RESEARCHES ON THE RADIOMETER

By Prof. Paul Volpicelli.

1. ALL radiometers do not possess the same sensibility necessary for every experiment.

2. The most sensitive of the two which are in the physical museum of the Roman University shows that the freezing mixture of chloride of sodium and snow, applied to the upper hemisphere of the small globe, produces a rotation of the mill in the same direction in which it is produced by heat radiation, *i.e.*, with the white face of the small discs in advance.

3. If to this lowering of temperature be added a radiation of heat, the rotation of the apparatus is accelerated at the same time.

4. If the freezing mixture referred to be placed on the lower hemisphere of the same small globe, the apparatus will rotate with the absorbing, *i.e.*, the black faces in advance, and consequently in the direction contrary to that of the preceding experiment, *i.e.*, to the direction produced, if to the same lower hemisphere, radiant heat be applied.

5. If during the rotation produced by the application of the freezing mixture to the lower hemisphere of the small globe we cause radiant heat to strike the same globe, the apparatus will be brought to a stop; and as soon as the source of heat is withdrawn, the rotation will immediately commence.

6. If the small globe is plunged entirely in a heated liquid, or even in a freezing mixture, the apparatus will remain at rest.

7. It should be noted that the freezing mixture applied to the upper hemisphere of the small globe, produces a rotation in the direction opposite to that produced by the same mixture when applied to the lower hemisphere.

8. It has been stated that the radiometer in darkness remains at rest; but it should be remarked that if even in darkness it is affected by dark radiant heat, the apparatus will assume a rotatory movement; yet the instrument may remain at rest even when placed in a dark space.

9. The luminous rays of the full moon focussed by means of a lens, do not cause rotation of the instrument.

10. If the radiation of the flame of a Locatelli lamp is caused to traverse several plates of perfectly transparent glass, it will be seen by the number of turns of the instrument, that the law of De la Roche is verified regarding the absorption of radiant heat through these plates, however many they may be. I have been able by this means to diminish the radiant heat to such an extent as to cause the rotation of the radiometer to cease, although the light of the same radiation was increased by means of a lens.

11. The same radiation, that, viz., produced by Locatelli's lamp, by traversing a saturated but perfectly transparent solution of alum, before reaching the radiometer, did not set it in motion, although the radiant light was but little diminished; and the same is the case when the light is increased.

12. It would appear at present that the rotation of the radiometer depends on radiant heat and not on the luminous rays.

13. It appears also that the mechanical cause of the rotation of the radiometer consists in the motion of the molecules of very rarefied gas in the small globe, which is in accordance with the opinion of modern thermodynamics.

THE SIPHON RECORDER AND AUTOMATIC CURB SENDER

FOR some time after the introduction of submarine telegraphy Sir William Thomson's mirror galvanometer was the only instrument delicate enough to receive the signals transmitted through a long cable. The spot of light reflected from the mirror moves over the scale and indicates every change of current in the cable. The clerks by degrees learn to interpret the motions of the spot of light, and are able to read the signals sent. The signals, however, must be read at the instant of arrival, and the clerk has no way of correcting what he receives

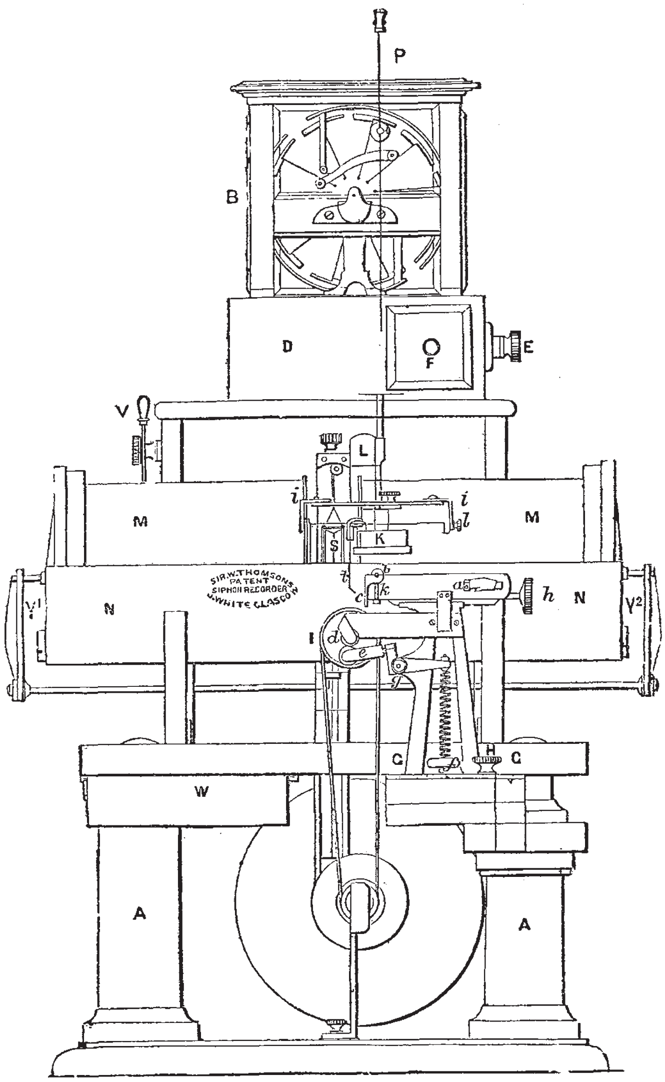

Fig. 1.

except by having the signals repeated from the distant end.

The Siphon Recorder was devised, more recently by Sir William Thomson, for the purpose of receiving and recording the signals transmitted through a submarine cable; though it may also be used for receiving signals sent along a land line. It actually draws on paper the curves corresponding to the changes of current which pass through the line. Thus a permanent record is made of every signal that is sent, and not only can the clerk be sure that he reads the signals correctly, but also any

F 2

mistakes in transmission can be traced to the station and person where they occur.

The Recorder consists of a powerful electro-magnet, between the poles of which a coil of fine insulated wire is delicately suspended, so as to be able to move round a vertical axis. The current from the cable is made to pass through this coil of wire. When a current passes through a coil suspended between the poles of a magnet, the coil tends to take up a position with its plane at right angles to the line joining the poles. There are two weights suspended from the bottom of the coil, which, when no current is passing, keep the plane of the coil in the line joining the poles of the magnet. When a positive current is passing, the coil tends to turn round a vertical axis in one direction, and when a negative current is passing, it tends to turn round in the opposite direction.

The coil is connected by means of silk fibres with a very fine glass siphon, suspended so that one end dips into a metal box containing ink, and the other end hangs down nearly touching a paper ribbon. The motion of the coil is thus transmitted to the glass siphon. The metal box containing the ink is insulated and is electrified by means of an electrostatic induction machine while the paper is connected with the earth. The ink being electrified, is drawn from the point of the siphon and spurted out in small drops on the paper. When no current is passing they form a straight line on the paper as it is drawn past the end of the siphon; but when a current passes through the coil, it being deflected, draws the siphon to one side, and the line on the paper is no longer straight, but indicates the deflections of the coil. The well-known Morse alphabet is used with the recorder. A deflection of the siphon-point to one side corresponds to a dot, and one to the opposite side to a dash.

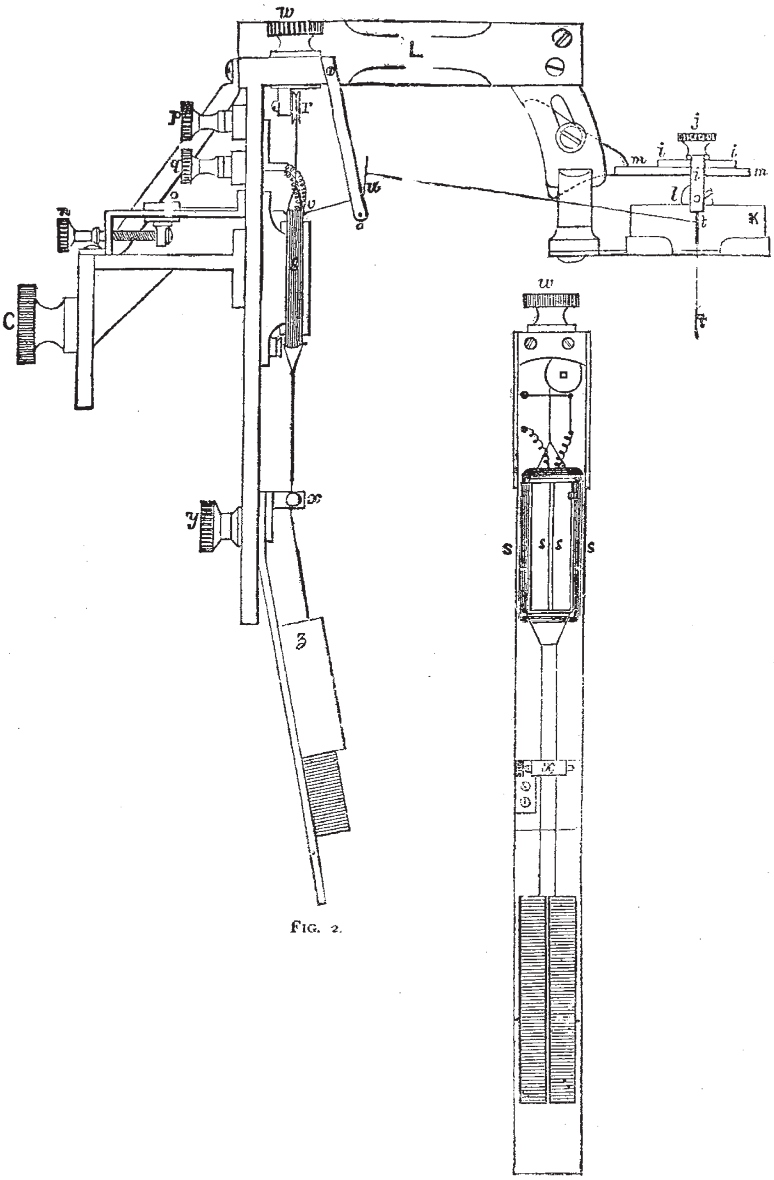

Fig. 2.

Fig. 3.

Fig. 1 shows a front view of the Recorder. B is the electrostatic induction machine, called the mouse-mill, which is driven by an electro-magnet inside the box D. The mouse-mill serves two purposes. It generates electricity, which is communicated to the box K, containing the ink, by means of the rod P, and it draws the paper along, past the siphon point. M M are the electro-magnets and S is the coil of wire suspended between them; *t* is the siphon, one end of which dips into the ink-box K, and the other end is almost touching the paper *c*. The paper passes under the spring *a* which keeps it stretched, over the roller *b*, then vertically down, past the siphon point, to the driving drum *d*. The battery used for the electro-magnet M M and for the mouse-mill is of the form of Daniell's battery known as the *Tray* battery. It is fully described in NATURE, vol. vi. p. 32.

Fig. 2 is an enlarged view of the signal coil and siphon. Fig. 3 shows a front view of the suspension of the coil. S is the coil suspended by a silk fibre passing round the pulley *r*. From the coil hang two weights, which can slide up and down the guides *z*. The coil surrounds a stationary piece of soft iron placed there for the purpose of increasing the intensity of the magnetic field. A silk fibre *v* connects one corner of the coil with one end of a vertical lever U. The other end of the lever is connected to the siphon *t* by means of another silk fibre, and the motion of the coil is thus communicated to the siphon.

In consequence of the electrostatic capacity of submarine cables, a retardation occurs in the transmission of signals, so that when a current enters at one end of a cable, a certain time elapses before any effect can be detected by the most delicate instrument at the other end. Fig. 4, Curve I., represents the strength of the current, received at the remote end of a cable, as it gradually increases, when the end operated upon is connected to one pole of a battery and kept permanently so. The vertical ordinates represent the strength of the current. The horizontal ordinates represent intervals of time reckoned from the first application of the battery in terms of an arbitrary unit, *a*. This unit of time, *a*, may be defined as follows:—Suppose a cable electrified so that the electrification along the cable may be represented by a harmonic curve, with single maximum in the middle and zero at each end. Now let both ends be connected to earth. Then the time that the harmonic electrification takes to subside to three-fourths of its initial value is denoted by a. Curve I. coincides so nearly with the line, O X, at first, as to indicate that there is no sensible current until the interval of time corresponding to a has elapsed; although, strictly speaking, the commencement of effect at the remote end is instantaneous. After the interval, a, the current rapidly increases in strength. When an interval of time equal to $5a$ has elapsed from the first application of the battery, the current will be about half its ultimate strength. After $10a$, the current will have attained to nearly its full strength, that the further increase will be scarcely sensible. Theoretically the full strength is not reached until an infinite time has elapsed.

Fig. 4, Curve II., shows the effect at the remote end of applying a battery during a time equal to $4a$, and then putting the cable to earth. It will be observed that a current gradually diminishing in strength continues to flow out of the cable for a considerable time after the battery has been disconnected. It is this after-effect which interferes so seriously with the working of submarine cables.

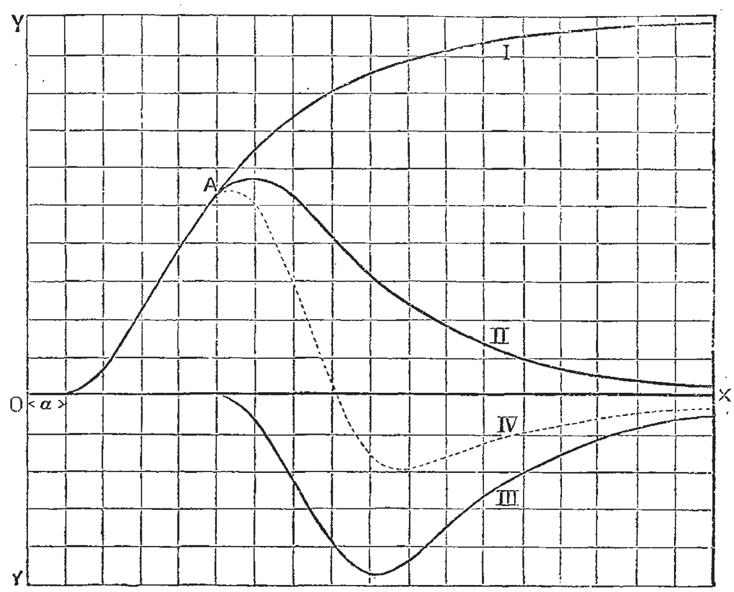

Fig. 4.

The Automatic Curb Sender was designed by Sir William Thomson and Prof. Fleeming Jenkin for the purpose of diminishing the effects of the retardation due to the electrostatic capacity of submarine cables. This was accomplished by making each signal consist of two currents, the second being of opposite name to the first and of a shorter duration. The latter, or curbing current, hastens the neutralisation of the cable after the first current has passed, and tends to do away with the effects of the first current. For example, let one end of the cable be connected to one pole of a battery for an interval of time equal to $4a$, and then let it be connected to the opposite pole for a time $3a$. The effect at the remote end of this latter current, if it had occurred alone, would be represented by Curve III. of Fig. 4. The joint effect of the two currents is represented by Curve IV., whose ordinates are the algebraic sum of the ordinates of Curves II. and III. The quick return of Curve IV. to the zero line O X, as compared with Curve II., shows the advantage of curb sending.

The curve traced out by the point of the siphon represents the curve of arrival, and the effect of curb sending is to give a sharp outline to the signals and to bring the point of the siphon back or nearly back to the zero line between each signal. It is necessary for the success of curb sending that the spaces for the signal and curb currents should be perfectly correct, and this can only be effected by means of automatic mechanism.

Fig. 5 is an engraving from a photograph of the automatic sender. The message to be sent is punched on a strip of paper in right and left holes, which correspond to the dot and dash of the Morse alphabet, and a central row of holes is punched for the purpose of carrying the paper through the machine. The paper is then put into

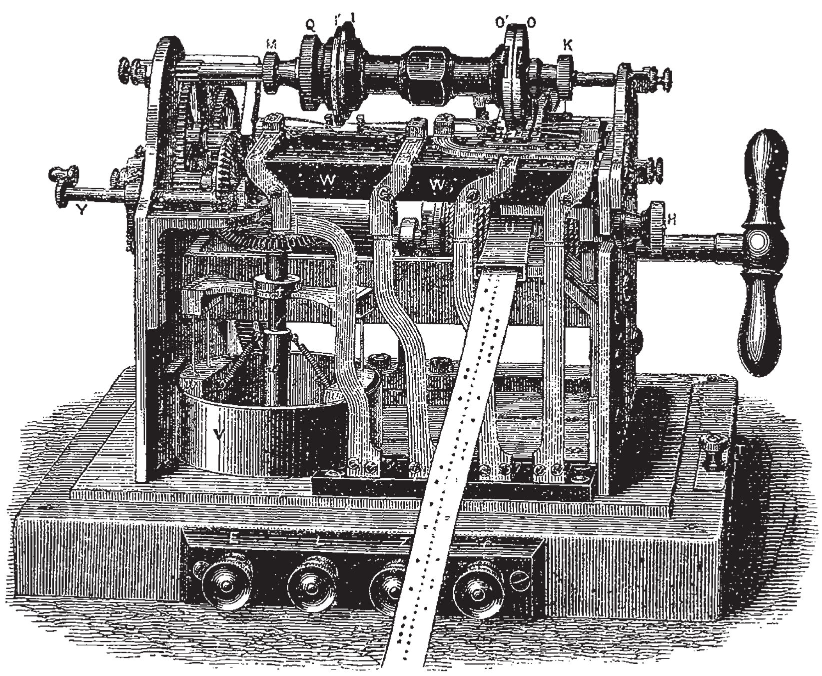

Fig. 5.

the machine and drawn along at a uniform speed by means of clock-work. The paper passes through the

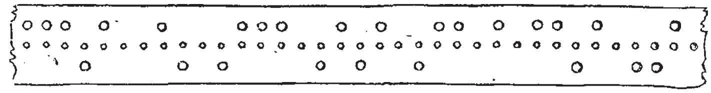

Fig. 6.

tube U and underneath two prickers placed so as to correspond to the right and left holes in the paper. When a right or left hole passes, the corresponding pricker falls into the hole, and in doing so lifts a spring through the opening *l* or *l'* into the rim of the revolving wheel O O'. The spring being caught in the rim of the wheel is obliged to remain there until the wheel makes one complete revolution, and the opening in the rim returns to free it. The wheel makes one revolution while one space passes the pricker. When the spring is lifted into the rim of the wheel it makes connection between the battery and another set of springs. The latter set of springs are acted on by a double cam, I I', which is connected with the same shaft as O O', and revolves with it. During one revolution this double cam by means of the second set of springs sends first one current from the battery into the cable, and immediately afterwards a second current of the opposite name and of rather shorter duration. The first current is the signal and the second is the curb current. If a left-hand hole in the punched paper passes, and the corresponding pricker falls into it, a positive current will be sent first, followed by a negative current, but if a right-hand hole passes, the first current will be negative, followed by a positive one.

Fig. 6 shows the appearance of the punched paper when it is prepared for the Automatic Sender. The specimen represents the signal "understand" and the first seven letters of the alphabet.

ON THE CONDITIONS OF THE ANTARCTIC[1]

MY principal object in this evening's lecture is to direct your attention to some of the peculiarities in the physical conditions of the Antarctic regions, and to put you in a better position to contrast these with the more generally known phenomena of the Arctic; and it seems specially appropriate to allow our thoughts to travel for an hour towards that other fortress of the Ice King, a fortress apparently even more hopelessly impregnable, now while the pulse of the nation is still throbbing in sympathy with the brave little band who have just added another chapter to a long and terrible record of daring and self-sacrifice, and have succeeded in the face of almost unparalleled hardships in once more planting the Union-Jack nearest to the North Pole. The propriety is all the greater seeing that Capt. Nares, the gallant leader of the northern explorers, is also the last of the few navigators who have crossed the Antarctic Circle.

I will first of all then give you a brief sketch of our Antarctic experiences in the *Challenger*, and then go on to consider what may be the most probable explanation of some of the most striking of the appearances which we observed.

After spending about a month at Kerguelen Island, making meteorological and other observations, and selecting a suitable spot for the observation of the transit of Venus by the English astronomical party in the following season, the *Challenger* left Christmas Harbour on January 31, 1874, and on February 6 we reached the desolate little group of the Heard Islands, and on the 7th continued our course southwards.

Early on the morning of the 11th a large iceberg was observed bearing south-south-east about six miles off. The berg was table-shaped, the top perfectly flat and covered with a dazzling layer of snow. The perpendicular ice-cliffs bounding it were of a delicate pale blue, apparently perfectly clear, with some caves and slight recesses, where the blue was of a deeper shade. The height of the berg above the sea was 219 feet, and its extreme length by angular measurement was 2,202 feet; so that, supposing it to be symmetrical in shape, the contour of the visible portion being continued downwards, its depth below the water may probably have been about 1,500 to 1,800 feet. In the afternoon Lord George Campbell observed during his watch a large piece come off the side, dashing up the spray, and we afterwards saw a quantity of fragments floating off.

The 12th was misty, with a breeze force = 3–4 from the north-west by west. Many icebergs came in sight from time to time and quickly became obscured in the mist. The position of the ship at noon was lat. 62° 36' S., long. 80° 4' E.

Towards evening we passed close to a very beautiful iceberg. One part of it was rounded and irregular in form, putting us in mind of the outline of the Sphinx, and another portion, separated from the first by a fissure, the sea dashing through between them, was like a fragment of a colossal cornice. As the sun sank the ice took a most lovely pink or mauve tint, and when we came close up to the berg it showed out veined in a wonderful way with lines of deep cobalt-blue. The ice was perfectly pure and clear. The bergs which we were passing at this time seemed to be breaking up very rapidly; some large fragments had been detached from this one shortly before we reached it, for a quantity of *débris* was floating at a little distance. The pieces washing about in the water very soon lose their edges and angles, and get rounded, and shortly disappear.

The 13th was a fine day, with a light wind from the north-north-east and occasional snow showers. There were some large tabular icebergs along the southern horizon. In the afternoon we passed close to a beautiful berg, very irregular in form, all the curves and shadows of a most splendid blue. The lower portion of the side of the iceberg next us formed a long steep slope into the water, and up this slope the surf ran with every heave of the swell, taking in its course the glorious blue of the ice and ending at the top of the glacis in a line of glittering foam.

The evening fell grey and slightly misty, with a number of icebergs looming through the mist. One or two of us were standing on the bridge about midnight looking at what seemed to be a low bank of white fog coming down upon us, when all at once a universal grating and rasping sound and sensation seemed to pervade the ship, and looking over the side we found that instead of sailing in open water we had passed into the edge of the pack, and as far as the eye could reach to the eastward the sea was closely covered with blocks of ice of all sizes up to six or seven feet in length among which the ship ground her way. A cold-looking moon struggled faintly through the cloud and mist and showed the pack vaguely for a mile or so ahead, covered with a light fog through which we could just see several icebergs looming right ahead of us and on either bow, and the masses of ice becoming larger and forming a closer pack as we passed inwards from the outer edge.

It was a wonderful and in a certain sense a beautiful sight, but one which would certainly require for its full enjoyment very fine weather such as we had, or a specially strengthened ship.

The necessary orders were given, and we veered round and slowly passed out of the pack and into open water; and we hung about beyond the line of wash-ice for the short Antarctic night.

On the following morning there were icebergs all round us, some of them of very fine forms. One which we saw all day on the port quarter was gable-shaped with a glorious blue Gothic arch in the centre, and a separate spire over 200 feet high. It was like a gorgeous floating cathedral built of sapphire set in frosted silver.

All day the pack could be seen from the deck stretching away to the east and south as far as the eye could reach, a mass of rugged glittering blocks one piled on the top of another. The ice-blink, a beautiful and characteristic phenomenon, was very marked above the pack—a clear

[1] The substance of a lecture by Sir C. Wyville Thomson, F.R.S., delivered in the City Hall, Glasgow, on November 23, under the arrangements of the Glasgow Science Lecture Association.