tube should be supported by an outer tube of equal length and thickness, but composed of more tenacious metal—wrought iron or gun metal.

If this cannot be satisfactorily accomplished, then the steel tube might be covered with at least two layers of coiled tubes—breaking joint. In this case the tubes should be *screwed* as well as shrunk over each other. If the screwed part was slightly conical it would be possible to adjust the tension with nicety. B.

January 25

THE ELECTRICITY OF THE TORPEDO

THE recent researches of Prof. Marey on the electric discharge of the torpedo have been presented by the author in an extended memoir published last year.[1] We propose to present to our readers the main conclusions reached by M. Marey, and the experimental demonstrations on which the principal of these are based. But before entering into details of the experiments let us indicate summarily the processes employed by M. Marey.

In previous researches,[2] made in 1871, he had at his disposal only the reactions of the muscles of the frog to analyse the electric phenomena of the torpedo; he caused to be recorded, upon an inclosed plate, the shock of a frog's muscle produced by the discharge of the electric apparatus of the torpedo. The instant of the excitation of an electric nerve or of the nervous centres of the torpedo was recognised; and it was seen that the movement of the foot of the frog presented, at the instant of excitation, a considerable retardation, equal, *e.g.*, to four-hundreds of a second, measured on the chronographic scale. But into this total retardation entered several diverse elements, which M. Marey took into account by causing the muscle of the frog to contract by an excitation directly acting upon it. The time lost by the muscle of the frog representing nearly the half of the total retardation, it was concluded that the time-test by the electric apparatus is equal to that of the muscle of the frog.

Since these first researches, M. Marey has been able to study more directly the electricity of the torpedo by making use of the electro-magnetic signals of M. Deprez and of Lippmann's electrometer.

M. Deprez's signal is composed of a small electro-magnet provided with an extremely light armature of soft iron, which is applied to the coils when the current which traverses them is closed, and which is drawn from it, without delay in demagnetisation, at the moment of the rupture of the current, by the contraction of the tight india-rubber thread. The armature is provided with a style which traces on the inclosed cylinder the closures and ruptures of a current, the duration and frequency of these successive acts, with such perfection that it is easy thus to obtain the record of 1,000 vibrations per second. In the tracing underneath the apparatus (Fig. 1) is seen the signals which it furnishes when acted on by a non-continuous scale of 500 simple vibrations per second.

It is this electro-magnetic signal which M. Marey placed in the circuit formed by the torpedo, whose apparatus was held between two metallic plates joined to the coils of the apparatus by two conducting-wires. We shall see, further on, what use he has been able to make of this.

The second instrument by means of which certain special points of the experiments have been made is Lippmann's capillary electrometer. This apparatus is formed essentially of a column of mercury sustained by capillarity, in a tube of extremely fine glass, the extremity of which is plunged in a bath of dilute acid. When the mercury of the apparatus and the acidulated water are placed in connection with two points of an electric circuit of unequal tensions the capillary column is displaced and is carried towards the side of strongest tension. This displacement is instantaneous, and if the variations of electric tension are produced successively with great rapidity we need not fear the inertia of the capillary column. All the variations are signalled whatever be their frequency. But as the movements of the capillary column cannot be registered themselves, M. Marey has had recourse to photography in a certain number of experiments.

Let us now consider the results following the order which we have indicated at the outset.

1. *A torpedo's discharge is not a continuous current; it is formed of a series of successive waves added one upon another.*

The fundamental experiment upon which the demonstration of this proposition rests was performed with the electro-magnetic signal (Naples, October, 1876). Having compressed one part of the apparatus of an active torpedo just drawn from the water between two metallic plates furnished with conducting wires, M. Marey placed the signal-machine of M Deprez in contact, and the magnet being stimulated he heard a shrill noise resembling that made by filing the end of a hard splinter of wood. The vibrations of the armature, therefore, had been produced by a series of successive electric acts. In defining these vibrations one is justified in stating that the discharge of the torpedo produced by the animal as the result of a local excitation, was composed of a variable number of waves or currents succeeding each other. Fig. 2 represents two tracings so produced. The great advantage resulting from the use of the electro-magnetic signal was to show definitely that the discharge is complex, an analysis which was not possible with the frog's-foot signal. The muscle used as reagent does not in fact react by means of the shocks apart from impulses which are sudden and frequent; it remains in a state of permanent contraction.

But the electro-magnetic signal, whilst showing the dissociation of the torpedo discharge, furnished no other result. It did not indicate how those successive waves follow each other, it seemed even to lead to the conclusion that one wave is quite completed when the next succeeds. At this point the induction is interrupted and the experimentalist adopts another mode of solving this question of the succession of waves in a discharge. M. Marey, in fact, being convinced that the electric action of the torpedo and muscular action should be assimilated, and wishing to see in the discharge the analogue of induced tetanus and even of voluntary contraction, could not resign himself to the admission of an absolute discontinuity between the successive acts constituting a discharge. Yet the electro-magnetic signal apparatus seemed to pronounce his theory wrong. But on passing through Lippmann's electrometer a slight current from the total discharge, M. Marey observed that the column underwent a series of successive impulses, the effects of which unite together. This progression by successive jerks indicated an increase of the intensity of the discharge, an increase in which each new wave is joined to what remains from those which have preceded it. Thus we derive the proof that the electric waves are *partially* united to one another like the muscular shocks of a tetanised muscle.

This first fact being gained, it was necessary to follow up the analysis of the torpedo-discharge, determine the nature of each of the independent electric acts which the electro-magnetic signal had revealed, measure their duration, phases, &c. These different points have been elucidated, each in its turn.

2. *To measure the duration of the electric-wave in the torpedo*, M. Marey has had recourse to the method devised by Guillemin for determining that of very short current, and used afterwards by Bernstein to measure the

[1] "Compte Rendu des Travaux du Laboratoire de M. Marey." T. iii. Paris: G. Masson. 1877.
[2] "Annales de l'École Normale Supérieure." 2e s., t. i., pp. 86-114.

duration of the negative variation of nerves and muscles. Guillemin's method is applicable in every case where a current passes several times in succession through a metallic circuit, with duration always the same. The electric condition of the circuit is investigated during a succession of very short intervals, beginning at the moment when current is complete.

The apparatus used by Guillemin and Bernstein was the galvanometer; M. Marey preferred to use a frog's foot, which, in the successive investigation, gives a movement which can be graphically recorded, as often as there is an electric current.

The graphic method, by which each duration is transformed into a length easily measured on the paper, is easily applied in performing those experiments of which we are about to explain the principle.

Let the point 0 (Fig. 3) correspond to the moment of electric excitation of a torpedo-nerve, and let the successive points 1, 2, 3, &c., denote successive hundredths of a second, which correspond to very short intervals during which the torpedo apparatus is put in contact with a metallic circuit passing through a frog's foot. In the two first trials, 1 and 2, after the excitation of the electric nerve, there are no signals recorded; the frog's foot remaining motionless shows that the discharge of the torpedo has not reached it, because, in fact, the phenomenon has not yet had time to take place. But at the instant 3 the frog moves, which is expressed in the diagram by a vertical stroke; at the instants 4, 5, 6, 7, 8, 9, and 10, the frog receives shocks which are indicated on the diagram by vertical lines; and finally, at the instant 11, and those succeeding, the frog shows no action, whence we conclude that the electric wave of the torpedo was finished before these last trials; and we see that, according to the tracing, the wave began three-hundredths of a second after the instant of nerve-excitation and finished ten-hundredths after the same instant.

FIG. 1.

It was exactly in the same way that M. Marey proceeded to measure the duration of the electric wave in the torpedo. An arrangement easily fixed induced electric action in *e* (Fig. 4) at constant intervals. A metallic contact, susceptible of being displaced at will, allowed him, during very short intervals of different lengths, to complete the circuit made by the electric wave of the torpedo to reach the frog's-foot-signal. Moreover, to avoid confusion of the curves which were registered by the successive experiments, he took care to change the position of the style each time, so that the curves appeared one under the other in order.

Fig. 4 shows that the first appearance of the electric wave took place at instant 1; that in a series of successive trials, each later than the preceding, after the excitation of the nerve, the wave was indicated at the instants 2, 3, 4, 5, and 6; and that at the 7th trial the frog gave no signal. The wave, therefore, was completed. Finally, by bringing the instant of trial nearer to that of nerve-excitation, the wave was retraced in experiments 8, 9, 10, 11, and 12; but in the 13th, occurring too soon after the instant of nerve-excitation, it was shown that the electric wave no longer existed.

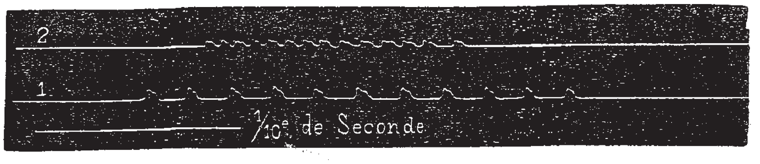

FIG. 2.

The approximation of these measurements necessarily depends on the number of successive trials, and is more delicate in proportion as they succeed each other more frequently.

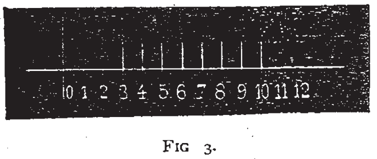

FIG 3.

3. *Each electric wave presents a phase of suddenly increasing intensity, followed by a phase of gradually decreasing intensity.*

On examining the tracings of electric waves obtained by the electric-magnetic signal, we observe an apparent contradiction between the indication, the wave-duration furnished by this apparatus, and that which we have just seen determined by the frog's foot. The waves traced by the signal of Deprez seem to measure not more than one-hundredth of a second; by Guillemin's method, on the contrary, their duration is much more considerable, being seven-hundredths of a second. This apparent contradiction results from the fact that in the torpedo the waves have not sufficient energy during the whole of their duration to act upon the signal, whereas, from beginning to end of their course they can act upon the frog's muscle, which is much more sensitive. There are, then, in every electric wave, phases of increasing intensity and decreasing intensity which remain to be determined.

M. Marey has endeavoured to obtain a tracing of these phases of variable intensity by a modification of the apparatus of M. Deprez. Instead of limiting the excursion of the style between two fixed obstacles, he allowed it an excursion which varies and is proportional to the intensity of the currents acting upon it.

With this object an india-rubber thread, bent over two bridges, was stretched horizontally between the soft iron bars of the armature (Fig. 5). The bars had a groove filed on the top to receive two demi-cylinders of metal which were soldered to the lower part of the armature. In this way the nearer those parts are brought which are subjected to the magnetic attraction the greater is the resistance. Thus if we consider the armature in its different stages when gradually lowered, first it meets the elastic thread with the two demi-cylinders borne on its lower surface, and then the extensibility of the thread is very great. But as the thread is lowered more and more, it rests on points more and more separated, and becomes less and less extensible. Lower down the india-rubber thread stretched over the groove made in the soft-iron bars is still less extensible; and finally, when the thread has taken the curvature of the surrounding parts, it opposes any further descent of the armature with the resistance which a stretched thread of india-rubber presents against being pressed or crushed.

This apparatus, to which M. Marey has given the name *electrodynamograph*, has still to receive further improvements, but even as it is, it has already furnished some interesting evidence as to the decrease in volume of the electric waves from the beginning to the end of the discharge; also as to the shape of these waves and the occurrence in the electric tetanus produced by strychnine, &c. Of these different results we shall at present consider only one—the form of a wave is traced by the electro-dynamograph :—an investigation which brings us to the analysis of the wave-phases.

In Fig. 6 the continuous line *b* is the tracing of a single wave obtained with the electro-dynamograph. From it alone we already have evidence that the ascending phase is much more sudden than the descending phase as also takes place in a muscular shock. We can

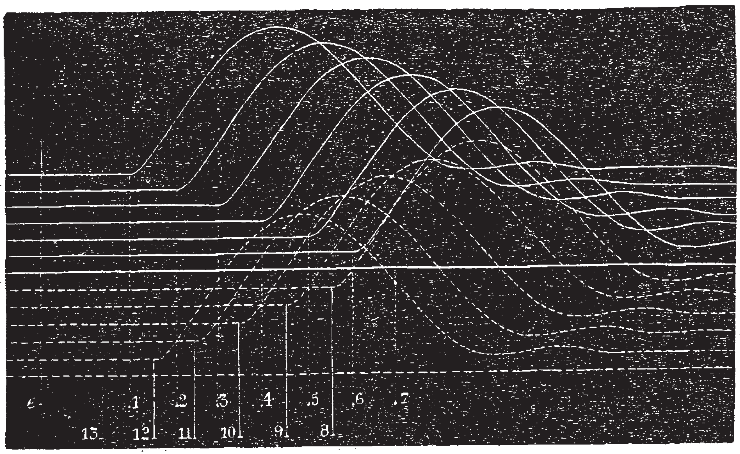

FIG. 4.

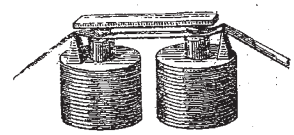

FIG. 5.

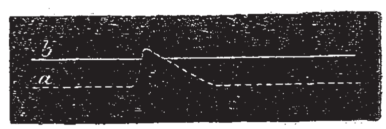

FIG. 6.

further theoretically complete the curve by taking into account what we have learned by Guillemin's method in the preceding paragraph about the duration of a wave. All that is necessary is to produce downwards the two ascending and descending lines till they intercept between them a distance equal to that which represents (on the time-line) the duration of the whole wave. Thus (Fig. 6) the pointed line *a* represents the actual position of the axis of abscissas and that part of the tracing which the instrument was unable to trace on account of its insufficient sensibility.

It is true that this curve is only probable, but there are great presumptions in favour of its reality. The points of origin and termination can determine it experimentally, as we have seen done by Guillemin's method (see 2).

We can now understand the reason of the special characteristics presented by currents induced in a secondary coil by the waves of a torpedo discharge which have been passed through an inducting coil. The phase of sudden increase of each wave is alone capable of giving birth to an inducted current. FRANCOIS FRANCK

(*To be continued.*)

GEOGRAPHICAL NOTES

AT the meeting of the Geographical Society on Monday, Sir H. Rawlinson read a paper, On the road to Merv from the Caspian. After some interesting remarks on the comparative geography of the eastern shores of the Caspian Sea, Sir Henry read some portion of the Russian letters on the earlier stages of the road to Merv, of which a summary appeared in our last issue, and afterwards gave from Russian official documents an account of two ancient cities, the probable relics of Khowrasmian times—Mestorian, or Mestdovran, and Meshed. The former in past ages was one of the most important cities of Central Asia, if one may judge from the remarkable aqueducts leading into it, which were the chief arteries of an entire system of irrigation canals thoroughly watering the whole country, and from the number of its buildings, the remains of which exist to this day. The course of the aqueduct was explored by General Lomakine's orders some two or three years ago, and was traced to the Sumbar, a tributary of the Attrek, a length of some sixty-five versts. The city of Mestorian appears to have consisted of a citadel and of two other inclosures with thick, high walls built of enormous bricks. The mass of the *débris* at the place is so extensive and in such good preservation, that it would be possible, we are told, to make use of it for building a large new town! The bricks, it may be added, are stated to be as hard as stone, and often carved and ornamented with friezes in relief, arabesques, and well-executed inscriptions; the last are sometimes in various colours, illuminated with flowers, and the letters about seven inches in height. Five versts from Mestorian is another remarkable place, known in the country as Meshed; it is, strictly speaking, an ancient necropolis. Here, according to report, is an open coffer holding the sacred books, a hanging lamp, and vases for ablutions, and although in a desert place and wholly unprotected, no one dreams of touching its contents. Sir Henry Rawlinson afterwards dealt at some length with the geography of the country further to the eastward, more especially with that on the northern slopes of the Attock, which is inhabited by three divisions of the Tekké Turcoman tribes.

WE regret to record the death, on Saturday afternoon, at a comparatively early age, of Commander G. C. Musters, so well known as the explorer of Patagonia. His work, "At Home with the Patagonians," is at present the best authority we have on this inhospitable country and its people, and Mr. Musters, as readers of the work know, obtained his information by living with the Patagonians for many months as their "king," and it was only by a *ruse* that he managed to get away from a people who