

THE ELECTROLYTIC DETECTOR, STUDIED WITH  
THE AID OF AN OSCILLOGRAPH.

BY GEORGE W. PIERCE.

## INTRODUCTION.

WHILE engaged in a series of experiments <sup>1</sup> on certain crystal rectifiers for alternating electric currents — these rectifiers also serving as detectors for electric waves — the writer made use of a sensitive form of Braun's cathode-tube oscillograph. The same apparatus is here applied to the study of the electrolytic detector. The purpose of the investigation is, first, to attempt to contribute to the understanding of the mode of operation of the electrolytic detector, and, second, to find out whether the experiment with the electrolytic detector will throw any light on the crystal detectors which, like the electrolytic detector, are rectifiers for small alternating currents.

*Method of Employing the Detector in the Reception of Electric Waves.* — The electrolytic detector for electric waves, as described by Fessenden <sup>2</sup> and shortly after by Schloemilch, <sup>3</sup> consists of a cell containing an electrolyte and having one electrode of very small area, usually in the form of an extremely fine wire of platinum, and as the other electrode a larger area of platinum or some other metal. When used in wireless telegraphy the two electrodes are connected in a circuit upon which the electric oscillations are impressed, so that the rapidly oscillating electric currents in the circuit are made to traverse the cell of the detector. An example of a simple form of receiving circuit, with the detector connected in the antenna, is shown at *MDG* of Fig. 1. A local circuit *TED*, through the detector, contains a telephone receiver *T* and an adjustable source of E.M.F., which is used to polarize the detector

<sup>1</sup> Pierce, Proc. Am. Acad., 44, pp. 317-349, March, 1909; PHYS. REV., 23, pp. 153-187, March, 1909.

<sup>2</sup> Fessenden, U. S. Patent No. 727,331, May 5, 1903.

<sup>3</sup> Schloemilch, E. T. Z., 24, p. 959, 1903.

by sending through it and the telephone a small direct current. Under the action of the electric oscillations through the detector the current in the telephone receiver is modified so as to produce a sound in the telephone with a period determined by the train fre-

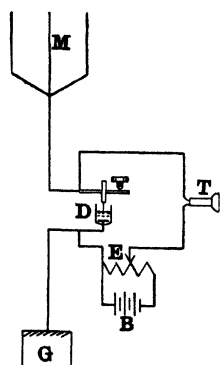


Fig. 1.

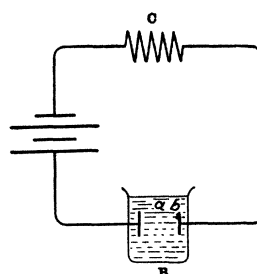


Fig. 2.

quency of the incident electric waves. The action is localized at the contact of the fine wire with the electrolyte.

*The Electrolytic Detector as a Rectifier.*—That an electrolytic cell with one of the electrodes small, when suitably polarized with a direct current, is a rectifier for alternating currents was first shown by Pupin<sup>1</sup> before such a cell came into commercial use as a detector for electric waves. The following account of Pupin's rectifier is translated from the "Jahrbuch der Elektrochemie," Vol. 6, p. 35, 1899: "In Fig. 3" (here reproduced as Fig. 2) "*A* is a battery, *B* an electrolytic cell with the platinum electrodes *a* and *b* and acidulated water. If the polarization of the cell *B* is as great as the E.M.F. of *A*, no current flows in the circuit. If one allows an alternating current to act upon the circuit *ABC*, the circuit contains resistance, self inductance, and a capacity localized in the plates *a* and *b*. The cell *B* acts, however, as a condenser only so long as the potential difference of the plates *a* and *b* is smaller than the decomposition voltage. If this value is exceeded, a current goes through the circuit. If the alternating current, for example,

<sup>1</sup> Pupin, *Electrical World*, 34, p. 743, 1899; *Zeitsch. f. Elektrochemie*, 6, p. 349, 1899; *Jahrbuch. d. Elektrochemie*, 6, p. 35, 1899; *Bul. Am. Phys. Soc.*, 1, p. 21, 1900.

has an amplitude that is twice as great as the E.M.F. of  $A$ , in case the phase has the same direction as  $A$  a current flows in the circuit, *e. g.*, in the direction  $BC$ ; when the phase is oppositely directed, the condenser  $B$  sends a current in the opposite direction. This last can be diminished by making the capacity of  $B$  very small. If, for example, the area of one of the electrodes is only one square millimeter, one may easily rectify alternating currents with a frequency of 1,000 per second; with greater frequency the electrode must naturally be made still smaller. It is best to employ a platinum wire sealed into glass — the wire being cut off immediately at the end of the glass. The author succeeded in rectifying electric oscillations of Hertzian frequency, and producing electrolytic effects with them; the wire for this purpose was .025 mm. in diameter."

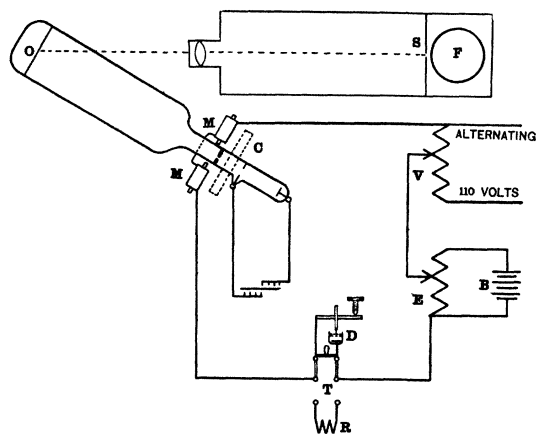


Fig. 3.

This quotation is introduced to show that Pupin had employed the electrolytic detector as a rectifier for electric waves of Hertzian frequency, and that he had a well-defined explanation of the processes occurring in the rectifier. The present experiment falls into close agreement with Pupin's explanation of the phenomenon.

Further study of the electrolytic detector, as a rectifier, has been made by Armagnat,<sup>1</sup> and Austin.<sup>2</sup> Armagnat has taken current-

<sup>1</sup> Armagnat, Bul. soc. française, session of April, 1906, p. 205; Journal de Physique, 5, p. 748, 1906.

<sup>2</sup> Austin, Bul. Bureau of Standards, 2, p. 261, 1906.

voltage curves of the detector with a galvanometer and a source of steady voltage, and by arguments similar to those employed by Pupin (but without reference to the polarization capacity of the electrodes) has shown more in detail how electrolytic polarization accounts for the rectification of alternating currents by the detector. Austin, also using a galvanometer as the indicating instrument, studied the effect of alternating currents of slow frequency and also the effects of electric waves, and came to the opinion that heat, chemical action, rectification and electrostatic attraction across the gas film might have a part in the explanation of the phenomenon.

In the present experiments the current through the detector under the action of an alternating E.M.F., superposed on a polarizing current, is determined by means of an oscillograph. The application of the oscillograph to the problem gives the instantaneous values of the current through the detector, and permits an examination of the wave form of the rectified cycle.

#### OSCILLOGRAPHIC APPARATUS.

##### *Circuits Employed with the Detector in Taking the Oscillogram.*—

The electrolytic detector used in these experiments made use of a platinum point, .005 mm. in diameter, dipping into 20 per cent. nitric acid, and was adjusted to high sensitiveness as an electric wave detector immediately before taking the oscillograms. A diagram of the circuits employed in the experiment, together with a sketch of the oscillographic apparatus, is shown in Fig. 3. The detector is at *D*, and is connected in series with the deflecting coils *MM* of the oscillograph and with the variable sources of voltage *V* and *E*. The voltage *V* is taken from a potentiometer connected with the 60-cycle alternating mains of the laboratory. *E* is an adjustable steady voltage taken from a battery. The voltage at *E* could be reversed. By opening the switch at *S* the electrolytic detector could be disconnected from the circuit, and by throwing this switch to the right an ohmic resistance could be substituted for the detector.

*The Braun's Tube Oscillograph.*—The oscillographic apparatus was essentially the same as that employed in the experiments on

crystal rectifiers (Part II.).<sup>1</sup> In the present experiments the high potential through the tube was produced by a Holtz influence machine, driven by an electric motor, whereas in the previous experiments Professor Trowbridge's high potential battery was used. The moving plates of the influence machine were of plain glass and did not carry any sectors or discs such as are used on the most common types of Toeppler-Holtz machines. This is important, since such sectors or discs produce a pulsewise discharge through the cathode tube, which results in a broadening of the cathode spot when it is deflected. The present machine in which the electricity was taken directly from the moving glass plates was very constant and gave cathode rays of great homogeneity, so that the luminescent spot produced at *O* on the screen of the tube remained sharply defined however far it was deflected.

The photograph of the moving luminescent spot was taken on a film carried by a rotating drum *F*, which made 20 revolutions per second about a horizontal axis. The drum was driven by a synchronous motor operating on the 60-cycle alternating mains of the laboratory, from which the alternating current sent through the rectifier was also taken. The synchronism of the drum with the deflections of the spot was so perfect that very long exposures could be made without any failure of perfect superposition, and without any appreciable fogging of the film.

The deflecting electromagnets *MM* had a combined resistance of 436 ohms, and were provided with soft iron cores about 6 mm. in diameter. With the small current employed the iron showed no appreciable hysteresis, and the deflections of the light spot were proportional to the currents. In oscillogram No. 1 (Plate I.) a deflection of .85 cm. on the film was obtained with a current of 1 milliampere. In taking the pictures, except No. 1, a Ryan focusing coil was placed about the tube so as to give a longitudinal field, which could be adjusted to bring the luminescent spot to have a circular area about .5 millimeter in diameter. This focusing device diminished the sensitiveness of the apparatus to about one third so that 1 milliampere gave a deflection of .28 cm. on the film, but the employment of the Ryan coil is a great advantage in producing a narrow line for the curves.

<sup>1</sup>G. W. P., *l. c.*

In taking the oscillograms the following steps were taken: The drum carrying the film was set rotating. The high potential current was started in the tube. The chosen value of the polarizing current was applied to the circuit and was read on a direct-current milliammeter. The alternating current was superposed on the circuit, and by adjustment of the potentiometer at  $V$  the voltage of this alternating current was given any desired value.

#### THE EXPOSURES.

After the preliminary adjustment of the direct and alternating currents through the detector, four exposures were made on each picture, while the film was being carried around continuously by the synchronously driven drum.

*Axis of Zero Current.*— This is the lower straight line across the pictures, and was obtained by an exposure of 20 seconds taken with the circuit open.

*Axis of Polarizing Current.*— This is the upper straight line across the picture, and was obtained with the detector in circuit and traversed by the polarizing current. The exposure was 20 seconds. In oscillogram No. 1 this axis is not apparent because on account of the small value of the polarized current employed it falls into coincidence with the axis of zero current.

*The Rectified Cycle.*— This cycle may be identified in the oscillograms as a positive<sup>1</sup> loop for a half-period, followed by a nearly straight portion lying along the axis of zero current for a part of a half cycle, and going over into the positive loop through an intermediate "building up" segment. This cycle (exposure of 60 sec.) was taken with the detector in circuit, with the alternating E.M.F. applied to the circuit, and with the polarizing current also flowing.

*The Voltage-Phase Cycle.*— This the sine-curve of the pictures, and was taken in order to obtain the E.M.F. immediately about the detector.<sup>2</sup> A similar curve was made use of in the writer's

<sup>1</sup> In describing the oscillograms, values *above* the axis of zero current are called positive; values *below* this axis are called negative.

<sup>2</sup> The ordinary method, which would be to take the leads from the two sides of the detector through a high resistance to the oscillograph, could not be used because the oscillograph was working at the limit of its sensitiveness on the full voltage without the added resistance.

experiments on crystal rectifiers and is there discussed. In the present experiments, because of the employment of the polarizing current with the rectifier, a question arises as to the appropriate method of taking this cycle. Two different methods were tried, either of which by proper elimination of the constants of the oscillographic apparatus, will give the desired result. The method yielding simplest results for the voltage-phase cycle is the following: After the exposure for the rectified cycle had been made, the alternating voltage was left unchanged, and a resistance was substituted for the rectifier. A double adjustment of the substituted resistance and the direct voltage was made by successive approximations until the result was attained that (1) the direct voltage alone gave through the substituted resistance a current equal to that used in polarizing the rectifier and (2) the alternating voltage superposed on this direct current gave a deflection of the luminescent spot to a point coincident with the maximum point attained with the rectifier in the circuit. This means that the voltage-phase cycle was taken with the axis of polarizing current as axis, and with amplitude equal to the maximum amplitude of the rectified cycle. This method was employed in oscillograms 1, 2 and 5.

TABLE I.

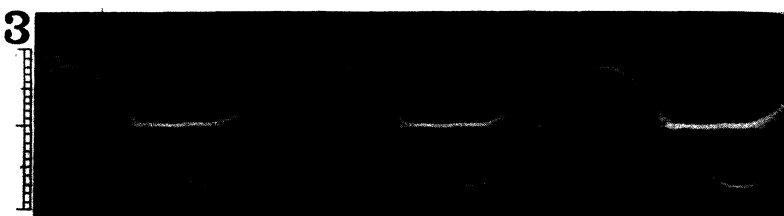
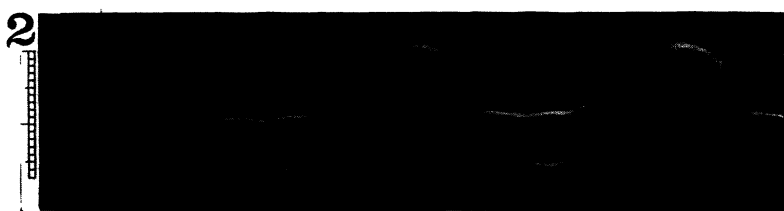
*Tabular Description of the Oscillographic Records.*

No.	Polarizing Direct Current in Milliamperes.	Polarizing E.M.F. in Volts.	R.M.S. Volts A.C.	Maximum Positive Current through Detector in Milliamperes.	Equivalent Resistance in Ohms.
1 <sup>1</sup>	Less than .1	1.45	2.09	2.37	440 <sup>1</sup>
2	1.0	5.5	4.00	9.6	70
3 <sup>2</sup>	1.2	5.5	4.00	9.6	00 <sup>2</sup>
4 <sup>2</sup>	1.4	Not measured.	5.00	10.0	00 <sup>2</sup>
5	2.2	"	5.00	11.0	150

The second method of taking the voltage-phase cycle was as follows: The polarizing voltage was reduced to zero, the detector was short-circuited, and an alternating voltage equal to that used with

<sup>1</sup> It should be noticed that the sensitiveness of the oscillograph when No. 1 was taken was three times as great as when the other oscillograms of the plate were taken

<sup>2</sup> The voltage phase cycle of oscillograms 3 and 4 were taken with the polarizing current omitted, so that they have the axis of no current as axis of the cycle.



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The Electrolytic Detector.



the detector was applied to the circuit. This method was employed in oscillograms 3 and 4.

*Coördinates of the Oscillographic Curves.*—In taking all of the curves of the oscillograms, the motion of the light spot over the film is from left to right; the time coördinate is, therefore, the abscissa of the curves and is drawn as usual from left to right. The current coördinate is given in the scale drawn in ink at the left hand margin of each picture — one division being one milliampere.

#### DISCUSSION OF THE OSCILLOGRAMS OF PLATE I.

The oscillograms shown in Plate I. are reproductions of positives printed from the films carried by the rotating drum. The reproduction is one third the size of the original. They were taken with a 60 cycle alternating current applied to the circuit containing the electrolytic detector. The several curves shown in the plate were obtained with different polarizing currents superposed on the circuit. Table I. contains a tabulation of the polarizing current and voltage, the applied alternating voltage, the maximum current through the detector and the substituted resistance employed in taking the voltage curve.

*Point Anode or Cathode — the Large Loop in the Direction of the Polarizing Current.*—Some of the oscillograms were taken with the polarizing current from the point to the electrolyte and some with the polarizing current in the opposite direction. Although the values of the polarizing voltage required to produce a given polarizing current were different in the two cases the general characteristics of the cycle were the same. A reversal of the polarizing current reversed the rectified current, and whether the polarizing current was from the point to electrolyte or in the opposite direction the large loop of the rectified cycle (always oscillographed positively) was obtained when the alternating current was flowing in the same direction as the polarizing current.

*The Form of the Rectified Cycle.*—The cycle obtained with the rectifier in the circuit has the same general form in all the pictures. When the current, having traversed the positive loop, comes to the axis of zero current, it follows along this axis for a short way, then takes a small negative dip, becomes positive again, follows

along just above the axis of zero current for a short time, and then rises along a transition curve to the positive loop.

*Calculations Concerning the Form of the Cycle.*—The rectified cycle, when examined by comparison with the voltage-phase cycle, makes a misleading impression unless one takes carefully into account the condition under which the curves are obtained. One must bear in mind that the form of the current through any rectifier is not determined by the rectifier alone, but is a function also of the constants of the circuits employed with the rectifier. In the present experiments, the deflecting coils of the oscillographic apparatus possessed appreciable self inductance and resistance, and these factors must be taken into account. It is proposed, therefore, to examine the problem in the light of the elementary theory of alternating currents.

The examination will be confined to oscillogram No. 2. The data for this curve are contained in Table I. The polarizing cur-

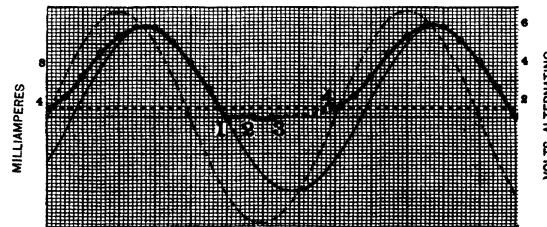


Fig. 4.

rent had a value of .001 ampere, obtained by impressing a steady voltage of 5.5 volts on the circuit containing the detector and the deflecting coils. The impressed alternating voltage had a R.M.S. value of 4 volts, and therefore a maximum value of  $4\sqrt{2} = 5.66$  volts. The equation of this voltage is

$$(1) \quad e = 5.66 \sin \omega t,$$

which is plotted as the dotted sine-curve of Fig. 4. The ordinate scale for this curve, in volts, is at the right of the diagram.

The voltage-phase cycle taken with this alternating E.M.F. and with a direct current of .001 ampere impressed upon the circuit, which consists of the coils of the oscillograph and a resistance of 70 ohms substituted for the rectifier, has the equation

$$(2) \quad i_1 = \frac{5.66}{\sqrt{R^2 + L^2\omega^2}} \sin \left( \omega t - \tan^{-1} \frac{L\omega}{R} \right) + 1 \times 10^{-3}.$$

$R$  is made up of the resistance of the coil, 436 ohms, plus the added resistance of 70 ohms, making 506 ohms. The maximum value of  $i_1$ , taken from the oscillogram, is  $9.8 \times 10^{-3}$  amperes. The values of  $R$  and  $i_{1(\max)}$  substituted in equation (2) gives

$$9.8 \times 10^{-3} = \frac{5.66}{\sqrt{506^2 + L^2\omega^2}} + 1 \times 10^{-3};$$

whence

$$(3) \quad L\omega = 397,$$

and

$$\varphi_1 = \tan^{-1} \frac{397}{506} = 38.1^\circ,$$

where  $\varphi_1$  is the angle of lag of the voltage-phase cycle behind the voltage  $e$  of equation (1). The value of  $i_1$  is now completely known, and is plotted as the *continuous* sine-curve of Fig. 4. This curve is the voltage-phase cycle of the oscillogram No. 2.

Let us next compute some points of the rectified cycle; namely, the points indicated by circles and numbered 1, 2, 3 and 4 on the diagram of Fig. 4. Let us at first assume that the rectified cycle and the voltage phase cycle come to the axis of zero current together. This gives us the point 1 as a starting point. Then the value of the current at the points 2 and 3 is also zero, because the impressed voltage is zero, being 5.5 volts (the polarizing E.M.F. externally applied) and  $-5.5$  volts (the corresponding ordinate of the dotted sine-curve). Thus the externally applied voltage is zero. Also, since the current is practically zero and the rate of change of current is practically zero in the neighborhood of the points 3 and 4, the internal E.M.F. of the circuit due to resistance and inductance is zero. This gives the total voltage as zero and the resultant current zero at these points. The point 4 has the abscissa  $2\pi$ , therefore the external alternating voltage (dotted curve) is zero; whence the current is equal to the polarizing current, and the point is on the axis of polarizing current. (This assumes that the current between points 3 and 4 is small and its rate of change is small, which is borne out by the fact that the current in this region has to remain between the two axes.)

The points 2, 3 and 4 are thus located by calculation. The march of the current intermediate between the points 3 and 4 is difficult to determine, on account of the unknown way in which the current grows during the polarization of the electrode. I have, therefore, indicated the current in this interval by a dotted line. We know, however, that between the points 2 and 3 there must be a tendency to a small negative maximum, because in this interval the negative value of the alternating voltage, taken from the dotted sine-curve, is larger than the positive polarizing voltage (5.5 volts). This small negative maximum is indicated on the diagram.

Having obtained the location of the four points 1, 2, 3 and 4, and of the negative loop between 3 and 4, let us next consider the large loop of the rectified cycle. In this loop the alternating voltage and the polarizing voltage aid each other, so as to produce large values of the current. With these large values of the current the resistance and the inductance of the coils come to play an important part, and the current tends to traverse an arc of a sine curve. However, since the current has been nearly zero for a large part of a half period, the "building-up" terms of the current equation are of importance. Let us attempt

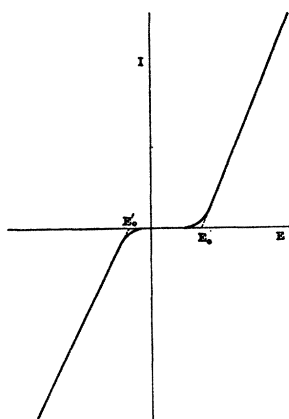


Fig. 5.

to obtain an approximate equation for this part of the cycle. To do this we need to keep in mind the experimental fact that it takes several volts to overcome the E.M.F. of polarization of the electrolytic cell with small electrode, but after this polarization has been overcome, the application of additional voltage produces additional current proportional to the additional voltage. This fact is illustrated by the current-voltage curve of Fig. 5, taken from the work was obtained by Armagnat by applying various values of steady of Armagnat.<sup>1</sup>

This curve voltage and measuring the current through the detector with a galvanometer. If we assume that a similar relation of current to voltage obtains when the voltage is rapidly changing with the

<sup>1</sup> *L. c.*

time, we shall be able to compute approximately the upper loop of the cycle. When the current in the positive direction in our experiments has reached the axis of polarizing current it is on the straight part of the curve of Fig. 5, so that above this axis the resultant current is made up of .001 ampere due to the polarizing voltage plus the current under the action of the alternating voltage — this added current being obtained by assuming that the resistance of the detector is constant. This assumption gives for the current of the upper loop of the rectified cycle, the following equation:

$$(4) \quad i_2 = \frac{5.66 \sin \left( \omega t_1 - \tan^{-1} \frac{L\omega}{R} \right)}{\sqrt{R^2 + L^2\omega^2}} + .001 + c\varepsilon^{-\frac{Rt}{L}},$$

in which  $t_1$  is measured from the instant at which  $\omega t$  becomes  $2\pi$ ,  $4\pi$ ,  $6\pi$ , etc.  $L\omega$  has the value given in equation (3) above, and because of the equality of the positive amplitude of the rectified cycle and that of the voltage-phase cycle, we know that  $R$  has the value it had above; namely, 506 ohms. Putting these values in equation (4) and remembering that when  $\omega t = 2\pi$ ,  $i_2 = .001$ , and  $t_1 = 0$ , we may determine the constant  $c$ . The value obtained is  $c = .0054$  ampere. By a comparison of equations (4) and (2) we have

$$(5) \quad i_2 = i_1 + .0054\varepsilon^{-\frac{Rt}{L}}.$$

By computing the values of the exponential term and adding them to the corresponding values of  $i_1$  we obtain the values of  $i_2$ . These are plotted as the positive loop in Fig. 4, which, together with the points 1, 2, 3 and 4, make up the complete computed curve for the current through the rectifier.

In justification of our assumption of the point 1 as a starting point it should be noted that, since the exponential becomes inappreciable in less than a half period,  $i_2$  becomes equal to  $i_1$  and the two currents approach the axis of zero current together.

*Comparison of the Computed Cycle with the Cycle of the Oscillogram No. 2.* — The scale used in plotting the computed curves is not identical with that of the original oscillogram. To show the agreement of the form of the computed curve of Fig. 4 with oscillogram No. 2, a tracing of the original oscillogram is drawn in Fig.

6. The computed values of the rectified cycle, reduced to the same scale, are also plotted as the circles of Fig. 6.

The computed points agree well with the oscillogram in the location of the negative maximum, the position of which with respect to the positive maximum is seen to be entirely due to the inductance and resistance of the circuit. The computed points also fall well into agreement with the oscillogram on the right-hand slope of the

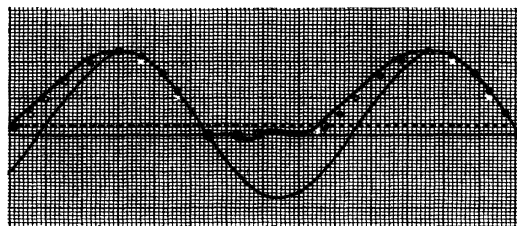


Fig. 6.

positive loop, but on the left-hand slope there is a considerable departure. On this slope the computed values of the current are all too low. This might have been expected because the "building up" had really begun earlier than the time assumed; that is, before the cycle had reached the point 4; and the computation in this segment is to be regarded only as a rough approximation.

*Evidence of Polarization Capacity.* — On oscillograms 1, 2 and 3 there is a small positive rise of the photographic curves in the region to the immediate right of the negative maximum. This rise is more striking in the original photographs than in the reproductions; and, though small, it deserves attention, because the occurrence of this small positive maximum is evidence of the existence for about  $1/1,500$  of a second of a positive E.M.F. greater than the E.M.F. immediately following. Now in this part of the cycle the externally applied E.M.F. is greater following the rise than during the rise; therefore the rise indicates the existence of a positive E.M.F. in the circuit itself. This is capable of the following explanation in terms of the theory of polarization. After the prevalent external E.M.F. has been in a negative direction and has returned to zero, the polarization tension which has been opposing the negative current at the electrode continues to exist for a short time and produces a positive

current. This action, resembling that of a capacity, is familiarly known as the polarization capacity of the electrode. By the existence of the small positive maximum near the axis of the cycle, the oscillogram shows that the polarization capacity of the electrode is not entirely negligible. Evidence of the existence of this polarization capacity is clearly given by the oscillograms 1, 2 and 3. The oscillograms 4 and 5, while not having a positive maximum near the axis, show also a striking tendency toward a maximum at this point, which is, however, masked by the rapid rise of the building-up curve in this part of the cycle.

#### CONCLUSION IN REGARD TO THE ELECTROLYTIC DETECTOR.

1. The whole phenomenon of the rectification of small alternating currents by the electrolytic detector seems to be explicable in terms of the theory of electrolytic polarization.

2. The polarization capacity of the small platinum electrode is not entirely negligible, even with currents making only 60 cycles per second. The polarization capacity may, however, aid in producing rectified current as well as oppose this effect, and apart from the effect of this capacity on the tuning of the circuit need not detract from the utility of the rectifier as a detector for electric waves.

3. The present conclusions in regard to the action of the detector is entirely in accord with Pupin's original brief description of the phenomenon as quoted above.

#### COMPARISON OF THE ELECTROLYTIC DETECTOR WITH THE CRYSTAL RECTIFIERS.

The resemblance of the oscillograms with the electrolytic detector to those with the crystal rectifiers<sup>1</sup> is close, in so far as depends on the fact that both classes of rectifiers are nearly perfect<sup>2</sup> rectifiers when employed under their best conditions. The electrolytic rectifier in order to approximate perfection<sup>3</sup> as a rectifier must be

<sup>1</sup> Pierce, Part II., *l. c.*

<sup>2</sup> A rectifier is called "nearly perfect" when the ratio of the current in one direction to that in the opposite direction is large.

<sup>3</sup> The current through the electrolytic rectifier is slightly asymmetric when no polarizing current is employed.

polarized by the superposition of a direct current ; while the use of the direct current with the crystal rectifier, though slightly lowering its resistance, does not materially improve the rectification. Also the two rectifiers are different, in that the electrolytic rectifier shows evidence of electrolytic polarization capacity, which, so far as may be judged from the oscillograms, is absent with the crystal rectifier. The experiment with the electrolytic detector, since it shows in the matter of polarization capacity the integrative action of this detector, which was sought for and not found with the crystal rectifier, is thus an interesting "control" experiment. Also an examination into the resemblances and differences of the two classes of rectifiers ought to aid us in seeking a rational explanation of the crystal rectifier.

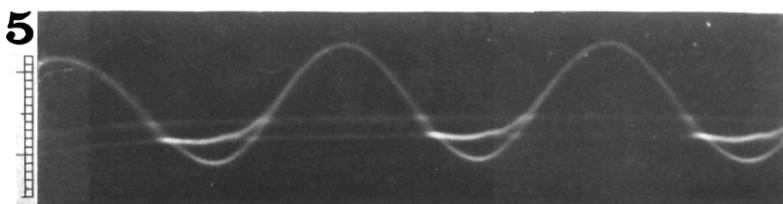
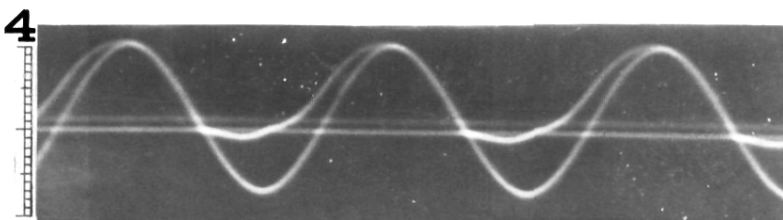
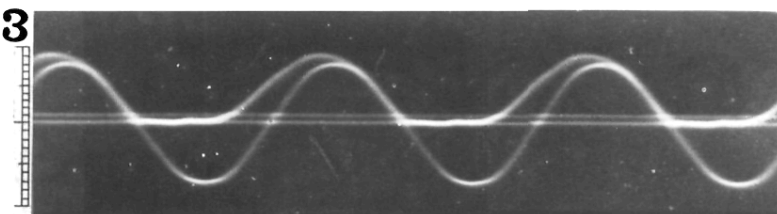
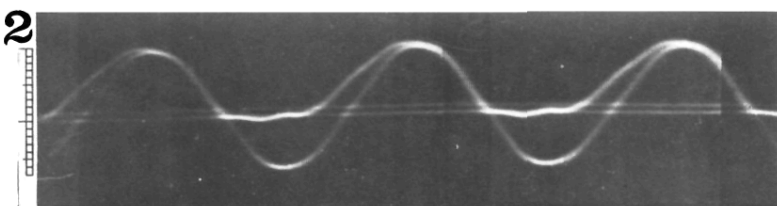
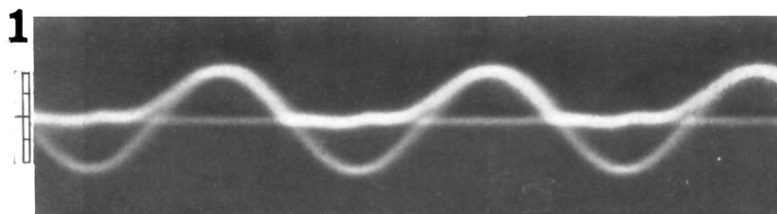
However, before attempting to give definite expression to any theory as to the nature of the action in the crystal rectifiers, it is proposed to attempt to study in this connection the action of some form of vacuum-tube rectifier, so that the vacuum-tube rectifier may also be compared with the crystal rectifier under similar conditions.

In the meanwhile, the results of some experiments on a crystal rectifier making use of iron pyrites is presented in a separate paper to appear soon.

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The Electrolytic Detector.