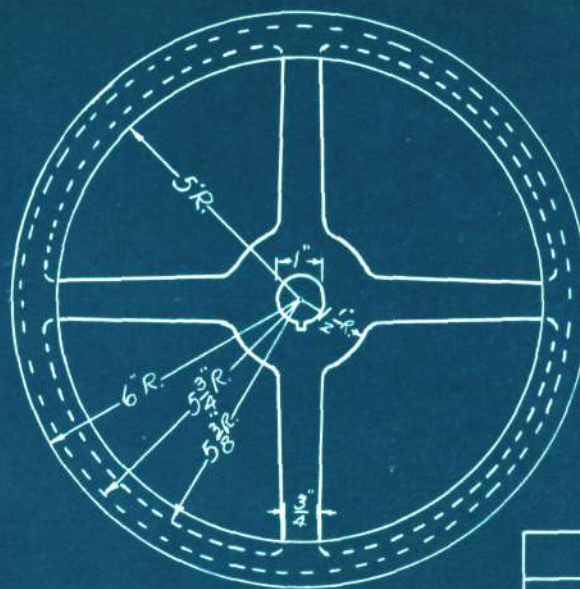
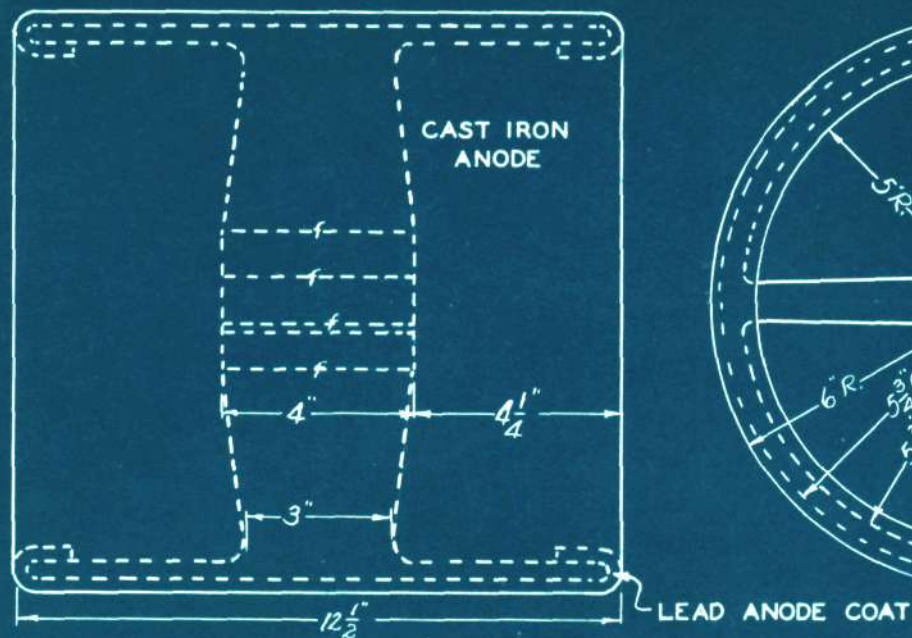
Work is also suggested on electrophoresis using some organic substance to deflocculate the ocher suspensions so that the electrolysis of water may be reduced.

There is also a possibility to make up a mixed suspension of ocher and kaolin and electrophorize it to obtain the color wanted.

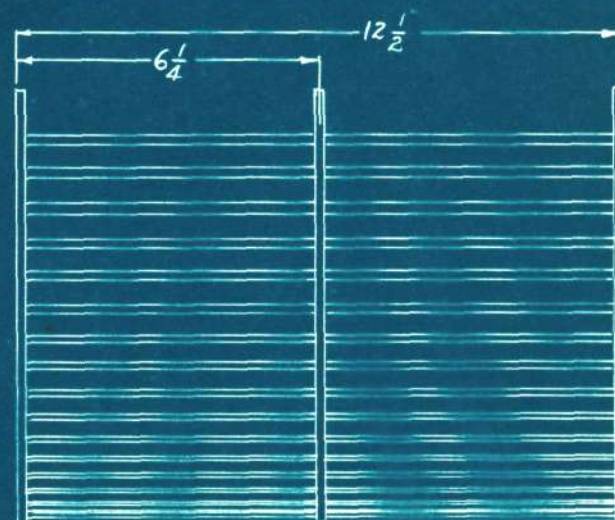
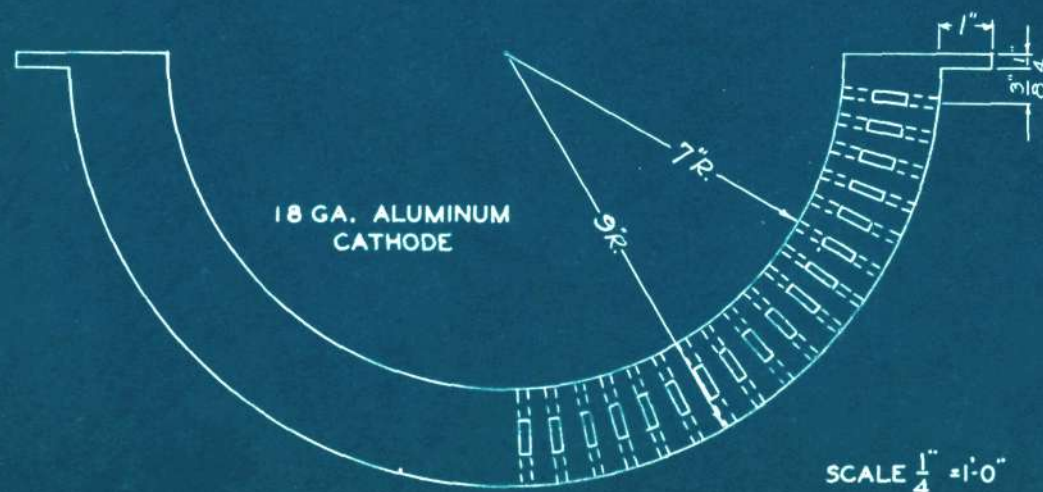


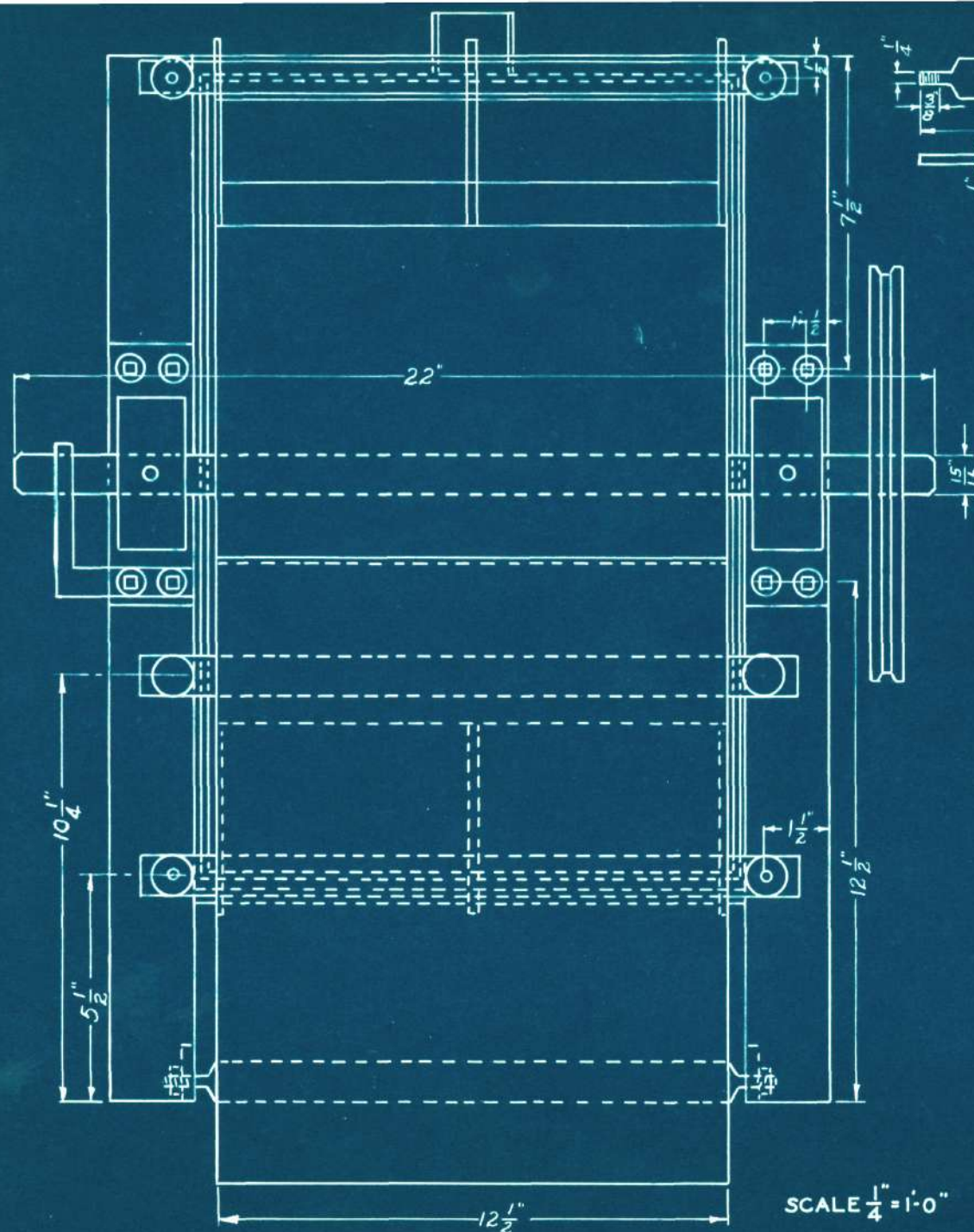
SCALE $\frac{3}{8}'' = 1'-0''$

FRAME AND CATAPHORESIS CELL	
CATAPHORESIS OF OCHER	
PROJECT 29	
STATE ENGINEERING EXPERIMENT STATION	
ATLANTA GEORGIA	
NOV. 23, 1936	CATER, T. J.

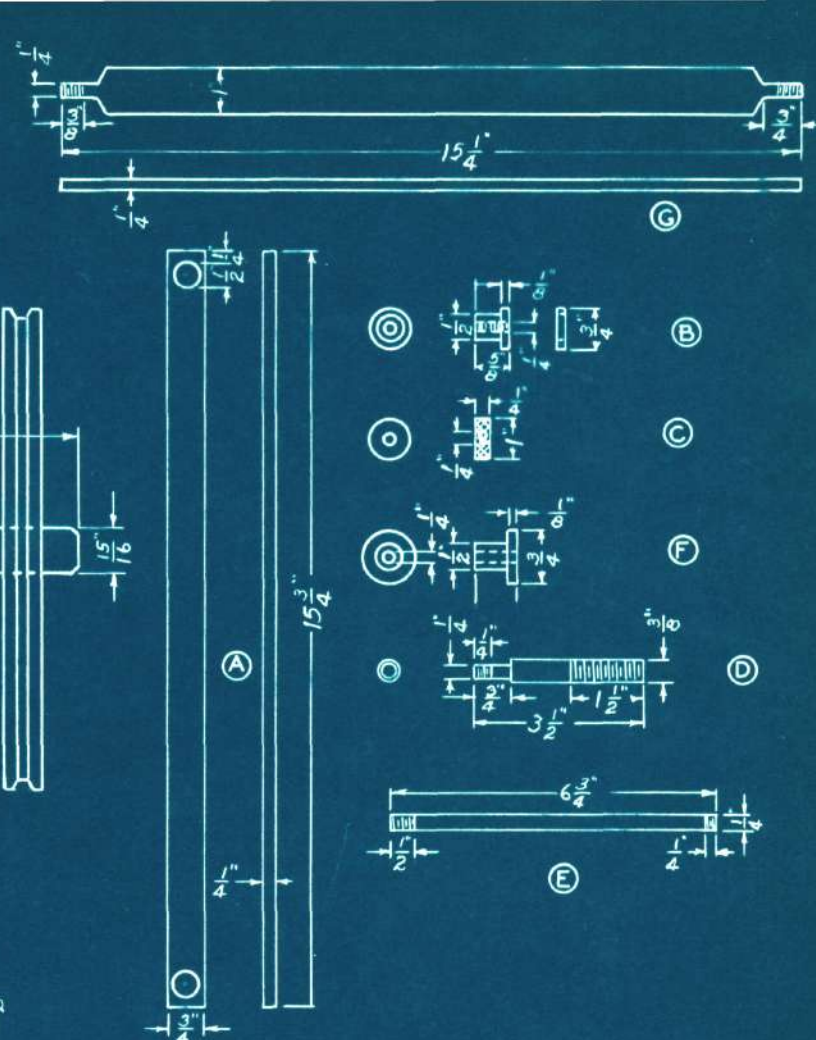


CATHODE ~ ANODE	
CATAPHORESIS OF OCHER	
PROJECT 29	
STATE ENGINEERING EXPERIMENT STATION	
ATLANTA, GEORGIA	
NOV. 23, 1936	CATER, T. J.



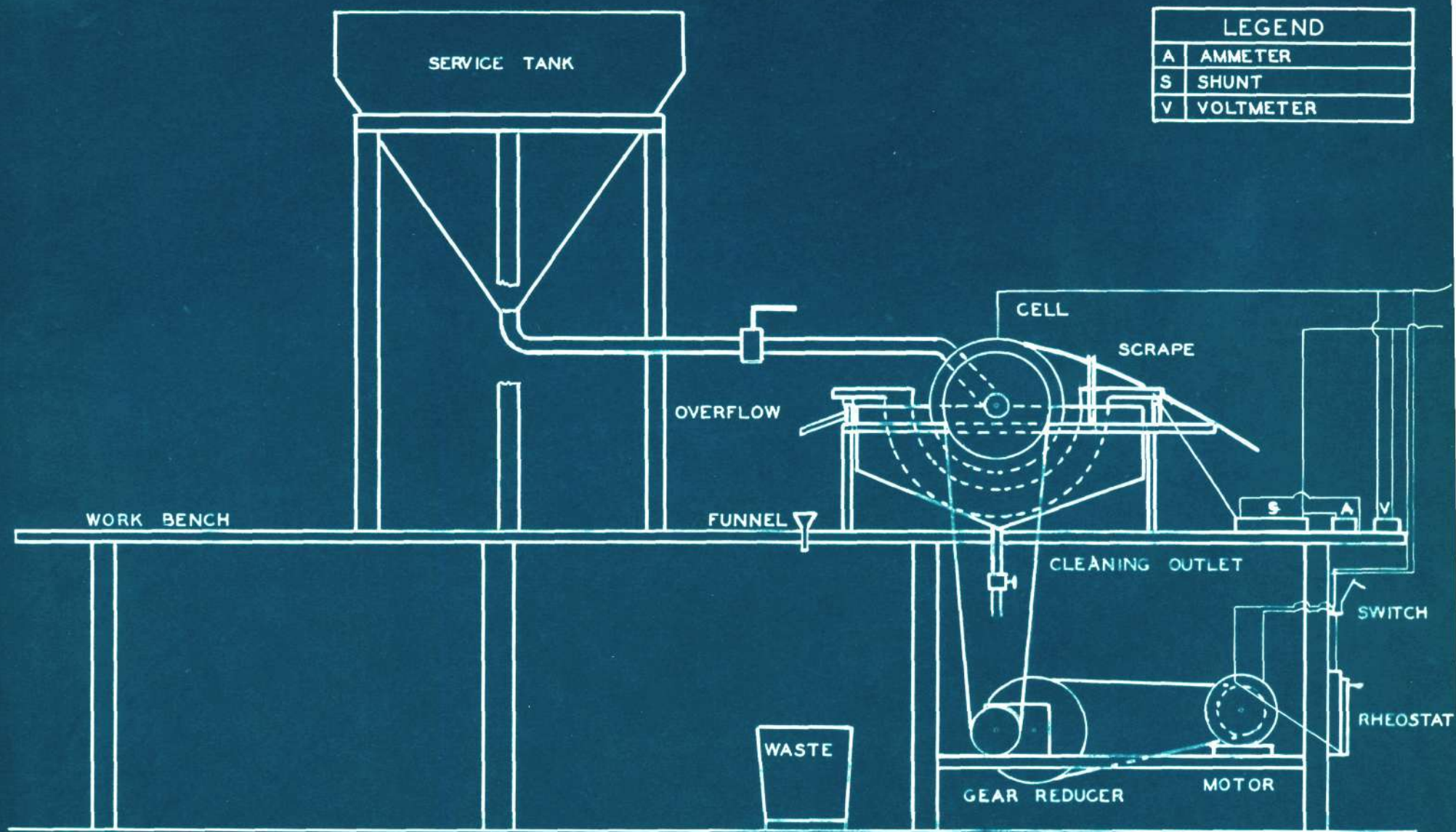


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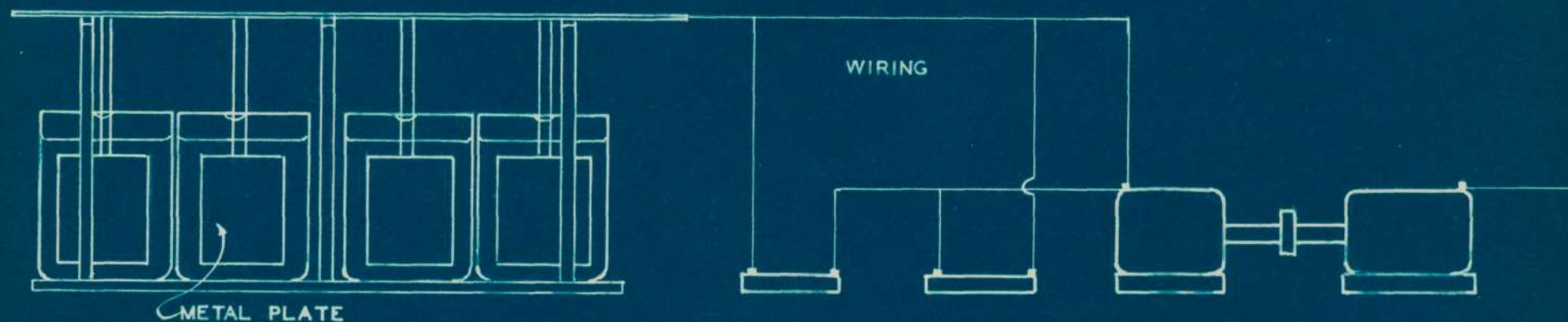
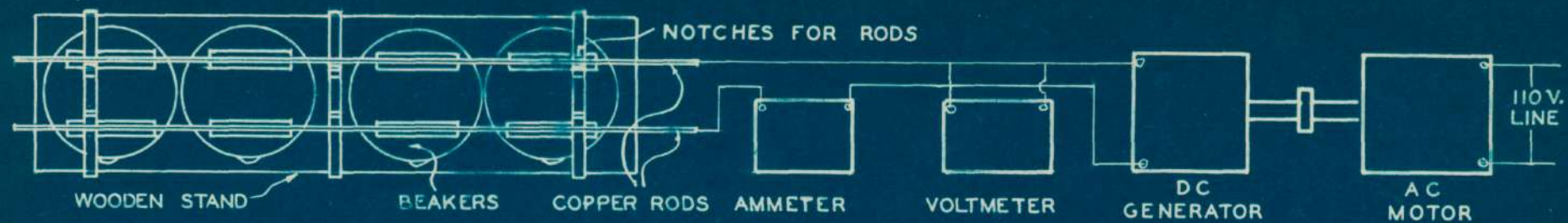


BILL OF MATERIALS

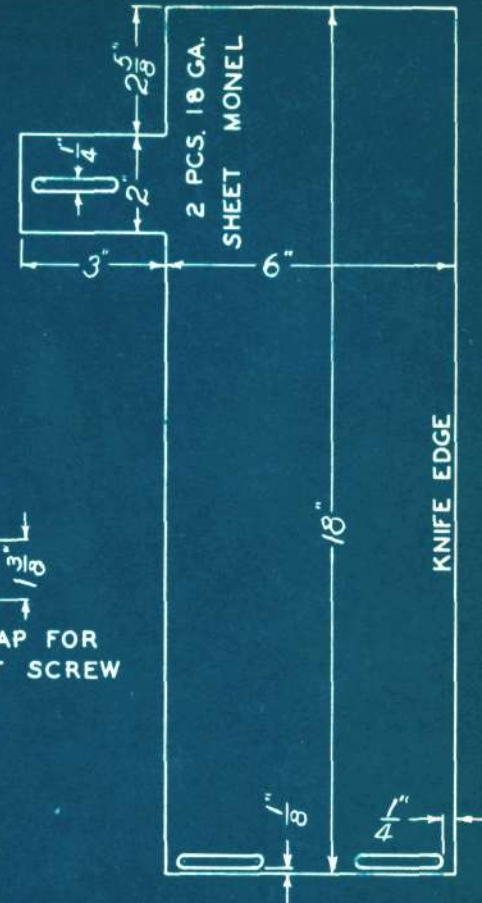
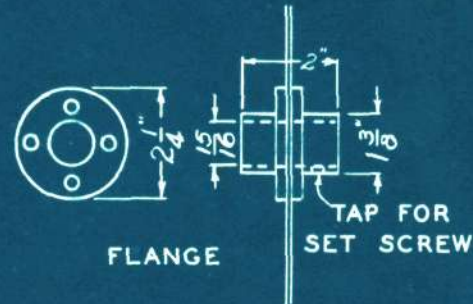
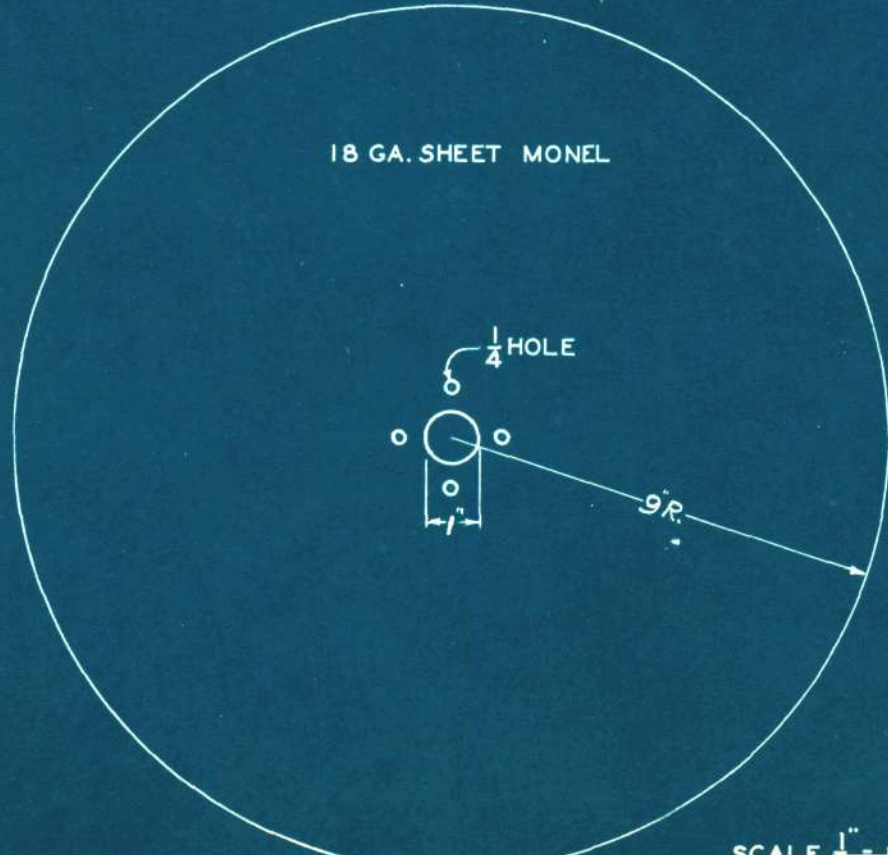
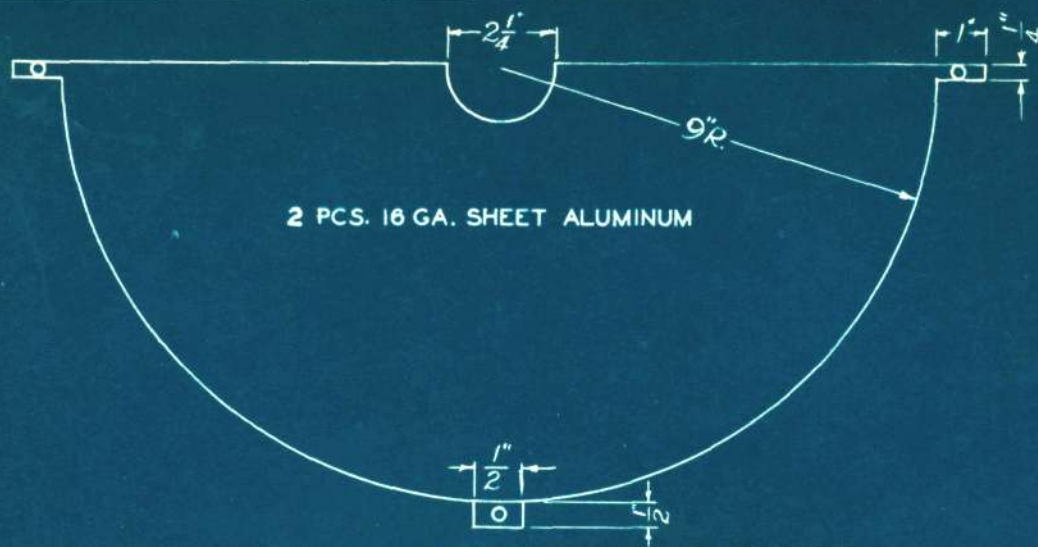
UNIT		MTL.	NO.
A	CATHODE INSULATOR	FIBER	2
B	INSULATOR BEARING	STEEL	4
C	ADJUSTMENT NUTS	STEEL	6
D	INS. ADJUSTING PINS	STEEL	4
E	SCRAPE PINS	STEEL	2
F	ANODE INS WASHERS	FIBER	8
G	SCRAPE PIVOT BAR	STEEL	1



SKETCH OF ELECTROPHORESIS EQUIPMENT



SKETCH OF APPARATUS USING SMALL PLATES



REDESIGN OF CATHODE -ANODE	
CATAPHORESIS OF OCHER	
STATE ENGINEERING	EXPERIMENT STATION
PROJECT 29	
ATLANTA GEORGIA	
JUNE 14, 1937	CATER T.J.

SCALE 1" = 1.0"