THE USE OF THE WEHNELT INTERRUPTER WITH THE RIGHI EXCITER FOR ELECTRIC WAVES.

BY A. D. COLE.

IN some earlier work with electric waves, generated by a Righi exciter and measured by a Klemenčič thermo-receiver,[1] it was found necessary to use a very sensitive galvanometer. Thus for most of the work a figure of merit of about 4.5×10^{-9}, in a 5-ohm galvanometer, was necessary.

Such sensitiveness in a galvanometer of resistance so low requires one to adjust its control magnet to produce a field so weak that the zero wanders badly and the vibration period is excessively long. This is a matter of serious consequence in these days when there is an electric railway or two in the near vicinity of nearly every physical laboratory. It is therefore desirable both for research and demonstration purposes to so increase the energy of the radiation as to allow the use of galvanometers of lower sensitiveness and shorter period.

As the integrated value of the energy is operative in receivers of the thermoelectric type, proportionately larger deflections are to be expected with an increase of frequency in the interrupter used with the induction coil. A test of this point was made several years ago by substituting a rotary break driven by an electric motor for the ordinary spring interrupter of the induction coil. Larger deflections were obtained in this way, but the action was quite irregular and the exciter soon became hot. So for the time the use of the ordinary interrupter was resumed.

Later, however, a plan for the constant circulation of oil through the exciter which had been adopted, gave promise of avoiding the troublesome heating effects of a high-frequency interrupter, and a new attempt was made. This time the Wehnelt interrupter was

[1] Cole, A. D., Wied. Ann., 57, 298, 1896. PHYS. REV., 7, 225, 1898; 20, 268, 1905.

tried and was found to answer the purpose admirably. A 4.5-ohm galvanometer whose figure of merit was 2.3×10^{-9} gave deflections of about 800 mm. with the scale 1 meter distant. The control magnet was moved until the figure of merit was only 4×10^{-8}, and its double vibration period only 2.7 seconds. Now the sensitiveness was only about one-twentieth what it had been before and yet the deflections are sufficiently large. The zero was steady (even with cars running every minute on the neighboring electric line). Further the greatly diminished period made it possible to obtain series of readings in a fraction of the time necessary before.

Considerable difficulty was found however at first in obtaining a form of interrupter which would remain in fairly constant condition for even an hour or two of steady use. The acid cell and the lead electrode were made of large size so that the interrupter would run cool, but the small electrode gave trouble. When made of platinum wire sealed into a glass tube it usually cracked out after a short time. The use of soft enamel glass for sealing in the wire reduced the difficulty, but did not remove it. An electrode which would not break was obtained by using several small platinum wires a millimeter or so apart sealed into the enameled tip. But these thin wires wore away too rapidly to be practical.

Various forms of adjustable electrode were tried. In these a single heavy platinum wire 1.4 mm. in diameter was used as an electrode. This was mounted in a surrounding glass tube of about 3.5 mm. internal diameter and projected through a plug or plate of insulating material at the lower end. Okonite insulation and rubber were first used for the plug, but they quickly softened by the heat and became disintegrated. Small discs cut from the bowl of a clay pipe were but little more durable. Compressed asbestos and a hard kind of talc were tried and rejected. Finally good results were obtained by using small discs cut out of a piece of close-grained slate. A small hole through the center of the disc allowed the platinum tip to be adjusted in length. This disc (see *a*, Fig. 1) was cemented to the end of the glass tube. The platinum wire was about 8 cm. long and soldered at *b* to one primary terminal of an induction coil. The cork shown at *c*, at the top of the glass tube, kept the tip from changing in length after it was suitably adjusted.

The tube usually projected down about 2 cm. into the weak acid of the cell. Details of construction are shown in the figure. The round battery jar of glass, 21 cm. high and 15 cm. in diameter, was filled to a depth of 13 cm. with dilute sulphuric acid of specific gravity 1.05. One electrode was formed of a strip of lead 50 cm. long and 9 cm. wide, bent up into a U-shape so as to present about 720 sq. cm. of surface to the acid. The other electrode consisted of the 1.4 mm. platinum wire, projecting usually 4 mm. Acid so weak was chosen because the frequent removal and adjustment of the platinum tip was thus made more convenient and the small increase of resistance was unimportant since it was found best to use additional resistance in series with the cell for control.

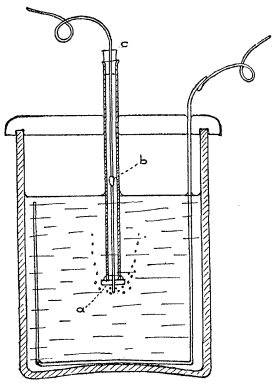

Fig. 1.

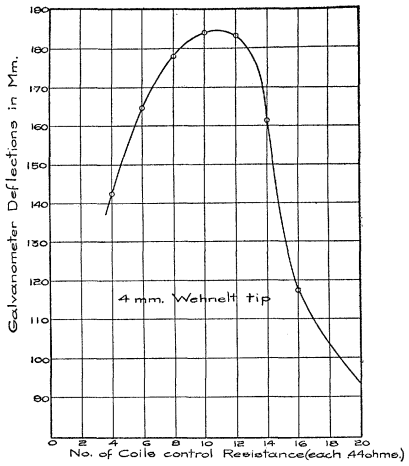

Fig. 2.

Alternating current of 110 volts was used for exciting this Wehnelt interrupter. When no resistance was used in series with it there was excessive heating, both of the interrupter and of the Righi exciter. This gave trouble in each by the occasional melting of the cement used in holding the parts together. The same trouble was experienced when the platinum wire of the Wehnelt tip was allowed to project more than about 6 mm. from the tube in which it was mounted. Of course direct current could be used equally well for exciting the Wehnelt interrupter.

The amount of control resistance which it is desirable to use in the primary circuit depends somewhat upon the length of tip used in the interrupter. Thus with 7.1 ohms of control resistance in the primary circuit, a 2 mm. tip gave better deflections than one of 10 mm., but with 4.4 ohms a 10 mm. tip gave the better effect. On the whole the best results were secured with the tip about 4 mm. long and with about 5 ohms of control resistance. The amount of effect caused by varying the resistance step by step with a fixed length of tip (4 mm.) is shown in Fig. 2.

The regularity of action that can be secured with the conditions right is illustrated by the following series of ten deflections taken in succession :

mm.	mm.
334	345
331	347
331	355
345	347
332	347

In this case 4.4 ohms of control resistance was used with the Wehnelt tip 10 mm. long.

The circulation of oil through the Righi exciter is a practically important feature, as it keeps the apparatus cool and prevents the irregularities in action which excessive carbonization of the oil would cause. This flow of oil is secured by drawing out the end of a long thistle-tube to a fine point and bending the tube to such a shape that it can be firmly held by a clamp to the upper edge of the frame of the parabolic mirror in which the exciter is mounted. It was adjusted to deliver about 30 drops of oil per minute to the vicinity of the central spark-gap. This construction is shown in Fig. 3. A constant-level overflow tube came up through the small oil chamber of the exciter to a height slightly above that of the spark-gap. After trying vaseline oil, olive

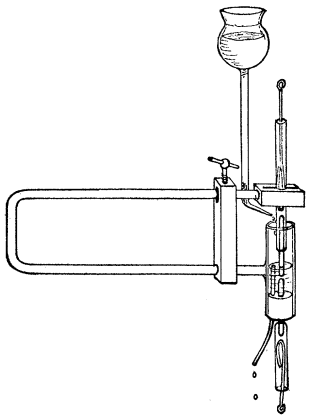

Fig. 3.

oil and lubricating oils of various degrees of viscosity, I have settled down upon ordinary refined petroleum (kerosene) as best adapted for use in exciters of short wave length.[1]

A Caldwell interrupter consisting of two vessels of acid with a small hole in a slate diaphragm between them was also tried, but proved inferior to the Wehnelt interrupter above described.

APPLICATION TO DEMONSTRATION PURPOSES.

This reduction of the necessary galvanometer sensitiveness to about one-twentieth of its former value makes the thermoelectric receiver for electric waves thoroughly practical for demonstration purposes, and its strictly quantitative character gives it an advantage over other indicators in use. The want of a suitable apparatus for demonstrating the optical analogies of electromagnetic radiation in class and lecture room has been seriously felt by many and the hope of securing it was the primary object of these experiments. Hertz's classic apparatus, so much used in Germany, is too cumbrous, its sensitiveness is small and its indications can be seen by only a few persons at once. The introduction of the coherer enabled Bose,[2] Lodge,[3] and others to reduce the apparatus to convenient dimensions, but this receiver is not strictly quantitative and it is very sensitive to all sorts of disturbing influences. The use of "copper hats" and small diaphragms to shield the coherer from side disturbances undoubtedly change materially the character of the radiation which is being studied. The mirror-strip receiver of Righi is obviously unsuited to demonstration purposes.[4]

The apparatus here described has been found as the result of

[1] To make an actual test of the magnitude of the results obtained with this Wehnelt interrupter in comparison with those secured with the ordinary type, two series of readings were taken, all the conditions being the same in each except that in the first the vibrator furnished with the induction coil was used (a Ritchie 4-inch coil with vibrating hammer interrupter) while in the second the Wehnelt interrupter was employed in its place. The mean galvanometer deflection in the first series was 9.2 mm. but in the second 96.1, or 10.4 times as much with the Wehnelt as with the ordinary interrupter. (Footnote added April 2, 1906.)

[2] Bose, J. C., Proc. Roy. Soc., 160, 167.

[3] Lodge, O. J., The Work of Hertz, etc., p. 32.

[4] Righi, A., Mem. R. Ac. Bologna, 1894. Phys. Soc. Abstracts, 1897, No. 196.

considerable experience to be well suited for demonstrations and I will close with a few illustrations of its usefulness in this direction.

A wave-length of 15 cm. has proved to be well adapted for demonstration. To secure this the total length of the two cylinders in the exciter should be 5 cm. and in the receiver 6 cm. The receiver is shown in Fig. 4. It is a special thermo-couple described more fully in PHYSICAL REVIEW, Vol. 20, p. 268. For most purposes both exciter and receiver are mounted at the foci of parabolic mirrors of sheet metal having an aperture about 35×35 cm., and placed from one to two meters apart.

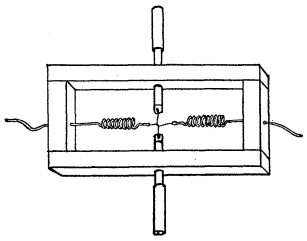

Fig. 4.

I have found it convenient to mount the receiver at the end of a revolving arm about 75 cm. long, swinging in the horizontal plane about a pivot half-way between exciter and receiver. This arrangement constitutes a spectrometer for electric waves.

All the experiments described in the culminating paper of Hertz's classical '87–'88 series[5] (and many others) are readily shown with this apparatus. For a plane reflector a sheet of metal 15 cm. square suffices, but it is better to use one 30 cm. square. A sheet of tin foil allows several per cent. of the radiation to pass through it, while ordinary sheet zinc transmits none. For a prism I use one of 30° angle and having faces 30 cm. square, cast in a wooden form with melted resin. Also a hollow one of glass plates filled with oil. My polarization grating is made of strips of tinfoil 2 mm. wide, 1 cm. apart on a sheet of cardboard. I am making a diffraction grating of tinfoil strips 12 cm. wide with 12 cm. spaces between them. For diffraction experiments I remove the parabolic mirror from behind the linear receiver and still have reasonably large deflections. (The multiplying power of the mirror is 6 to 8 fold.) For a concentrating lens I use an ordinary 5-pint acid bottle filled with benzine. Kerosene or gasoline will answer, but neither seems to be as good as benzine. Placing such a lens before a receiver will increase the radiation received about 5-fold. Stationary waves

[5] Hertz, H., Wied. Ann., 36, 769, '88.

are formed readily in several ways, as by perpendicular reflection from a plane mirror behind the receiver, or by a similar mirror behind the exciter, or by Boltzmann's two-mirror method.[6] I have given examples of curves showing the maxima and minima obtained by the first two methods in an earlier paper.[7] I add in Fig. 5 an example of the first method named.

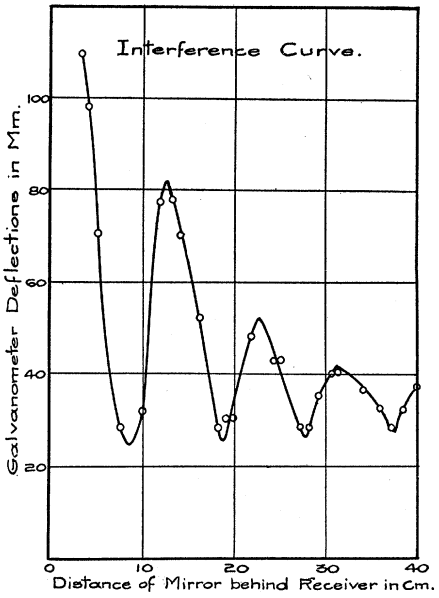

Fig. 5.

These illustrations suffice to show some of the uses of the apparatus and the results that can be obtained. Taking into consideration its comparative handiness, the ease with which its indications can be projected before a large class and the quantitative character of the results obtained, it seems to be adapted for demonstration purposes as well as for research.

PHYSICAL LABORATORY, OHIO STATE UNIVERSITY,
January 1, 1906.

[6] Boltzmann, L., Wied. Ann., 40, 399, 1890.
[7] Cole, A. D., PHYS. REV., 20, 270, 1905.