in working order. After having fixed in its support the tube filled with mercury, and being assured that the fine extremity dips well into the cup g', we place the balance in equilibrium by adding weights to the other scale. The bell-glass V, which has been raised for this operation, is then put in its place, and the instrument is ready for action.

The registering apparatus is composed of the double differential wheelwork of M. Rédier, which works as follows :—Two wheels M and M′ moving in opposite directions, are terminated by small flies, very delicate, and turning very swiftly ; they are connected by a differential train, the axis of which carries a pulley with a double groove A. Between the two flies oscillates a needle, one extremity of which serves to arrest alternately one of the two flies. At the other extremity *a*, of the needle, is a soft-iron pallet on which acts an electro-magnet E, every time contact is made by the balance at C. The needle is mounted on an axis which permits it to oscillate right or left according as it obeys the electro-magnet or a small antagonistic spring.

The double-grooved pulley A carries two threads the one attached to the pencil K and terminating in a weight O, the other bearing a small cylinder and plunging into the cup G containing glycerine and connected by a tube with the cup *g* placed on one of the scales of the balance. Of course the cups G and *g* must be placed in the same horizontal plane. A cylinder H, moved by the clock-work L, carries the paper. A second pencil K′ serves to trace upon the paper a small mark intended to control the progress of the wheel-work L. This mark may be made automatically by an electric contact proceeding from a regulator of precision.

Let us see now how things work. Suppose the temperature rises (the explanation which follows will account for the mode of action of the apparatus when the temperature falls), the weight of the mercury in the cup at g' will increase, the equilibrium will be destroyed, and the contact C of the balance will be established ; the electro-magnet E will attract the end *a* of the needle, and the fly of the wheel M′ will be free ; the pulley A will then turn to the left, the float will sink in the cup G, and the pencil will be directed towards K′. The float of the cup G, in descending, will raise the level of the liquid at G, and at *g*, and consequently will increase the weight in the scale of the balance which holds the cup *g*, and at the moment that equilibrium is thus again established, the contact at C will be broken. The end *a* of the needle ceasing to be attracted by the electro-magnet will respond to the appeal of the antagonistic spring, and disengage the other fly. This fly of the second wheel M disengaged, permits the pulley A to turn to the right, drawing the pencil from K′ to K, and causing the float of the cup G to reascend, and consequently diminishing the weight at *g*. That loss of weight breaks anew the equilibrium of the balance, the contact at C is re-established, and the same course is repeated as we have explained above.

It will be seen from what we have said that the clock-work is always in motion—now to the right, now to the left—even when the temperature does not vary ; the curve obtained has then the aspect of a small zigzag, but so fine that it is difficult to detect it. This arrangement permits, so to speak, the double wheel M M′ to test the balance for the slightest change in the conditions of equilibrium.

The tube T T connecting the two cups G and *g* may be placed underground, and the electrical communication between the balance and the electro-magnet E is easily established at any distance desired.

On the prolonged axis of the pulley A we may place a rigid needle, and indicate by a simple transmission the temperature on a large card placed outside.

This apparatus has been constructed in a thoroughly artistic manner by the able constructor, M. Redier.

NEW ELECTRIC LIGHTS

AN examination of the voluminous records of the Patent Office discloses the fact that the activity in a particular line of invention periodically waxes and wanes. After slumbering for a number of years the problem of procuring effective electrodes for the production of the luminous electric arc has of late been revived, and with a success hitherto unattained. The immediate cause of this has probably been the recent improvements of magneto-electric machines culminating in the Gramme and the Siemens machines. An efficient source of electricity for the production of the light having been supplied by these and other machines of a similar kind, a stimulus was given to the invention of electrodes or *wicks* which would employ the magneto-electric current to best advantage in giving out light. The old faults of the carbon points had never been quite overcome. The manufacture of the points from soft-wood charcoal, fine coke dust, lamp-black, calcined sugar, tar, resin, or mineral oil, &c., had done much to render their consumption steady and uniform ; and the regulators of Serrin and Dubosq had very successfully overcome the widening of the luminous arc by the wasting of the positive electrode. For large fixed lights with several sets of luminous points, such as are employed as beacon-lights on land or at sea, the ordinary carbon points thus improved answered very well, but for the purposes of general illumination they are still defective. To give a light suitable to a room or hall the points require to be small, and any inequalities in their action are very discernible in the light. One great difficulty to be overcome, too, is the division of the light. How to cause the current from a powerful magneto-electric machine to produce a number of separate small lights, such as would be essential for the lighting of streets or buildings ? If the different lights were all joined up "in circuit" and the currrent sent through the whole series one after another, the break-down of any one of the series would extinguish the whole and plunge the street or building into darkness.

During the last thirty years there have been many attempts made to secure good electrodes for the electric light as well as devices for adjusting them. Electrodes of spongy platinum, palladium, and iridium have been used. Another plan was to make the positive electrode a fine stream of mercury flowing from a funnel and breaking upon a negative electrode of carbon or platinum placed underneath. An objection to these metals was the coloured lights they produced owing to the incandescence of their vapours in the arc. The carbon electrodes were given divers shapes, and various combinations of carbon and metal electrodes suggested. For instance, it was proposed to use bar electrodes emitting the light from their sides, and also to fuse iridium between two carbon electrodes. An ingenious plan for getting a steady light was proposed by Mr. Harrison in 1857. It consisted in giving a rotary motion to the positive electrode and pointing the negative electrode at right-angles to it and giving the latter a motion of translation, so that fresh surface of the positive carbon was always appearing in front of the negative carbon. A similar idea was again patented in 1874 by Messrs. Wildman and Whitehouse. About twenty years ago there was a great deal of activity in this direction, but up till quite lately the usual carbon points have always been fallen back upon.

Within the last five years, however, two notable new lights have made their appearance, namely, the lights of Lodighin and of Jablochkoff. M. Alexandre Nicolævitch Lodighin is a Russian engineer of St. Petersburg. His plan was first publicly tried there in 1873, and patented in England in the previous year. It is designed to facilitate the use of the electric light for general lighting purposes. The great defect of the ordinary carbon points is the flickering of the light caused by the consumption of the carbon points, a great portion of which is due to the combustion of the points in the air. M. Lodighin's plan is to employ not two but a single stick of carbon, inclosing it in a hermetically sealed glass chamber from which all air has been exhausted, and an azotic gas which does not combine with carbon at a high temperature, such as nitrogen, let in. When the current from a magneto-electric machine, such as Wilde's, Gramme's, or Noble's, is passed through this carbon it gradually gets heated to a white heat, and emits a brilliant, and at the same time soft and steady light. Fig. 1 shows the form of the carbon used; the light is given off at the narrow central part. The advantages of this plan are that there is a continuous circuit, so that any number of lights may safely be joined up in series to form one or more lamps. The lights can be made as small as desired, the flame is continuous and not injurious to the eye, the cost of new carbon points is saved, and the current can be strengthened or weakened at will very easily. It burns equally well under water, and would be very useful for illuminating dangerous mines, there being no fear of explosion from it. One magneto-electric machine driven by a 3 horse-power engine, generates a light equivalent to many hundred lanterns, and the light can be easily divided up into smaller ones. There was one defect in M. Lodighin's original light which has been remedied by M. Kosloff, of St. Petersburg. The unequal expansion of the metal holder of the carbon and the carbon itself caused the latter to split and give way. The metal also fused, and sparks passed between the carbon and the expanded sockets. Kosloff fixed the carbon on insulating supports of china, clay, crystal, &c., and connected it in circuit by wires. The improved light of Lodighin and Kosloff was first tried in London in 1874, and was very successful. It was awarded the Lomonossow Prize by the Russian Academy of Sciences.

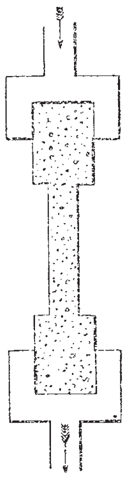

Fig. 1.

But the "electric candle" of M. Jablochkoff has, for the nonce at least, quite cast Lodighin's light into the shade. It appears to be one of those lucky inventions crowning a long series of more or less unsuccessful ones in the same direction. In the electric candle the two carbon points are not dispensed with. They are placed side by side and separated from each other by a slip of an insulating substance such as porcelain, brick, magnesia, but preferably kaolin or pure clay. One of the points is a little longer than the other, and may also be stouter. The positive current is passed down the longer carbon, and leaps across the air space to the shorter carbon, forming the luminous arc at the point of the candle. Such an arrangement of the points is shown in Fig. 2. It is called

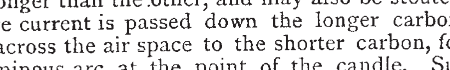

Fig. 2.

a candle because it can be burned upright in a support like a candlestick. The kaolin plays an important part besides insulating the carbons from each other. It becomes incandescent, emitting a beautifully soft, steady, light, and melts away like wax at the same rate as the carbons, just as a candle is consumed with the wick. No mechanism is required for the adjustment of this electric candle. The discovery that kaolin becomes intensely incandescent under the current also enables M. Jablochkoff to dispense with the carbon points for small and medium lights. He made the discovery, we believe, in studying the effect of a succession of sparks from the secondary coil of an induction machine on refractory bodies. He first heated a plate of kaolin to incandescence, but did not fuse it. Then he led the induction current along the edge of the plate by means of a more conductive coating. This caused the edge to fuse and emit a splendid band of light as soft and steady as any known source. This discovery disclosed a feasible system of lighting towns and dwellings by dividing the electric light. It would be possible to generate lights of all sizes by means of the kaolin; and by employing a number of separate secondary coils, one to each candle, for one primary, the current could be simply and effectively divided. By having the carbon candles for large warehouses and public buildings, and a very simple pincher holding a kaolin wick for offices and corridors; and by having separate secondary circuits to each set of lights, electricity could be laid on for illuminating purposes as easily as gas. The passage of the current through the kaolin makes the circuit complete as in Lodighin's plan, and a number of lights can be joined up in the same circuit, so as to form a set of luminous centres. As many as eight candles have been kept steadily burning in the circuit of an ordinary magneto-electric machine. Some of the principal halls of the Louvre have have been lighted by the candle in this way. MM. Denayrouze and Jablochkoff have, we are told, easily obtained fifty luminous centres of various intensity in graduated series, the weakest yielding a glow equivalent to one or two gas burners, the strongest equal to fifteen burners, from one current. By employing a magneto-electric machine giving alternating currents the current interrupter and condenser of the induction coil may be dispensed with, the alternating currents being simply passed through the primary coil. Again, by employing a magneto-electric machine yielding several powerful intermittent currents, the induction coil with its several secondary coils may be dispensed with altogether and the magneto-electric currents passed through the candles. This power of being able to divide up the current so as to have several circuits with several candles of various degrees of illuminating effect in the same circuit, or only one, gives to electric lighting the convenience of gas. It cannot be so expensive as gas, and it must be far less pernicious and dangerous than gas in a house. The lights require to be shaded by ground or opal glass shades to diffuse the rays. The consumption of kaolin is very small. It is said that a piece the length of a centimetre will last ten hours.

The recent public trials of Jablochkoff's light at the West India Docks have been recorded in NATURE. The first was unsuccessful owing to some defect in the magneto-electric apparatus. An account of the second and successful trial was given in NATURE, vol. xvi. p. 152. A large tent inclosing 900 square feet was illuminated by four candles fixed on lamp-posts and surrounded by globes of opal glass. At twenty or thirty feet from the lamps very faint pencil lines could be distinguished on paper, and small print read at a considerable distance. When common candles were substituted for the electric lights the effect was most marked, and the light a sickly yellow. In the electric illumination the most delicate colours retained their purity of tint. A warehouse was also lighted up by three naked candles; and a ship lying alongside a wharf by two, in order to show that lading or unlading could be carried on at night.

J. MUNRO

REDUCTION OF THE HEIGHT OF WAVES BY LATERAL DEFLECTION UNDER LEE OF BREAKWATERS[1]

WHEN a wave encounters an obstacle such as a breakwater, the portion which strikes it is either entirely destroyed or reflected seawards, while the portion which is not so intercepted passes onwards, and spreading

[1] By Thomas Stevenson, F.R.S.E.