$$\text{Efficiency} = \frac{2 \times 15{\cdot}2}{(66)^2}(66 - 15{\cdot}2) = 35{\cdot}4 \text{ per cent.}$$

If the same formula is applied to the *Waterwitch*, at 9·3 knots—

$$\text{Efficiency} = \frac{2 \times 15{\cdot}7}{(30)^2}(30 - 15{\cdot}7) = 49{\cdot}9 \text{ per cent.,}$$

giving about 20 per cent. less efficiency to that vessel, than is given by the accepted formula first stated.

It has been explained that the assumptions upon which the first formula rests are not fairly representative of the conditions of practice. For example, the deduction therefrom (stated above), that it is advantageous to operate upon larger quantities of water, and to reduce the excess in speed of outflow above the speed of the ship requires an important qualification in practice This deduction would be absolutely correct were it not for the waste-work which has to be done in giving the motion to the water; but in actual practice the growth in that waste work may exceed the gain obtained by dealing with larger quantities of water. The parallel case in a screw steamer is that wherein screws of too large diameter or too large surface may involve so much more waste work on frictional or edgewise resistances, that it is preferable to use smaller screws, which operate on smaller quantities of water, but secure a more economical expenditure of power for a given speed, or enable higher speeds to be attained with a given horse-power. In setting aside the commonly received view, and making trial of a system wherein the mean velocity of the outflowing jets is extremely great, while the quantity of water operated on is small, Dr. Fleischer has made an experiment of the greatest interest to all concerned with steam propulsion. If his figures are accepted it is obvious that his system involves much less waste work than the Ruthven system, between the power indicated in the cylinders and the power accounted for in the outflowing jets. On the other hand, as we have endeavoured to explain, this economy of the Fleischer system does not represent the comparative efficiency of the propelling apparatus: because the high and variable velocity of outflow must involve a considerable amount of waste work in the race. A complete comparison could only be made if in the same vessel, or in two vessels of identical form and with identical boiler-power, there were fitted, first, the Fleischer hydromotor; and secondly, the Ruthven arrangement. Then with the same steam-producing power a careful series of trials would settle the matter conclusively. The Swedes did something of this kind in order to compare the efficiencies of twin-screws and water-jets, with the result that the latter were shown to be greatly inferior. Of course it cannot be expected that Dr. Fleischer would undertake such trials unaided; on the other hand, if his system is put forward for adoption in preference to the Ruthven system, it must, at least, be shown to be more efficient, not only in certain intermediate stages in the operations of giving momentum to the jets, but as a whole. This result does not appear to have been attained as yet, so far as can be judged from the published results of trials. The information which is accessible is not complete, and some of the proposed standards of comparison are open to doubt. It is to be hoped, however, that the zeal and ability which have been displayed already by Dr. Fleischer will be still further illustrated in the continued investigation of the capabilities of his novel system of propulsion.

W. H. WHITE

A RAPID-VIEW INSTRUMENT FOR MOMENTARY ATTITUDES

THE wonderful photographs by Muybridge of the horse in motion and those by Maret of the bird on the wing induced me to attempt the construction of apparatus by which the otherwise unassisted eye could verify their results and catch other transient phases of rapid gesture. Its execution has proved unexpectedly easy, and the result is that even the rudest of the instruments I have used is sufficient for the former purpose; it will even show the wheel of a bicycle at full speed as a well-defined and apparently stationary object. This little apparatus may prove to be an important instrument of research in the hands of observers of beasts, birds and insects, and of physicists who investigate such subjects as the behaviour of fluids in motion.

My object was (1) to transmit a brief glimpse of a moving body, (2) to transmit two or more such glimpses separated by very short intervals, and to cause the successive images to appear as simultaneous pictures in separate compartments in the same field of view.

The power of the eye to be impressed by a glimpse of very brief duration has not, I think, been duly recognized. Its sensitivity is vastly superior to that of a so-called "instanteous" photographic plate when exposed in a camera, but it is of a different quality, because the impression induced at each instant of time upon the eye lasts barely for the tenth of a second, whereas that upon a photographic plate is accumulative. There is a continual and rapid leakage of the effect of light upon the eye that wastes the continual supply of stimulus, so that the brightness of the sensorial image at any moment is no more than the sum of a series of infinitesimally short impressions received during the past (say) tenth of a second, of which the most recent is the brightest, the earliest is the faintest, and the intermediate ones have intermediate degrees of strength according to some law, which an apparatus I shall describe gives us means of investigating. After the lapse of one-tenth of a second the capacity of the eye to receive a stronger impression has become saturated, and though the gaze may be indefinitely prolonged the image will become no brighter unless the illumination is increased.

This being premised, let us compare the sensitivity of the eye with that of the rapid plate in the photographic camera under conditions in which the eye is just capable of obtaining a clear view, let us say during an overcast day in a sitting room whose window does not occupy more than one-thirtieth of the total area of wall and ceiling, which is the light under which most of us habitually write and read. A glimpse under these circumstances of one-tenth of a second in duration, suffices, as we have just seen, to give a clear view, but the sensitive photographic plates sold in the shops as "instantaneous" will not give a portrait in that light under thirty seconds exposure. In other words, the sensitivity of the eye is fully 300 times as great as that of the plate. Of course I am aware that more sensitive plates than these have been made, and I have seen a rapidly revolving wheel photographed under the momentary illumination of an electric spark, but I have never heard of that being done when at the same time the revolving wheel was not perfectly distinct to the eye.

The range of ordinary illumination is very great. The photographer who requires thirty seconds in a dim window-light, would photograph clouds in some minute fraction of a second, showing that the illumination of the latter is fully one thousand-fold greater. If then the eye has been shaded and adapted to a dim light, an object in bright sunshine may require no more than the thousandth part of the tenth of a second to be visible, and in saying this, I am confident that I am underestimating what could be done. Consider what even this means: a cannon ball of ten inches diameter in its mid career travels with a velocity of little more than 1,000 feet in a second; in one ten thousandth of a second it would shift its place through only one tenth of its diameter, and would present to the eye, if it could be viewed under the above-mentioned conditions, the appearance of an almost circular disc elongated before and behind by only a slight blur.

It may be said, how is it possible to give such brief exposures as the above? I see no difficulty at all in the matter. Let us take two examples, (1) of quick movement, and (2) of very quick, but by no means the quickest possible, movement. As regards the former, I can flip with my forefinger, and with the greatest ease, a light weight (such as a very small stone) nine feet up in the air; now the maximum velocity of the tip of my forefinger is that of the initial velocity of the stone, which is calculated at once by the usual formula, $v = \sqrt{2fs}$, or taking $2f = 64$, which it is very nearly, $v = 8\sqrt{s}$, the units being in feet and seconds. The velocity in question is therefore 24 feet, or 288 inches per second. As regards a very rapid movement, we may take that of the wing of a bird, which can undoubtedly be rivalled mechanically. A pigeon is by no means the swiftest of birds, but it can fly easily at the rate of 35 miles an hour, and the part of the wing by which it is chiefly propelled and which cannot be its extreme tip, must move much more rapidly than this; let us say, very moderately, at 70 miles an hour, or 1,232 inches per second.

Now the duration of an exposure depends on three data, namely, the rapidity with which the screen moves past the eye, the width of the slit through which the momentary glimpse is obtained, and the diameter of the available portion of the pupil of the eye. I prefer not to limit the pupil by using a small eyehole which is a source of much trouble in actual work, but to have as large an eyehole as is in any way desirable. I find the width of the pupil of my eye in an indoor light as measured by holding a scale beside it and reading off in the looking-glass, to be about 0·1 inch, and I use a slit of the same diameter. The exposure begins when the advancing edge of the slit is in front of the near edge of the pupil, and it ceases when these conditions are reversed, in other words it lasts during the time that the screen is occupied in moving through one fifth of an inch. In the cases just taken of velocities of 288 and 1,232 inches per second, the duration of the exposure would be the 1,440th and the 6,160th part of a second, respectively. There is therefore no difficulty either theoretical or practical about shortness of exposure and sufficiency of illumination. The power exists, and can be utilized, of seeing bodies in motion by a rapid-view instrument, showing them in apparent stillness, and leaving a sharply-defined image on the eye, that can be drawn from visual memory, which in some persons is very accurate and tenacious.

I find on trial that great rapidity of exposure is in nowise essential for analysing the attitudes of a galloping horse or a flying crow. The instrument I commonly carry with me is a very rude one, but convenient for the pocket, and is shewn below. The duration of the exposure given by it under the action of its spring is the 360th part of a second, but the beginning and end of the exposure ought not to count, so little light passing through the edges of the pupil at those times that what is then seen is relatively faint and is disregarded. I estimate its practical duration at about one 500th of a second, and it is rather less when the finger acts with a sharp tap in opposition to the spring. The instrument is shewn in Fig. 1, without its sliding lid, which protects it from injury in the pocket. A is an arm which turns through a small angle round C, its motion being limited by two pins. Its free end carries a vertical screen, R R, which is a cylindrical (or better, a conical sheet described) round an axis passing through C perpendicular to the arm. As the arm travels to and fro, this screen passes closely in front of the end of the box, which is cut into a hollow cylinder (or cone) to correspond. There is a slit in the middle of the screen, and an eyehole in the centre of the end of the box. When the slit passes in front of the eyehole, and the instrument is held as in Fig. 2, a view is obtained. A stud, S, projects upwards from the arm, and an india-rubber band, B, passing round a fixed pin and a descending spoke of the arm acts as a spring in causing the stud S to rise through a hole in the side of the box, where the finger can press it like the stop of a *cornet à piston*. In using the instrument it is held in the hand as in Fig. 2, with the eyehole in front of the eye. Nothing is then visible, but on pressing or tapping the stud the slit passes rapidly in front of the eyehole, and the view is obtained.

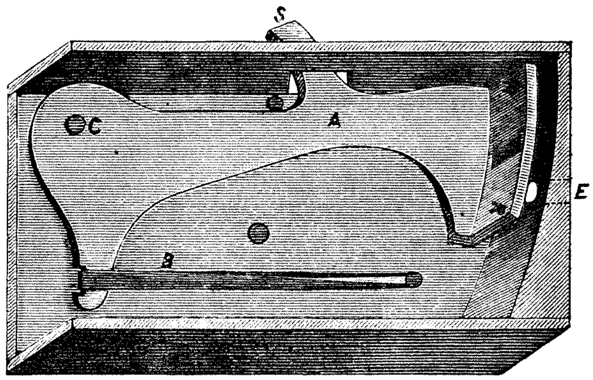

FIG. 1.

After this, the stud is released and the arm springs back wards, when a second view can be obtained, or the eye may be purposely closed for the moment.

I measured the velocity of the instrument by filing a nick on the stud and laying a light weight (a small bent nail) upon it, after having temporarily put in a peg that checked the arm in its recoil when the slit was opposite the eyehole. Then holding the instrument firmly against the wall with the projecting end of the stud as vertical as might be, I drew back the arm and released it, and noted the height to which the weight was tossed. It was three inches. This gave the velocity of the stud in the central portion of the arm, and from this datum the velocity of the more distant screen was easily calculated. I have made more elaborate instruments with multiple levers and with revolving discs (Messrs. Tisley, 172, Brompton Road, are now making one of these for me), but am not as yet

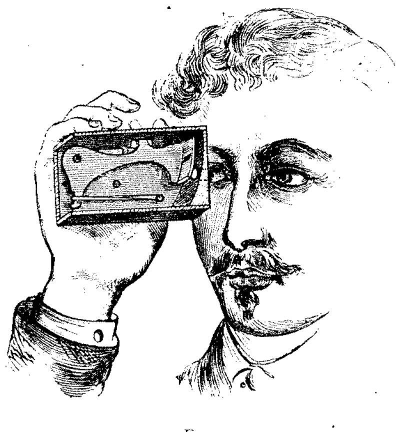

FIG. 2

prepared to recommend any one of them in particular. Different sorts would be probably be wanted by different persons. For instance it might in some cases be convenient that the trigger should be pulled at the right moment by a bystander, the eye of the observer being in the meantime kept closely shaded from the surrounding light. Again, there are periodic movements which would be best analysed by a slit in a rotating disc whose period of rotation was a little slower than that of the movement, so that each exposure should show a phase one step in advance of the previous ones; or, again, the rapidity of the periods or that of the motion may be such as to make it necessary to expose only at each second, third, or longer periodic interval. This would be effected by the use of two discs rotating at different velocities. Suppose, for example, one to revolve three times while the other revolved twice, then the two slits would be in accord in front of the eye-hole only once in three revolutions.

In order to present the images formed by two successive glimpses as simultaneous pictures seen side by side in the field of view, I took a prismatic eyeglass of the sort sold by spectacle-makers to correct want of parallelism in the optical axes. I cut it in two pieces, and placed these in opposite ways in front of two horizonal slits, lying one above the other in a shutter that fell vertically between slides. When the first slit came in front of the eye, the image it transmitted was deflected four degrees to the left; and when the second slit followed it, its image was deflected four degrees to the right, and two apparently simultaneous pictures were produced. Also, by crossing the prisms I found it would be easy to construct an apparatus with four successive slits shewing four images; 1, up to the left, 2, up to the right; 3, down to the left, and 4, down to the right. I doubt, however, whether this would be often found a useful development of the instrument, owing to the difficulty of watching more than a small area with attention.

I noticed an important optical effect, namely that the image first seen was always considerably fainter than the others, showing that its brightness had faded in the brief interval that elapsed before comparison began. It would appear that the law of the rate of fading could be investigated by this apparatus. I have not now the opportunity of doing so myself, but if I had, I should mount two prisms below radial slits in a disc that was revolving steadily at a known velocity, and I should watch a circular wafer through them. The width of the slits would be adjustable, and so would the angular distance of the prisms, and I should measure under various circumstances the width of the second slit that was necessary to tone down its image to an equal brightness with that seen through the first. Or the investigation might be made without prisms, by using two wafers and watching them with the same eye through slits at different radial distances, separated by various angular intervals, the adjustments being such that only the outside wafer should be seen through the outer slit, and the inside wafer through the inner one.

FRANCIS GALTON

THE CHEMISTRY OF THE PLANTÉ AND FAURE CELL

PART III.—*The Discharge of the Cell*

THE two plates of a Planté or Faure battery consist essentially of lead peroxide as the negative element, and metallic lead in a spongy condition as the positive. These are brought into communication with one another through the lead plates which support them, together with the connecting wire.

The lead peroxide reacts both with the lead plate that supports it, and with the lead on the opposite plate. At first sight, it might be expected that the reaction between it and the supporting plate would be the greater, as the space between them is so small, and the resistance of the intervening liquid in consequence almost inappreciable. The action is, indeed, probably greater at the first moment, but, as explained in our first paper, sulphate of lead is immediately produced, and that which lies at or near the points of junction, forms no doubt a serious obstacle to further local action, and admits of the lead on the opposite plate coming more fully into play.

If we consider *a priori* what is likely to be the reaction between lead peroxide and lead, with water as the connecting fluid, we should expect :—

$$PbO_2 \mid H_2O \mid H_2O \mid Pb = PbO \mid H_2O \mid PbH_2O_2.$$

On experiment this is found to be actually the case, yellow oxide appearing on the negative plate, and white hydrate on the positive.

If, however, the reaction takes place in presence of dilute sulphuric acid, the result will inevitably be sulphate on both sides, for even if oxide be first formed, it will be attacked by that acid. Of course this production of lead sulphate on each side might be expected gradually to produce a perfect electrical equilibrium. This, in fact, does take place under certain circumstances, but not under others. The reaction on the negative plate is always of this character, as far as our analyses have shown. We have invaraibly found the deposit to consist of sulphate of lead mixed with unaltered peroxide. If, however, the cell be allowed to discharge itself rapidly, the lead on the positive plate is converted, not only into the sulphate, but, very partially, into lead peroxide. This is sometimes evident to the eye from the puce colour of the superficial layer, and we found also that this was confirmed by several chemical tests.

It is difficult to conceive how the reduction of the peroxide of lead on the one plate to oxide or sulphate, should be attended by a direct oxidation of lead on the other plate up to peroxide itself, as that would involve a reversal of the electromotive force. It is more easy to imagine that the peroxide results from the oxidation of sulphate of lead already formed, through the agency of electrolytic oxygen.

When this peroxide is formed on the positive plate, it is not difficult to foresee what must happen. A state of electrical equilibrium will be approached before the peroxide of lead on the negative plate is exhausted. But the two sides are in very different positions with regard to local action. On the negative plate, the peroxide being mixed with a great deal of lead sulphate, it will suffer decomposition only very slowly through the agency of the supporting plate, but the lead peroxide on the positive plate, being mixed not only with lead sulphate, but with spongy metallic lead, will be itself speedily reduced to sulphate. Hence, on breaking the circuit, when local action alone can take place, the peroxide formed on the positive plate during the discharges will be destroyed much more easily than the original peroxide on the other plate. The difference of potential between the plates will be restored, and on connection the cell will be again found in an active condition.

Now it has been frequently observed that partially discharged accumulators do give an increased current after repose, that is, after the circuit has been broken and re-established. It remained for us to ascertain whether the chemical change above described coincided in any way with the physical phenomena. For this purpose we prepared plates according to the method of Faure, and examined carefully the changes of electromotive force and strength of current, which took place during their discharge under known resistances, and the chemical changes that took place under the same circumstances.

We found that the initial electromotive force of freshly prepared cells was 2·25, 2·25, 2·21, and 2·31 volts, averaging 2·25, but that after standing for thirty minutes or so, or when allowed to discharge for a few minutes, it was reduced to about 2·0 volts. We take this to represent the normal electromotive force of the arrangement of lead, lead peroxide, and dilute sulphuric acid, and believe that the higher figure obtained at the first moment is due to the hydrogen and oxygen occluded on the respective plates, and which either diffuse out or are speedily destroyed.

We found, however, that in the discharge the electromotive force diminished under certain conditions. Thus, in