

acid. Hence the active agent is here also nitric acid, but in using the mixture, the disagreeable fumes of nitrous acid produced by strong nitric acid alone are in a great degree avoided.

466. Two of Grove's batteries, of the form represented in Fig. 178, were connected with the magnetometer, at first united as a single pair and afterwards consecutively, strong nitric acid being used in the porous cell. The following table gives the magnetizing power obtained:—

TABLE IV.

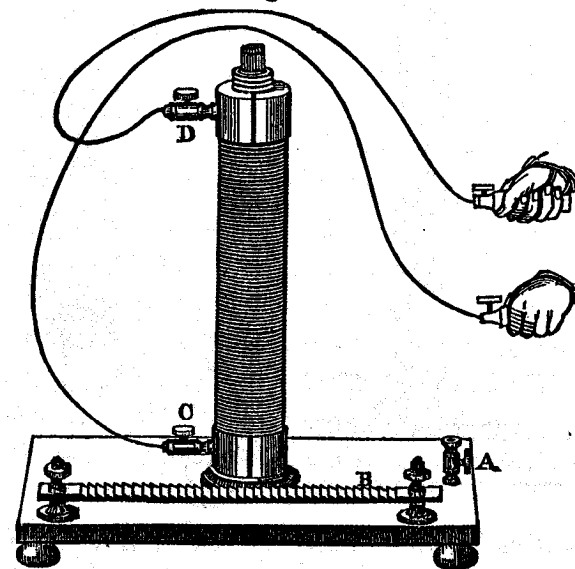
Battery No. 1,	80,000	grs.
“ No. 2,	82,000	“
Both, as one pair,	88,000	“
“ consecutively,	97,000	“

Owing to the magnetizing power being so great as nearly to reach the limit of saturation of the electromagnet, the numbers in this table do not indicate so great an increase as really occurs; but they show that no great advantage is gained by connecting two pairs as a single pair. The large-sized Smee's or Grove's batteries are not much superior to the small ones. Ten pairs of Smee's battery, connected as one, are but little better than one pair.

467. SEPARABLE HELICES.—In this instrument, which is represented in Fig. 179, there are two helices entirely separate from each other. The inner one, composed of several strands of insulated coarse copper wire, is fixed in a vertical position on the base

board. One of its ends is connected with the screw-cup A, and the other with a steel rasp, B. The

Fig. 179.

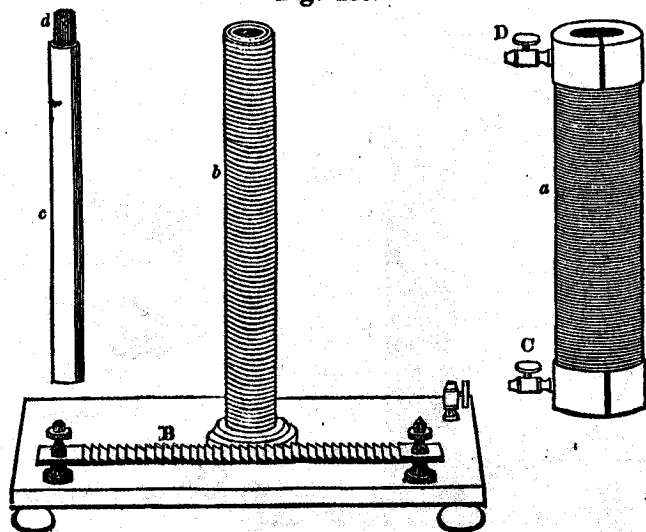


exterior helix is of fine insulated wire, and can be lifted off from the other, which it surrounds. Its ends are enclosed in two brass caps, to which the extremities of the wire are soldered. To these caps are attached the screw-cups C and D. A bundle of annealed iron wires, of which the ends are seen in the cut, can be removed from the inner helix when desired.

468. In Fig. 180, the different parts of the instrument are shown separately. The exterior helix, *a*, is removed from the inner coil, *b*, which is fixed to the base board. At *c* is seen a brass tube, within which

is the bundle of iron wires, *d*, intended to be introduced into the interior helix. For giving the strong-

Fig. 180.



est shocks, the bundle should fill the hollow of the helix. The other parts are lettered in correspondence with the last figure.

469. The bundle of iron wires being withdrawn, let a wire connected with one pole of a galvanic battery be fixed in the cup A, and the other battery wire be drawn over the steel rasp. Bright sparks will be seen, and if metallic handles connected with C and D are grasped in the hands, as represented in Fig. 179, slight shocks will be felt on completing the circuit at the rasp, and stronger ones when it is broken, as with the instrument described in § 402, which is on the same principle.

470. If a rod of soft iron is introduced into the

helix, the spark is much increased, brilliant scintillations are produced, and the shock, when the circuit is broken, becomes powerful. The iron acquires and loses magnetism whenever the current begins or ceases to flow, and induces secondary currents in both of the coils which surround it. In the coarse wire coil, which conveys the battery current, this appears in the increased sparks and scintillations. In the fine wire coil it is felt in the strong shock which results.

471. When the bundle of iron wires is substituted for the soft iron rod, the spark and shock are much greater. If the rod or bundle of wires is introduced gradually into the helix, the spark and shock increase as it enters. The intensity of the shock may be varied at pleasure, by altering the number of iron wires, the addition of a single wire producing a manifest effect. If a glass tube is slipped over the iron wires in the helix, it does not interfere with their inductive action on the surrounding coils. But if a brass tube is passed over them, their influence is entirely suspended, so far as the shock and the spark are concerned. When the tube is slipped partly over them, their influence is partially suspended. This also is a means of regulating the shock without altering the battery current.

472. The neutralizing action of the tube is thus explained. The magnet induces in the tube, as well as in the two coils, a secondary electric current, which flows around it when the circuit is completed or broken. This secondary induces a tertiary cur-

rent in each of the coils, which flows at the first instant in an opposite direction to the secondary induced in the coil by the magnet, and therefore retards it. As the secondary current in the tube is, however, instantaneous, it induces another tertiary in the same direction with itself when it ceases to flow. The consequence is, that the quantity of the current in either helix is not altered, but its intensity is reduced, owing to the slowness of its development. This is always the effect of any closed circuit in the neighborhood of an inducing magnet or current, on other circuits near it.

473. If the cups of the fine wire coil are joined by a wire, it will form a closed circuit around the magnet, and will impair the spark when the current in the coarse wire is interrupted, though not to so great an extent as the brass tube, since the latter offers a freer and shorter circuit for the induced current. The spark is but slightly lessened when shocks are taken from the fine wire coil, because the human body is too poor a conductor to allow of the ready flow of the secondary through it. A metallic cylinder surrounding the helices will neutralize the sparks and shocks as completely as the enclosed tube.

474. When a bar of iron is placed within the helix, a secondary is induced in it in the same manner as in the brass tube, which somewhat retards the secondary currents in the coils. Hence the greater shock obtained from a bundle of wires, where this secondary current cannot circulate. To this cause is added another—the more sudden change in the mag-

netism of the wires, when the battery current ceases, from the neutralizing influence of the similar poles of the wires on each other.

475. If the secondary current can be hindered from circulating in the brass tube, its retarding influence will be prevented. Thus, if the tube is longitudinally divided on one side, it no longer diminishes the shock or spark. With the solid iron bar, the shock and spark are increased by sawing it open longitudinally to the centre. A soft iron tube, divided like the brass tube, gives a stronger shock than the bar, but is still inferior to the bundle of wires. The two brass caps at the ends of the fine wire coil would exert a considerable neutralizing influence if they were not divided on one side, as shown in the cut. The ends of the caps are also cut through for the same reason.

476. In this instrument there are some peculiarities in the shock occasioned by the motion of the battery wire over the rasp. If it is moved slowly, distinct shocks are experienced; if the motion is quickened, the arms are much convulsed; and if it is drawn over rapidly, the succession of shocks becomes intolerably painful. This, however, can be easily regulated. The shock from the secondary coil increases within certain limits in proportion to the length and fineness of the wire of which it is composed. There is no advantage obtained by employing a very long wire, unless the battery is powerful. The shock is also lessened if a very fine wire is used, unless its length is moderate.

477. The strength of the shock depends greatly upon the extent of the surface of contact between the hands and the metallic conductors. Thus, if two wires are fixed in the cups C and D, and grasped in the hands, the shocks will be slight in comparison with those given by the handles, and still more so if the wires are held lightly in the fingers. These effects, as well as the increase of the shock by wetting the hands, are due to the comparatively low intensity of the secondary current, which causes it to be transmitted imperfectly by poor conductors. With frictional electricity it is well known that no difference in the shock is thus occasioned.

478. When the quantity of the secondary current is very small, an imperfect conductor, or a surface of limited extent, may be able to convey the whole of it, even if its intensity is not very high; in which case, the sensation and muscular contractions produced by it will not be increased, but even lessened, by any further increase in the conducting power. Thus, if the shocks are received by placing the hands in two vessels of water connected with the cups of the outer helix, and the current is rather feeble, it will produce the strongest sensation when the ends of the fingers only are immersed. With a powerful current, the shock is intolerable, whether the surface of contact with the water is large or small; in the latter case, it extends to a less distance up the arms, though it may be felt very strongly in the fingers.

479. The shocks have sufficient intensity to pass without much diminution through a circuit formed

by several persons with their hands joined, especially if their hands are moistened. Different individuals will be found to manifest remarkable differences in regard to susceptibility to the shocks; some being but slightly affected, perhaps feeling the shocks only in the hands or arms; while others will feel them as far as the shoulders or across the breast, and will experience strong muscular contractions in the arms.

480. The difference in the strength of the shock in the two arms, which has been described in the case of the magneto-electric machine (see § 442,) is exhibited more satisfactorily by the separable helices, as a rapid succession of shocks may be obtained of very nearly the same intensity. Suppose the handle connected with the positive cup of the exterior helix to be held in the right hand, and the one connected with the negative cup in the left hand. The left hand and arm will then experience the strongest sensations, and be most convulsed. In determining the positive or negative character of the cups, regard should be had only to the terminal secondary current, it being found that the initial secondary, whether induced by means of a voltaic battery or a permanent steel magnet, produces comparatively feeble physiological effects, and consequently need not, in this case, be taken into account. This singular difference in the intensity of the shocks is regarded as a purely physiological phenomenon, the greatest effect, both as respects sensation and muscular contractions, being produced by the electric current when it proceeds in the direction of the ramification of the nerves.

481. If the ends of the secondary wire are put into vessels of water, a peculiar shock may be taken by putting the fingers or hands into the vessels, so as to make a communication between them through the body. If both wires are put into a trough, at some distance apart, and two fingers of the operator are placed in the water in a line between the two wires, a shock will be felt. Here the current prefers a passage through the body to that through the water which intervenes between the fingers. The conducting power of the water may be made better than that of the human body by the addition of a sufficient quantity of common salt; in which case, little or no shock can be perceived. If the fingers are placed at right angles to the line between the wires, no shock will be felt. The trough should not be of metal, but of some poor conductor of electricity.

482. If a delicate galvanometer is connected with the ends of the fine wire coil, the needle will be deflected in opposite directions, and equally far, when the battery circuit is closed and opened. The same effect is produced when the brass tube is slipped over the iron wires. In this case, though the shock may have been prevented, the induced current still passes. The reduction in the intensity of the current, while its quantity remains unaffected, depends upon the same cause as with the flat spirals, when a metal plate is interposed. (See § 421.)

483. When a flat coil of fine wire, such as that represented at W, in Fig. 167, is passed over the in-

terior helix (the exterior one being removed), the shocks will be found strongest when the coil surrounds the middle of the helix, and to decline considerably in strength as it is either raised or depressed from this position. Now, the magnetism of the enclosed iron wires, which induces the principal part of the current, manifests itself chiefly at the ends of the bundle; it might, therefore, have been expected that the flat coil would give the strongest shock when surrounding one of these ends. The shocks from the exterior helix are also lessened when it is raised from the stand so as to enclose only the upper part of the inner helix.

484. Slight shocks may be obtained from the inner helix itself, by connecting one of the handles with the cup, A, and the other with the rasp, B. The bundle of iron wires should be within the helix. The shocks are somewhat stronger when one handle is in connection with the rasp, and the other with the battery wire which is drawn over it; in this case, the battery is included in the circuit of the secondary current.

485. The most important principles of magneto-electric and electro-dynamic induction are conveniently illustrated by the separable helices, in consequence of the facility with which the powers and uses of its several parts can be exhibited. The observations which have been made with regard to it apply equally well to the following instrument, which is a modified form.

486. SEPARABLE HELICES AND ELECTROTOME.— In the instrument represented in Fig. 181, the inner