PLEOCHROISM OF DYED CELLOPHANE

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A THESIS SUBMITTED FOR THE DEGREE OF

BACHELOR OF SCIENCE

ELECTRICAL ENGINEERING COURSE

The University of Tennessee

1931

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PREFACE

In the field of physical optics, the information on double refractive crystals is very extensive. The rapid advances of the last decade or two have accentuated the need for information regarding this property of various substances. Particularly is this true in the uses of the photo-electric cell for the transformation of light waves to electrical impulses. The uses of this apparatus in connection with the transmission of moving pictures is in its infancy at the present time, but with the rapid strides being made, both in research and perfection of apparatus, it is to be expected that many uses will be made of the knowledge obtained in the use of various refractive substances. Especially is this true in the transmission of colored pictures.

At the present time no data has been published that gives any information on the optical properties of dyed cellophane. For this reason, this experiment was conducted purely as a preliminary experiment to advanced research on this subject. The results of this work being a step in the direction of a greater and better knowledge of the optical properties of the dye and dyed cellophane.

GENERAL SURVEY OF THE SUBJECT

At the present time there is no available information on the subject of pleochroism of dyed cellophane. Due to the limited time and apparatus available this test was performed for the purpose of obtaining a general survey and preliminary knowledge for an extended and more accurate test to be conducted later. With the results shown by the curves in the various figures (1, 2, 3, 4, 5, 6) it is seen that dyed cellophane is doubly refracting and the magnitude of which depends on the dye used.

The possibilities of using dyed cellophane as an analyser and polarizer cannot be estimated at the present time. This is due to the small amount of information available on flexible polarization substances. Perhaps two of the greatest improvements would be the reduced cost of apparatus requiring a polarizing substance and the possibilities of its uses in connection with the conversion of light waves to electrical impulses in the art of television. This may be proven by the uses to which the Nicol prism is being used in present experiments being conducted for transmission of moving pictures of theatre size.

GENERAL THEORY

The accidental refraction of celloidin and the cellulose prepared from it is dependent upon the refractivity of the liquids with which these compounds are saturated. It has been found that the value for the double refraction of celloidin may be positive, negative, or even zero. In the case of cellulose it has been found that the value is positive and never zero. In order to explain these results, there is assumed a combination of the double refraction of rods as proposed by Wiener with the proper double refraction of the rod-like particles; the proper double refraction has a negative sign in the case of cellulose. Not only is the accidental double refraction in both compounds a remarkable instance of double refraction of rods, but it also appears to be a confirmation of Nagel's theory of crystalline millicae. The strong dichroism shown by the natural fibers as well as by the permanently stretched celloidin and cellulose strips likewise confirms the correctness of Nagel's theorem.

The phenomenon of streaming double refraction with vanadium pentoxide solutions observed by Diesselhorst,

Freundlich, and Leonhardt has been established with the following solutions: soap, clay suspensions, benzopurpurin, benzobrown, parazonxyplienetole, anthracene, cerasin orange, and many other organic compounds. However the one pertaining to this test and in all probability accounts for the fact that dyed cellophane is double refractive is that observations were made of double refraction in moving solutions. On allowing the solution to flow between crossed Nicols in the direction of the axis joining the Nicol, dark crosses were obtained which are analagous to the figures given by a uniaxial crystal with convergent light. The distortion of the crosses into vortices towards the direction of polarization demonstrated that the direction of flow did not necessarily conform with one of the directions of primary vibration of the light.

From this we may conclude that cellophane upon being pressed through the machine in the liquid state assumes practically the same form as that of the liquid being poured from a container for the previous test. It is pointed out that the growth of nonspherical colloidal particles are not due to crystalline structure but to the rearrangement of these particles in a parallel position.

METHODS OF PERFORMANCE

Several obstacles were encountered in the set-up of the apparatus for the performance of this test. Since the walls of the room in which the test was performed were slightly reflective, the apparatus was placed a maximum distance from the walls (center of the room) in order to reduce the inaccuracy of reflection. An additional precaution against reflected light was made by enclosing the photo-electric cell in a large box. The inside of this box was painted black in order to absorb all reflections near the cell.

In the first test to be conducted an effort was made to use a galvanometer and vacuum type photo-electric cell, but the particular type of galvanometer available was not of sufficient sensitivity to record any results near the required accuracy for the allowable amount of light. The apparatus was then rearranged to accommodate a cell of greater output per unit quantity of light received. This cell was a liquid cell, but the time log and the difference in repeated readings proved that it was far from satisfactory and this arrangement was then discarded. The final arrangement consisted of the vacuum type photo-electric cell and the Zeleny

electroscope, as shown in figure 7.

After several tests on successive days, it was found that the results varied from day to day. Particularly was this true on the days of high humidity. The noticeable feature being the higher rate of discharge on days of high humidity. It was then concluded that a leakage discharge was taking place between the electrodes and on the outside surface of the cell. With the application of a small tray of calcium chloride inside the box containing the photo-electric cell, the trouble was remedied and the results were then consistent.

The arrangement for the final test and recorded data is given in figure 7. This is a schematic arrangement of the apparatus. A source of constant potential was impressed on the lamp B. The voltmeter A was used to record the voltage. In case of a variation from day to day in the voltage, the resistance C was adjusted to bring the voltage back to normal. Light rays from B passed through the sample to be tested at E. F was a Nicol prism with the plane of vibration horizontal. G is the photo-electric cell which emits electrons directly proportional to the intensity of light striking the cathode. Battery L was used to maintain a positive potential on the anode of cell G. Connected in series with the circuit was the Zeleny Electroscope. (For description see Appendix A.)



SCHEMATIC LAYOUT

FIG. NO. 7

By means of a stop watch the time required for a certain amount of discharges was recorded. Since the time required is directly proportional to the amount of current discharging through the electroscope the ordinates on the curves are then inversely proportional to the amount of light passing through the sample of cellophane.

Readings were taken at every ten degrees rotation of the cellophane over an arc of 325 degrees.

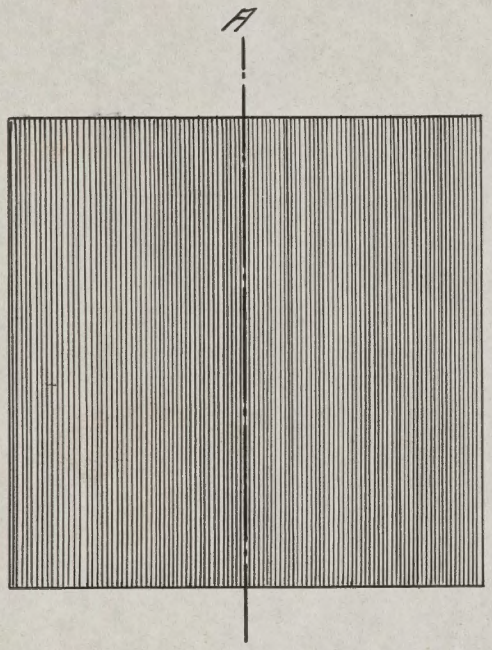
The final test consisted of testing the photo-electric cell to determine if the current flowing through it was directly proportional to the amount of light striking the anode. Since the light striking any object is inversely proportional to the square of the distance between the source and object, it would be concluded that with a parabolic curve or a straight line curve on a semi-logarathmic scale the discharge of the cell would be directly proportional to the amount of light striking it. Figure 6 is the curve and proves that the cell discharge is proportional to the amount of light striking it.

CONCLUSIONS

From the tests conducted on the violet, green, red, and transparent cellophane it was found that they exhibited double refraction. The amount of refraction depending on the dye used. The transparent cellophane was found to be only slightly birefringent. In fact the results show a ratio of such small magnitude that it is possible that an error could have produced this result.

After each test the cellophane was removed from the holder and the direction of the grain with respect to the axis of the Nicol prism was noticed. It was found that the maximum light was transmitted through the cellophane when its grain was parallel to the plane of vibration of the Nicol prism. The extraordinary ray passing through when the planes of vibration were parallel (see position B, Figure 8) and the ordinary ray passing through when the planes of vibration were perpendicular to each other (see position A, Figure 8). From the above results we may conclude that pleochroism is a property of dyed cellophane.

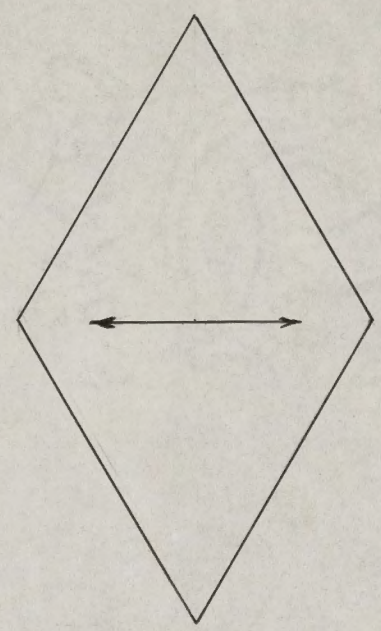
After the test had been concluded and curves drawn to show the ratio of refraction an attempt was



POSITION A

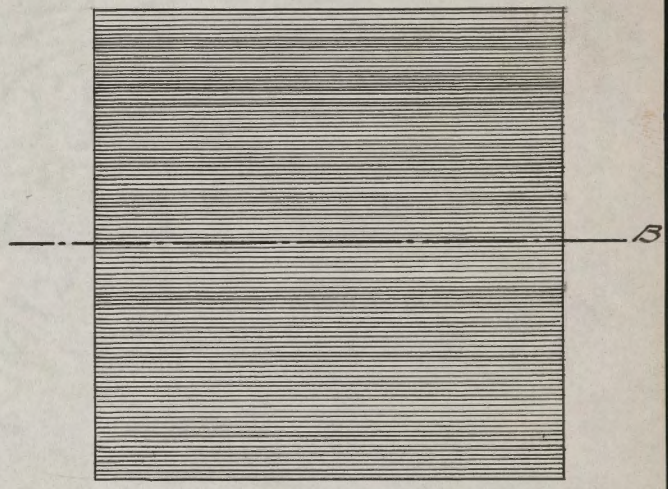
CELLOPHANE SHOWING DIRECTION

IT WAS PULLED THRU MACHINE



NICOL'S PRISM

PLANE OF VIABRATION HORIZONTAL



POSITION B

CELLOPHANE SHOWING DIRECTION

IT WAS PULLED THRU MACHINE

FIG. NO. 8

made to verify these results visually by the use of the Wollaston prism. It was found that the red cellophane which had the greatest pleochroism in the test with the photo-electric cell, had the least when the visual test was performed. This can be accounted for due to the fact that red has a wave length of between 0.647 and 0.810 microns with a relative visibility of 0.094 to 0.00005 taking 0.556 microns as unity. Knowing that the average photo-electric cell is highly sensitive for short wave lengths, and the human eye is highly sensitive for the long wave lengths, we can account for this difference between the visual and photo-electric cell test.

All other visual tests compared favorably with the photo-electric cell test.

The variation in the amplitude of the ordinates every 180° could not be accounted for unless there is a possibility that the thickness of the cellophane was not uniform. Repeated tests were made to check these readings, but the results were always of the same value for corresponding degrees of rotation.

From the results of the test on the photo-electric tube we found that the current flowing through it was directly proportional to the amount of light shining on it.

The following is the approximate ratio of

minimum to maximum of the current flowing through the tube for the various colors and therefore a measure of the pleochroism.

Transparent	0.95
Violet	0.81
Green	0.62
Red	0.324

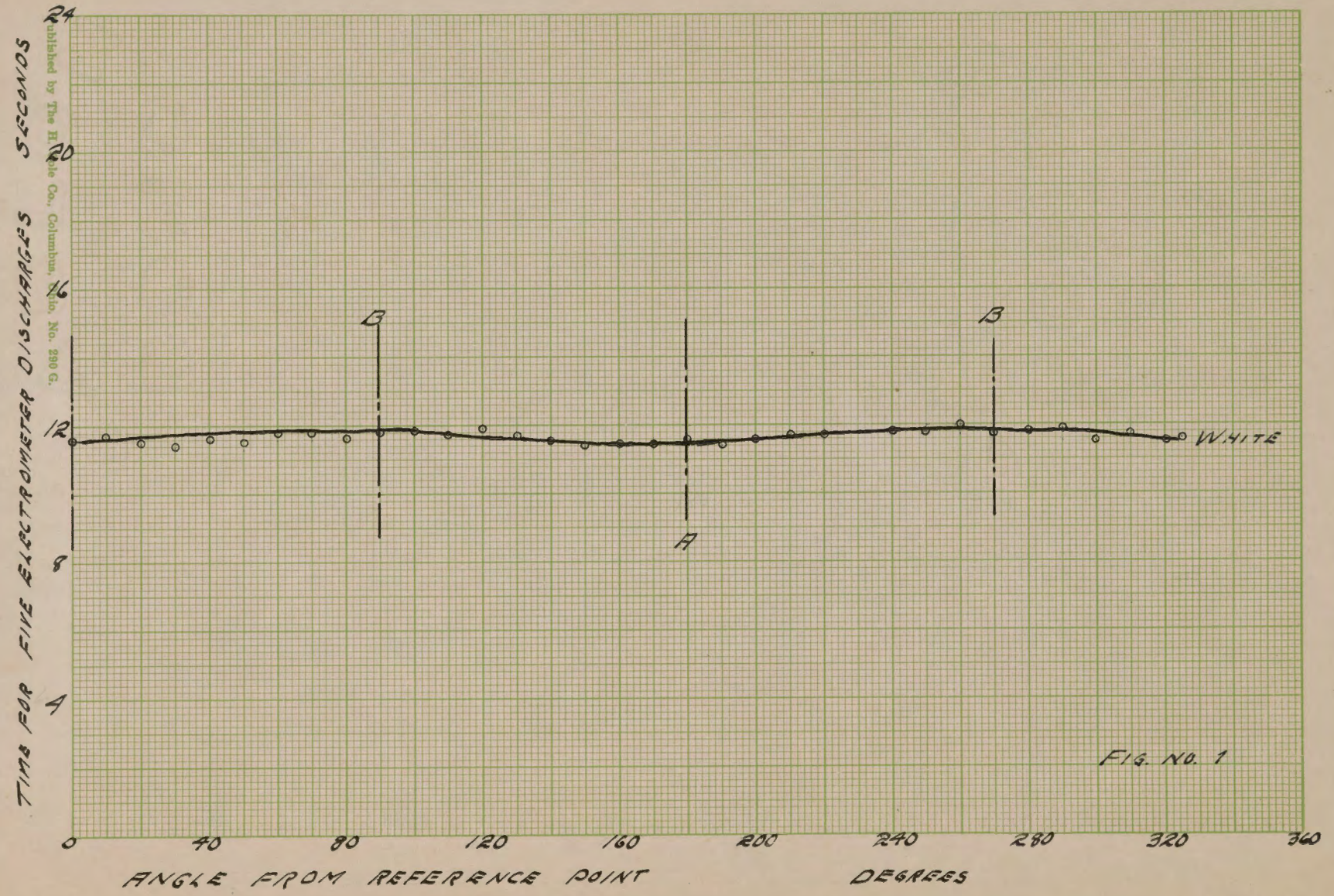


FIG. NO. 1

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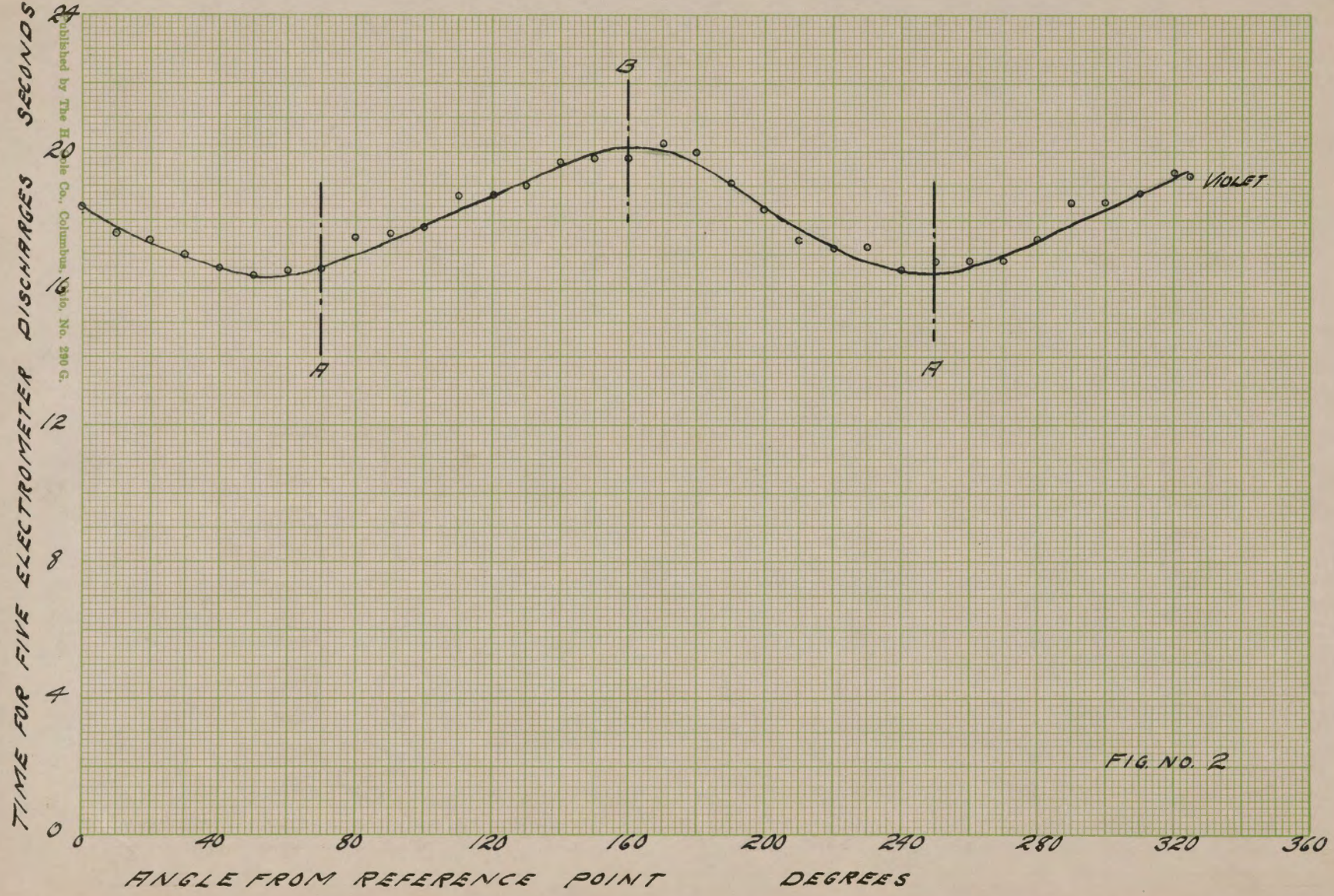

FIG. NO. 2

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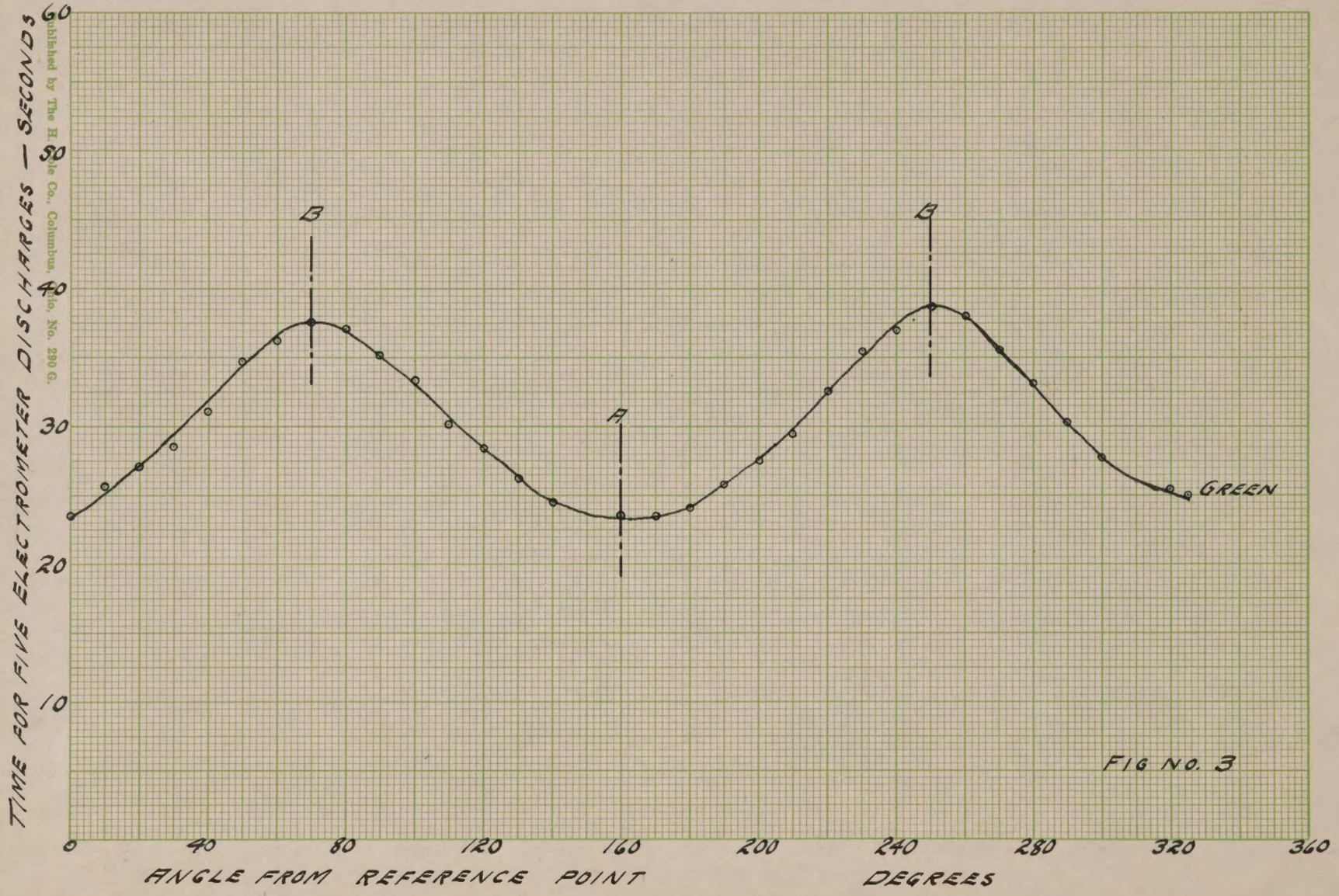

FIG NO. 3

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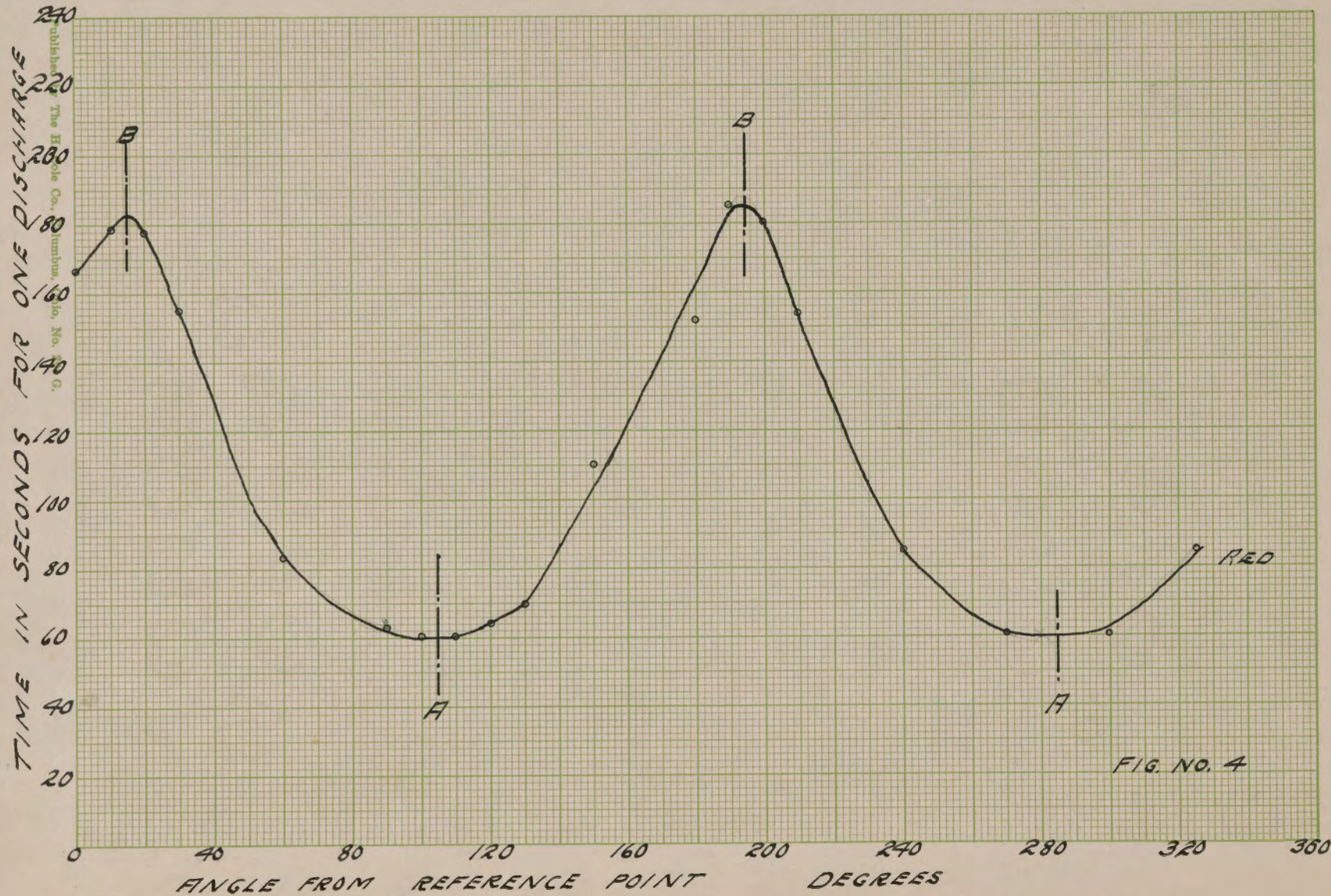
TIME IN SECONDS FOR ONE DISCHARGE
240
220
200
180
160
140
120
100
80
60
40
20
0
40
80
120
160
200
240
280
320
360
ANGLE FROM REFERENCE POINT DEGREES
B
B
A
A
RED
Published by The Hoole Co., Columbus, Ohio. No. G.

FIG. NO. 4

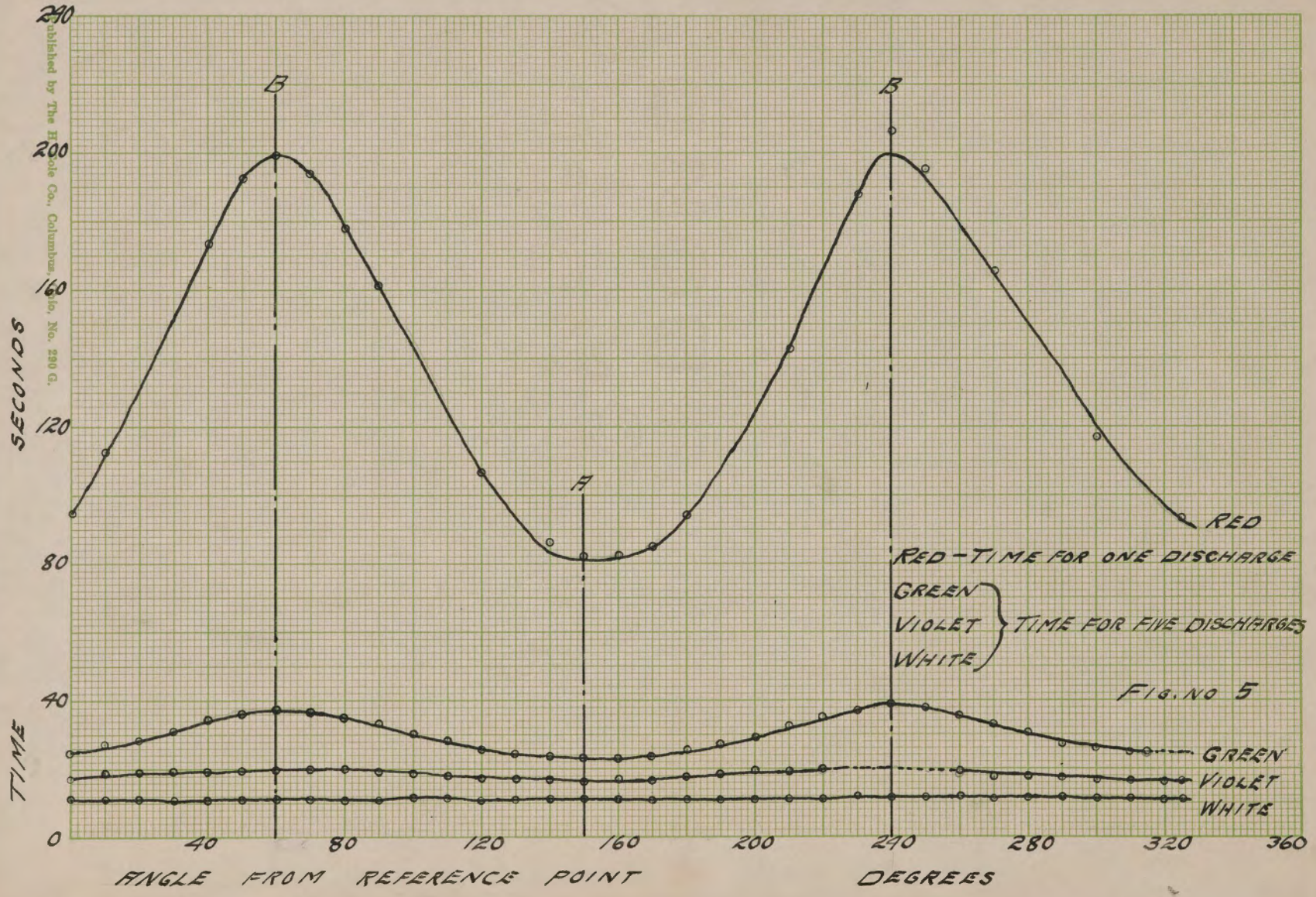

FIG. NO 5

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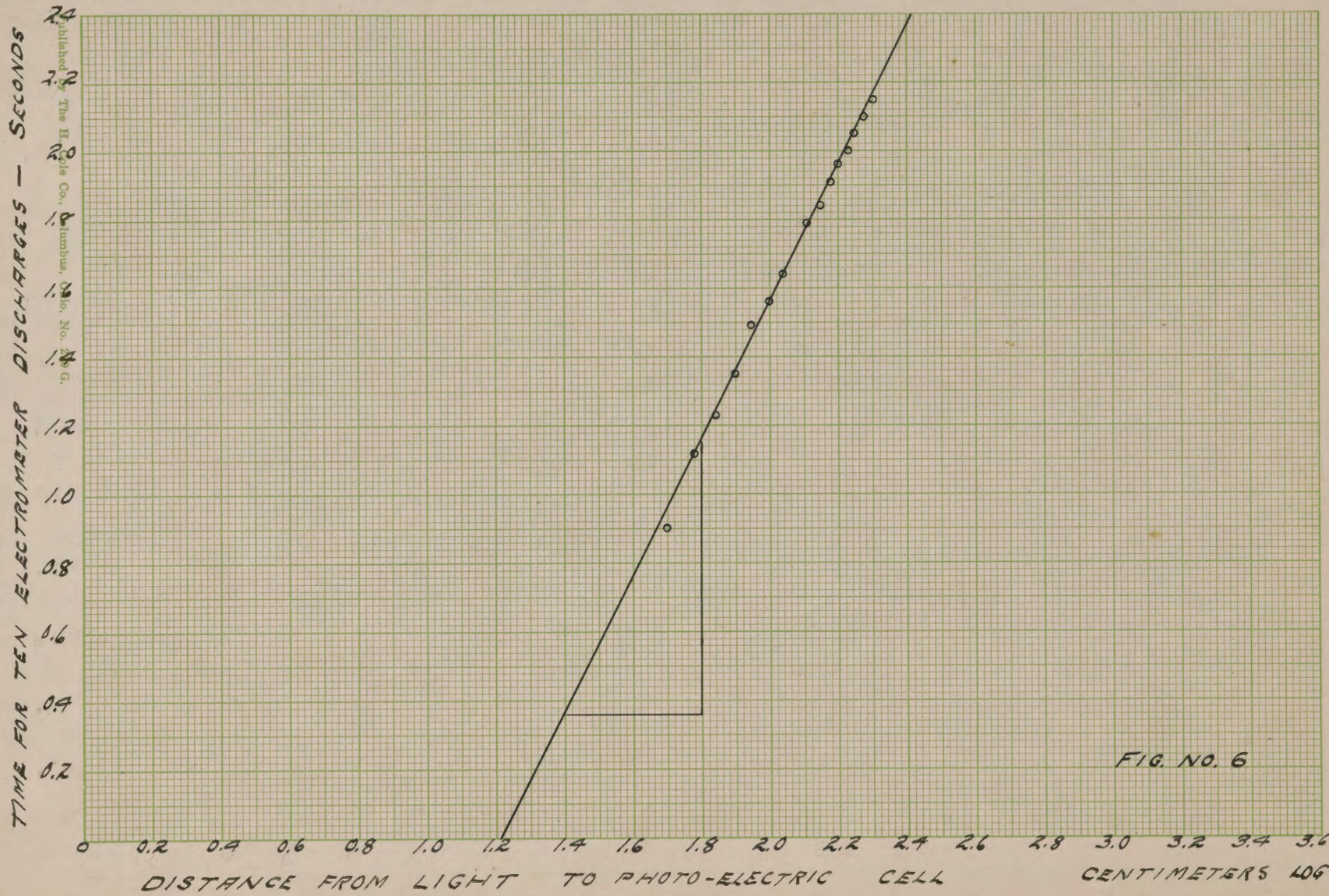

FIG. NO. 6

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DATA FOR VIOLET

Angle from Reference Point Degree	Time Five Discharges Seconds	Angle from Reference Point Degree	Time for Five Discharges
0	18.4	160	19.8
10	17.6	170	20.5
20	17.4	180	20.
30	17.0	190	19.1
40	16.6	200	18.3
50	16.3	210	17.4
60	16.5	220	17.2
70	16.5	230	17.2
80	17.5	240	16.6
90	17.6	250	16.8
100	17.8	260	16.8
110	18.7	270	16.8
120	18.7	280	17.5
130	19.0	290	18.5
140	19.7	300	18.5
		310	18.8
150	19.8	320	19.4
		325	19.3

DATA FOR GREEN

Angle from Reference Point Degrees	Time for Five Discharges Seconds	Angle from Reference Point Degrees	Time for Five Discharges Seconds
0	23.6	170	23.5
10	25.7	180	24.0
20	27.0	190	25.8
30	28.6	200	27.6
40	31.0	210	29.5
50	34.8	220	32.6
60	36.2	230	35.5
70	37.4	240	37.0
		245	37.7
80	37.2	250	38.8
		255	38.6
90	35.3	260	38.0
100	33.2	270	35.5
110	30.2	280	33.2
120	28.5	290	30.3
130	26.2	300	27.6
140	24.5	310	26.0
150	23.8	320	25.6
160	23.6	325	25.0

DATA FOR TRANSPARENT

Angle	Seconds for 5 Discharges	Angle	Seconds for Discharges
0°	11.6	190	11.4
10	11.7	200	11.6
20	11.5	210	11.7
30	11.4	220	11.7
40	11.6	240	11.8
50	11.3	250	11.8
60	11.6	260	12.0
70	11.6	270	11.7
80	11.6	280	11.8
90	11.8	290	11.9
100	11.7	300	11.5
110	11.8	310	11.8
120	11.9	320	11.5
130	11.7	325	11.6
140	11.6		
150	11.4		
160	11.5		
170	11.5		
180	11.6		

DATA FOR RED

Angle from Reference Point Degrees	Time for one Discharge Seconds	Angle from Reference Point Degrees	Time for one Discharge Seconds
0	95	240	206
10	112	250	195
40	173	270	165
50	193	300	117
60	199.4	325	93
70	194		
80	178		
90	161		
120	106		
140	87		
150	82		
160	82		
170	85		
180	94		
210	142		
230	187		

DATA

RELATION OF CONDUCTION OF TUBE TO LIGHT INTENSITY

Distance of Light from Cell Cms.	Log of Distance	Time for Ten Discharges Secs.	Log of Time
50	1.70	8.5	.90
60	1.78	13.0	1.11
70	1.84	17.0	1.23
80	1.90	22.6	1.35
90	1.95	31.0	1.49
100	2.00	36.6	1.56
110	2.04	43.7	1.64
130	2.11	61.3	1.79
140	2.15	68.2	1.84
150	2.18	82	1.91
160	2.20	91	1.96
170	2.23	101.3	2.00
180	2.25	113.5	2.05
190	2.28	126.0	2.10
200	2.30	140	2.15

APPENDIX A

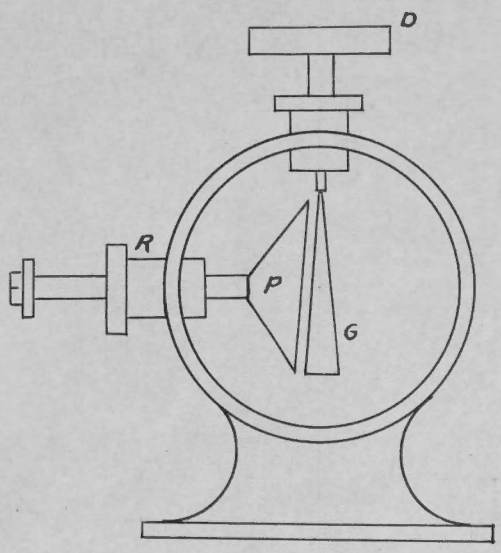

Fig. 9

The Zelęny electroscope was used as a means of measuring the variation in the current flowing through the photo-electric cell. The quantity in amperes was not calculated due to the fact that in this preliminary test only the ratio was needed in order to obtain the desired results.

A diagramatical sketch is shown in figure 9. P, is a rectangular plate which can be moved in or out by means of the screw threads on the ebonite plug. The front face of this plate is coated with india ink. The gold leaf G is supported in front of the plate P from the disc D which acts as one of the terminals. An amber plug inside of an ebonite plug insulates the conductor from the case. A high resistance R is an internal part of the ebonite plug.

The operation of the electroscope is as follows: Plate P is connected through the high resistance R to the positive terminal of the battery. The gold leaf G is attracted to P by the difference in charge between the two. After making contact with P the gold leaf G and plate P have like charges and are then separated by repulsion and the action of gravity due to G having its center of gravity at a greater horizontal distance. G, being connected through the photo-electric cell to the negative terminal of the battery allows its charge to build up at a rate depending on the conductivity of the photo-electric cell. When the charge has built up to the value required by the distance separation between G and P the leaf is again attracted and discharged. The action is continuous since a definite amount of charge must be accumulated before the leaf will swing over and discharge.

It will be noticed that the gold leaf is placed with its plane parallel to its direction of swing. The chief advantage of this position is that it allows a more abrupt "kick-back" due to less air resistance. Also the tendency of the leaf to adhere to the plate is minimized. In the early stage of development of the electroscope much trouble was had by a tendency for the leaf to stick to the plate. However this was eliminated by the use of a thin coating of india ink on the plate.

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APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, only for the purpose for which it is submitted.

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Title May 29, 1931