Experiments on the Faure Accumulator

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greater density than the hot solid at a temperature just below melting-point.

This, so far as it goes, is confirmatory of the results obtained by us. If diagram No 2. be examined, it will be seen that the line of volume rises gradually to the line of equilibrium, indicating expansion; and just before the ball melts rises above the line, indicating a floating effect, when the temperature approximates to the melting-point.

Tin therefore appears to be similar to iron ; viz. it is at its maximum density when cold, and at its minimum density when at a temperature just below melting, and that the fluid-density is between the two.

The results obtained by MM. Nies and Winkelmann on bismuth will serve to illustrate the degree of approximation of these limiting values.

A piece of bismuth, when allied with a platinum block weighing 21·76 grammes, sank ; and another piece, weighing 35·4 grammes, floated; which is equivalent to stating that the specific gravity of the melting bismuth is between 10·28 and 10·12.

They arrive at the general result that not one of the eight metals they examined will justify the assertion that "bodies contract on becoming solid;" but the experiments rather favour the view that metals when solid, *at a temperature close upon their melting-points*, are less dense than when molten.

Without accepting MM. Nies and Winkelmann's results as final, we do not consider them to be opposed to our own, as theirs relate solely to the ratio of the densities of the solid and liquid metals at as nearly as possible the same temperature, while our experiments were undertaken with a view to determine the actual density of a metal at the *lowest* temperature at which it is perfectly liquid.

XII. *Experiments on the Faure Accumulator.*

By Professors W. E. Ayrton *and* John Perry*.

Having made, at the request of the Faure Accumulator Company, a series of experiments on some of their cells, we have thought that a short account of some of the results obtained

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may not be uninteresting to the members of the Physical Society.

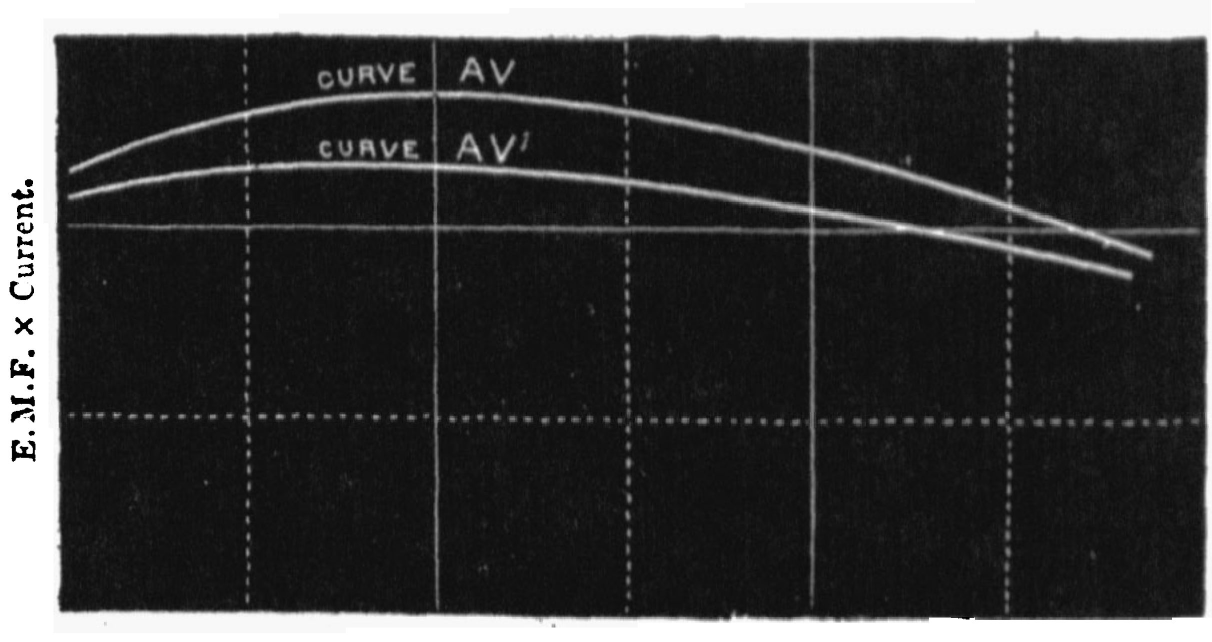
The object of the experiments was to ascertain, *first*, the efficiency of a cell—that is, the ratio of the energy given out by it to the energy put into it; *secondly*, the storing-power of a cell; and, *lastly*, whether or not there was a deterioration in its working-powers. To measure the energy put into any electric circuit, we have merely, of course, to take time-readings of the current flowing through the circuit, as well as the difference of potentials between its two extremities. The current in ampères multiplied by the electromotive force in volts and by 44·25, gives the number of foot-pounds per minute that is being put into that part of the circuit as electric energy. For measuring the current we have used throughout our ammeters (short for ampère-meters), and for measuring electromotive force our voltmeters, the latter being employed of course in a shunt circuit.

Of the total electric energy put into the circuit, and which is measured, in foot-pounds per minute, by 44·25 AV, a portion will be employed simply in heating the circuit, and the remainder may be utilized in producing useful work. For example, if a time-curve be drawn for 44·25 AV when charging a Faure accumulator, the area of the curve will measure the total energy put into the accumulator in foot-pounds; but of this some portion has been wasted in heating the cell, due to the charging having been more rapid than was absolutely necessary. It was, of course, of considerable importance in our experiments to ascertain what portion of the energy put into the cell was really thus wasted; and to measure this the following experiments were made.

Occasionally the main current was stopped, the shunt current through the voltmeter being left completed. The reading now on the voltmeter gives the difference of potentials produced by the cell itself, whereas the previous reading was the combined difference of potentials produced by the cell and the dynamo-machine charging it. If now a new time-curve be drawn in which the ordinates represent the product of 44·25 AV′, where V′ is the electromotive force of the cell measured on the circuit being broken, and A is the mean value of the current flowing just before breaking and just after closing the circuit, the area of the new curve will represent that portion of the energy put into the cell which is usefully employed in chemical decomposition. The difference between the areas of these two curves represents, then, the amount of energy wasted in heating the cell in foot-pounds.

Again, on discharging the cell, experiments of a similar nature have to be made. The product 44·25 AV represents the number of foot-pounds of work per minute the cell is producing in the external circuit, V being the difference of potentials between the two poles of the cell while it is discharging; but, in addition, there is a certain amount of energy which is being expended in heating the cell itself during discharge.

This, as before, may be ascertained by breaking the main circuit, leaving the shunt-voltmeter circuit completed. The reading on the voltmeter V′ now indicates the real electromotive force of the accumulator during discharge; whereas the previous reading, obtained just before breaking the circuit, represents merely the fraction of the total electromotive force employed in sending the current through the external resistance. If a time-curve be drawn with its ordinates proportional to 44·25 AV′, where A is the mean value of the current just before breaking and just after closing the circuit, its area will represent the total number of foot-pounds of energy per minute being given out by the cell; and the difference between the areas of the last two curves will represent the number of foot-pounds of energy employed in heating the cell itself. It is to be noticed that during charging V′ is less than V, whereas on discharging V′ is greater than V.



An examination of thirty-five sheets of time-curves, which we have drawn from the experiments we made, shows that, in charging, the curve for AV rises at first; and as it rises more rapidly than that for AV′, this means an increase in the resistance of the accumulator.

As the charging continues, the two curves for AV and AV′ approach one another, showing that the internal resistance of the accumulator diminishes again. On the other hand, at the end of a long discharge the curve for AV falls more rapidly than that for AV′, due to an increase in the internal resistance. Now our experiments show a great constancy in the electromotive force of a Faure cell, and that the falling-off in discharging which occurs during a very rapid discharge, or at the end of a long discharge, is due more to an increase in the internal resistance of the accumulator than to a diminution in the electromotive force, which our methods of experimenting above described enable us to separate and measure independently. But, whether discharging rapidly or whether discharging slowly, there is a most curious resuscitating-power in the cell, which, if disregarded, will cause totally erroneous underestimates to be made of the efficiency of the cell.

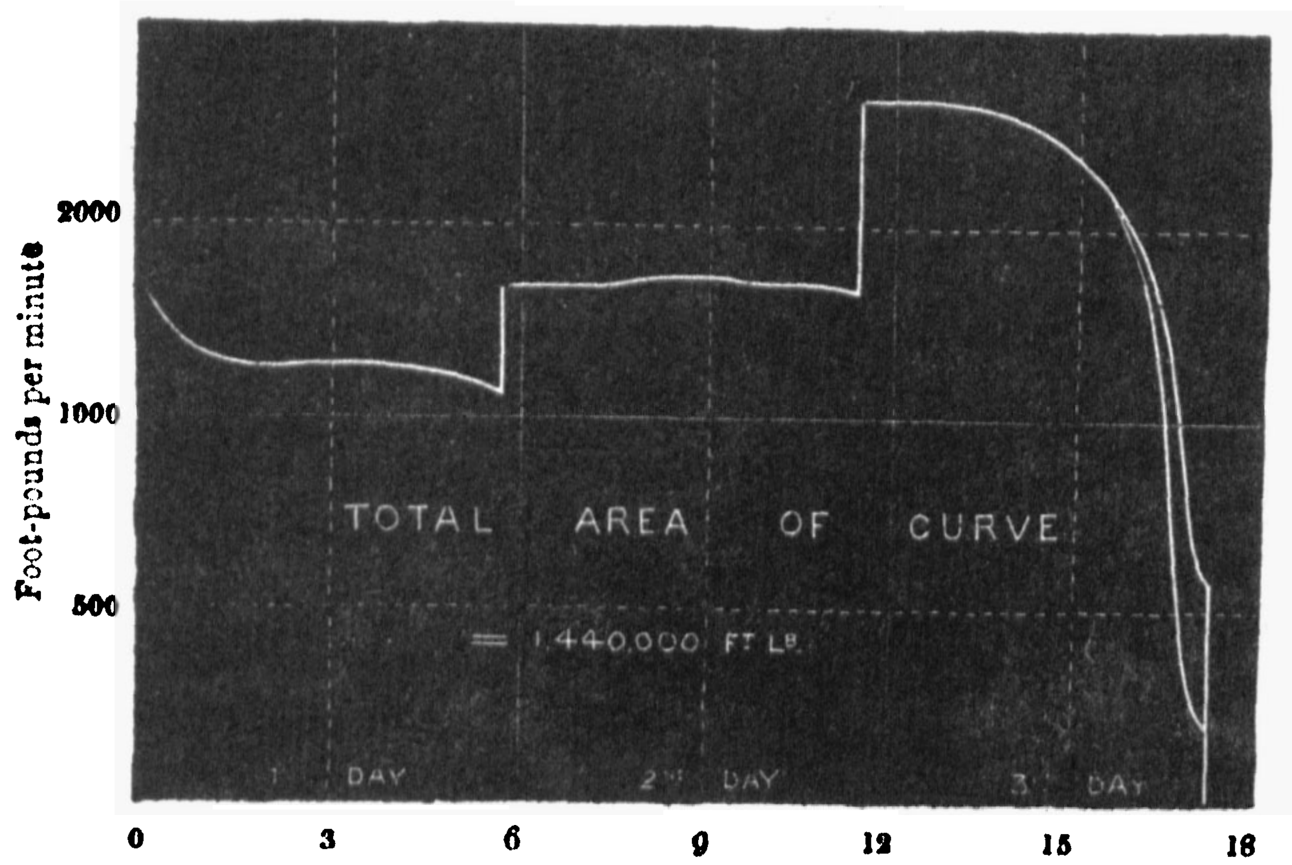
This resuscitating-power is more marked for rapid discharges than for slower ones. In the case, for example, of an extremely rapid discharge, we found that when the flow had become apparently so feeble that the cell appeared totally discharged, leaving the poles of the cells insulated caused three times as much electric energy to be given out all together in the second discharge as had been given out in the first. And even when several days are taken to discharge the cell—and we may mention that we have had continuous observations made day and night for several days in certain cases—this resuscitating-power is wonderfully marked. An insulation of a few hours will cause the energy given off per minute on redischarging to be eight to ten times as great as it was before insulation. Indeed on one occasion, after a cell had apparently nearly discharged itself, it was left shortcircuited with a thick wire for half an hour, then insulated all night, when the number of foot-pounds of work per minute given off at the commencement of the discharge the following morning was found to be ten times as great as it was on the previous evening, and a greater amount of energy was actually taken from it in the second discharge than in the first. This phenomenon gives the Faure accumulators a great value for tramcar propulsion, since, as is well known, it is just on starting after stopping that the strain on the horses is so great.

Efficiency.—To determine the efficiency of cells we commence with them empty, or at least as empty as many hours' shortcircuiting with a thick wire could make them. We then measured the total amount of energy put in and the total amount subsequently given out, and we found that, for charges up to a million foot-pounds put into the cell and discharged with an average current of 17 ampères, the loss in charging and discharging combined may not exceed 18 per cent. Indeed, for very slow discharges the loss in charging and discharging combined in some of our experiments has been as low as 10 per cent.

Storing-power.—It is a little difficult to measure the maximum storing-capacity of the cell at the same time that measurements are made of its efficiency, because in the latter case we must take care that we do not put in more electric energy than the cell can hold; on the other hand, if precautions are taken to avoid overcharging, it is a little difficult to ensure that the full charge has been put in. We have therefore separated our experiments for measuring the efficiency from those employed to ascertain the storing-power.

Let us take a single example of the storing-capacity. A certain cell containing 81 lb. of lead and red lead was charged and then discharged, the discharge lasting eighteen hours—six hours on three successive days; and it was found that the total discharge represented an amount of electric energy exceeding 1,440,000 foot-pounds of work. This is equivalent to one horse-power for three quarters of an hour, or 18,000 foot-pounds of work stored per pound weight of lead and red lead. The curve shows graphically the results of the discharge.

Horizontal distances represent time in minutes, and vertical distances foot-pounds per minute of energy given out by the cell, and the area of the curve therefore the total work given out. On the second day we made it give out energy more rapidly than the first, and on the third more rapidly than on the second, this being done of course by diminishing the total resistance in circuit. During the last day we were discharging with a current of about 25 ampères. And this cell, like the others, showed, on being insulated after having been apparently



totally discharged, that there was still a large charge stored up; hence the numbers given above for the capacity are probably under the total value.

Deterioration.—As to deterioration, two months constant charging and discharging of the two accumulators under test showed no signs of deterioration.

XIII. *A Simplified Dispersion-Photometer.* *By* Professors W. E. Ayrton *and* John Perry*.

It will be in the recollection of the Members that in 1879 we described to the Society a dispersion-photometer which enabled measurements to be made of the intensity of the strongest electric light in a small room and for the rays coming from the electric light at any angle—two essentials which appeared to us necessary in an electric-light photometer. The principle of this photometer consisted in our use of a concave lens to weaken the strength of the light, so as to make the illumination of a screen comparable with the illumination of a standard candle, instead of keeping the lamp a distance of 50 or 100 feet away, which was the plan in use until that time.

* Read February 25, 1882.