a ready means of obtaining the values of any related magnitudes expressed by a curve, which shows the relations of the numbers corrected of their errors; for, as M. Regnault remarks, "the graphic method when it is properly executed, is preferable to all methods of interpolation by calculation; it permits us to distinguish, immediately, the variations due to the accidental errors of the observations, and the constant errors which depend on the diversity of the methods which we have employed."

(To be continued.)

THE AIR-TIGHT GALVANIC BATTERY.

BY CHAS. T. CHESTER, ESQ.

THE galvanic battery serves many important purposes, which no other apparatus properly supplies. But the use of acids, with the destruction of material that they occasion, the space occupied, the expense and trouble attending their care, have prevented many from using any combination for producing dynamical currents of great intensity. Induction currents from coils of wire and magnets have formed a convenient substitute for those generated by the acid batteries, but it is becoming recognized that these induction currents will not produce the same effects as those from batteries, and especially for electro-therapeutics, an effort is being made to produce a battery of long endurance, and requiring little care. In Europe, wherever the teachings of Remak and his followers have prevailed over those of Duchenne, the great advocate of the Faradaic (or induction) currents, much attention has been given to the production of a good galvanic battery, easy in management, and not too self destructive. The ingenious manufacturers of France and Germany have made several useful batteries, but all of them of considerable size, and not portable. The principle aimed at has been, in almost all cases, to place certain plates and chemicals together, but also so to manage the diaphragm that chemical action is controlled. The stronger or denser the diaphragm, the slower is chemical and electrical action. Most of these combinations have been modifications of the sulphate of copper battery of Daniell. The battery of Stohrer is made up of more energetic elements, viz: zinc, carbon, and chromic acid. These, when immersed in an acid, both form a very self-de-

structive combination. So it is arranged that the carbons shall be raised at pleasure out of the glasses, and to effect this easily, the usual porous cell is omitted, and a hole in the carbon cylinder receives the chromic acid. Practically, this beautiful arrangement gives much trouble, and in all of these batteries the waste of material is not due to the useful currents drawn out on medical practice, but to self-destruction in the elements. We think that we shall show that as far as medical electricity is concerned, we need not resort to batteries of great plate surface and "quantity" power, and there are other uses for which small batteries of great intensity may prove quite as powerful as those of much greater size, as for instance, the testing of long telegraph lines and delicate instruments in many electrical researches, and in the ignition of blasts in mining and excavations. For this last purpose, magneto-electrical machines have been provided, which give sufficient quantity and intensity to fire a large number of fuses at one time, by the ignition of an exceedingly attenuated conductor, like the mark of a lead-pencil. The force of these machines has to be nicely adjusted to secure precision in blasting, and a small battery of adjustable force would be an excellent substitute. For all these purposes, a battery requires to be used only a short time at once. We wish, therefore, to find some arrangement that will give currents of sufficient quantity, adjustable, however, to our requirements, also capable of a very high intensity, but also adjustable; it must be brought into action speedily. It must remain out of action indefinitely, without loss of power. It must be portable, clean, and not too expensive.

In the attempt to produce such an instrument, a number of questions must be solved. First: What amount of battery "quantity" is necessary for currents through the body, or similar resisting media, such as long telegraph circuits? Secondly: Can we find any combination of elements in a very small space that will give us this force? Third: Can we dispense with acid? Fourth: Can we absolutely remove the elements from the exciting fluid when the battery is not in use? Fifth: Can we prevent evaporation and the generation of gas? Sixth: Can these other requirements be made consistent with simplicity of structure and great ease in renewal?

In answer to the first, we have testimony extending through two or three years. In the *Journal of Psychological Medicine*, July, 1867, we have an account of a voltaic pile, consisting of perforated zinc and brass wire gauze, excited by cloth moistened in acetic acid.

These plates were about two inches square, and numerous. During two or three years use, it had touched certain cases in which the induction currents commonly used, had no effect whatever, muscular contractions taking place instantly with the pile, but not with the inductive apparatus. In other hands, similar effects were produced. Paralysis yielded to these galvanic currents. The piles would produce, when their current was broken rapidly, shocks similar to those from inductive apparatus, but superadded and accompanying these evidences of currents of high tension, an appreciable "quantity" current was present. A sensation may be produced by a current of exceeding small quantity, as will be shown, but a degree of "quantity" higher than that produced by coils is necessary in many medical cases.

The piles, though efficient, are practically very troublesome and uncertain. A convenient substitute would be valuable, whose "quantity" current at least equals that of the pile. The battery we propose to describe, is capable of giving a range of effects from 256 down to 0. We will describe, without entering into detail, some experiments made in comparison with well known forms of battery, and we will term "electro-motive force" the power exerted to move certain magnetic instruments. In its highest activity, one cell of the new battery gave a force equal to that of a Smee battery, exposing 16 square inches of zinc surface; when nearly spent, the force equalled that of the same Smee battery, exposing $\frac{1}{4}$ inch surface. The range is here from 1 to 256. To equal the force 1, fifteen plates of the pile, soldered together for surface, were required. The greatest power of the battery therefore exceeds that of one set of pile plates 3840 times. Now batteries of different kinds have been employed to drive currents through the body, having ten times the quantity of the 16-inch Smee, and thus a force 38,400 times greater than that of the pile has been attempted to be passed through a very resisting medium, and it would seem that curative or other effects must be enhanced, if the attempt be successful. How much "quantity" current can pass through the body or other resisting media, is a question of interest. We can easily ascertain the "resistance" to conduction of the human body, by moistening the hands, and grasping electrodes. We find that the "resistance" equals almost 550 miles of telegraph iron wire. It is well known that we cannot cause "quantity" currents to pass through this length of conductor. It requires much intensity to pro-

duce magnetic and other effects, and quite delicate instruments to indicate it. We may use a battery, which, with short conductors, acting directly upon a magnet, would raise 500 pounds; and this same battery, interposing the body in the circuit, would have no apparent influence upon the same magnet. But to measure more exactly the effect of this resistance, and having a battery capable of so great a range of force, and giving the conductivity of the body

the fairest chance, by the employment of large moistened electrodes, we measure different effects upon a galvanometer of fine wire. Our battery is made capable of its quantity range from 1 to 256, and in

intensity from 1 to 150. With the intensity of 1, almost any quantity power will drive the needle to 90° . Through the body no effect is perceptible. We now increase the intensity, until the current passing through the body, drives the needle to 27° . The intensity being the same, we increase the "quantity" from 1 to say 25. The needle advances to 37° . We now use the same intensity, and give the battery a quantity of 256, and the needles sluggishly advance to 47° . Thus, with an increase of quantity power from 1 to 256, we have only slightly increased the effects of the current. The inference is unavoidable. The body refuses to carry these currents, and all other highly resisting conductors follow the same law; and so, for many purposes, we are employing a force vastly in excess of our necessities, and we waste in self-destroying combinations for dynamical electricity, fifty times as much as we make good use of. At the same time, many useful purposes can be served only by the actual use of very great and continued force, and here the small battery exhibited in the engraving would be entirely out of place. A description of it, and the mode of using it, as well as what has been done with it, will prove, however, that it is possible to secure the results we aimed at, as far as regards cleanliness, portability, power, with extreme range of adjustment, freedom from consumption when not in use, and ease in renewal.

The engravings represent glass cells, three inches long, and one inch in diameter, inserted in a wooden block; a zinc cover is provided for each glass, and a projection from this zinc cover, running down into the glass, forms the zinc element. The other element is carbon, carefully connected with platinum, and well insulated from the zinc cover. This cover has a plate of soft rubber interposed between it and the glass top, and the packing is made completely air-tight and water-tight, by the pressure of two rubber springs pulling the cover firmly down. Connection from one cell to the next is quickly made by short pieces of spiral springs. The battery is charged by filling the glasses half full of water, adding some bisulphate of mercury, and a little shred of cloth is interposed between the plates, so as to retain moisture. To use this battery, we invert it, and thus allow the fluid to flow over the plates and saturate the piece of cloth. Restoring the battery, the fluid leaves the plates, though a drop remains in the cloth shred, and in this state, simply from these drops of moisture, powerful intensity currents, producing

violent muscular contractions, are given off, and this is the case even forty-eight hours after the immersion of the plates. It is evident that

if we can employ these currents, resulting from the simple expenditure of one drop of the fluid, usefully, that we have exhausted a very small portion of the force in reserve, and it is also evident that we can, after use, place the battery out of use for an indefinite time, ready, by the expenditure of another drop of fluid, to give off the desired currents. Properly constructed, we cannot see any reason why the arrangement should not last in good power a year or more for occasional effects; and it can be completely renewed, at the rate of fifty cells in one hour; one hundred and fifty cells exceed in intensity one hundred cells of Grove. The parts are all quickly replaced, no acid is used, and no gas generated.

The second figure shows a modification of the construction. Supposing we wish to employ a fluid of greater energy, but which in decomposition produces gas from which the tight cell must be relieved; we insert a tube through the cover; the opening being just half way down the cell, and the surface of the fluid below. Care being used in inverting the battery, this tube orifice is always in the air space of the cell, whether upright or inverted.

When we wish for convenience a battery of large quantity, to be used occasionally, we employ large glasses and elements; but we substitute bolts for the rubber bands, to bind down the zinc covers. An exceedingly convenient battery is thus formed for electric cauterization, where the operation is not too extended. The use of the rubber bands, however, in batteries of high tension, is far preferable to bolts, or their equivalents. The very high insulation of this packed battery is evident from the retention of its power for forty-eight hours and more, where the exciting power is derived from a mere drop of fluid.