(No Model.)

2 Sheets—Sheet 1.

G. & A. PFANNKUCHE.

ELECTRIC CONVERTER.

No. 476,816.

Patented June 14, 1892.

Fig: 1.

Fig: 2.

Fig: 3.

Fig: 4.

Fig: 5.

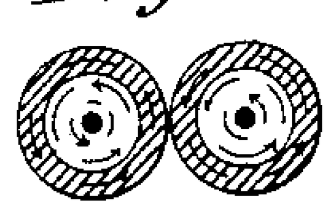


Fig: 6.

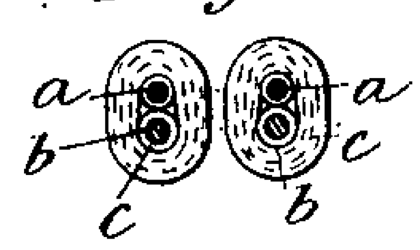


Fig: 7.

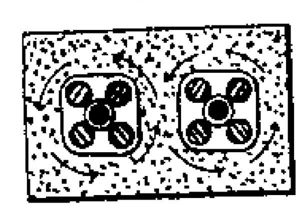


Fig: 8.

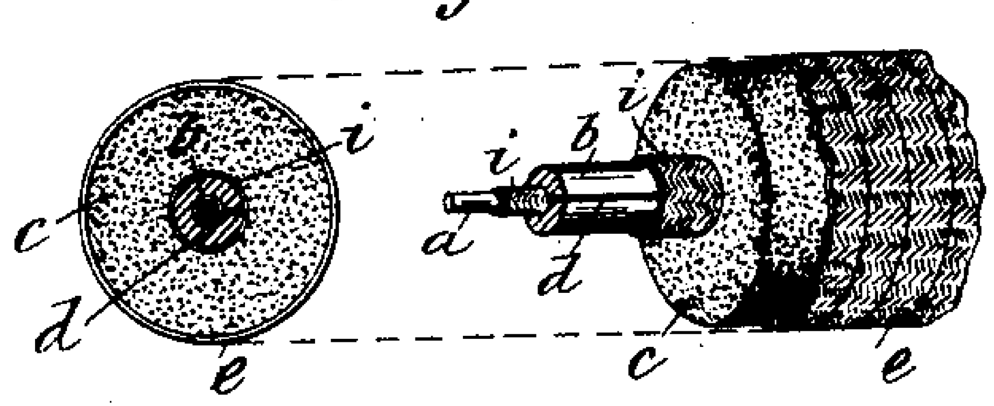


Fig: 9.

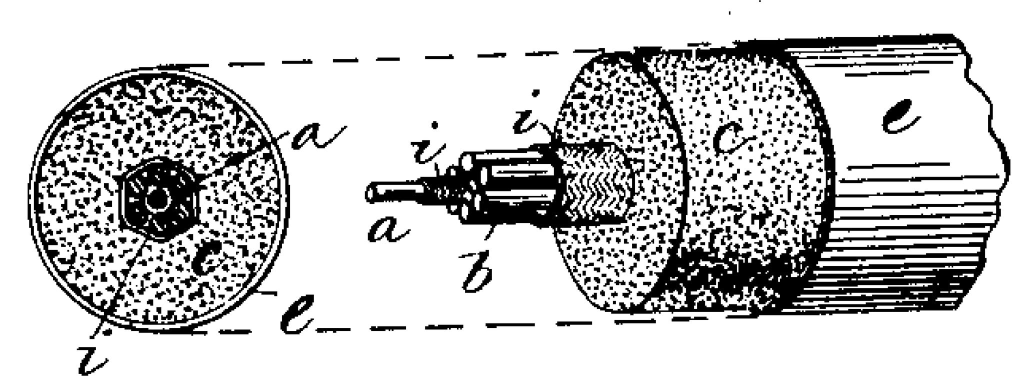


Fig: 10.

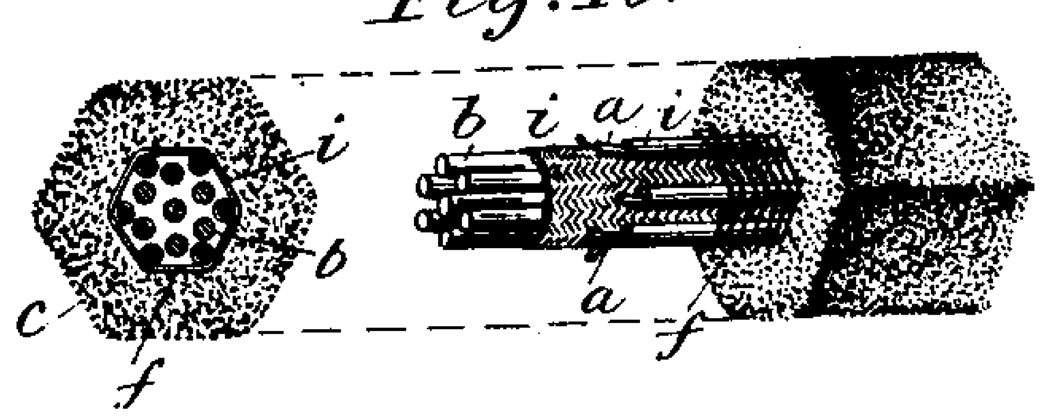


Fig: 11.

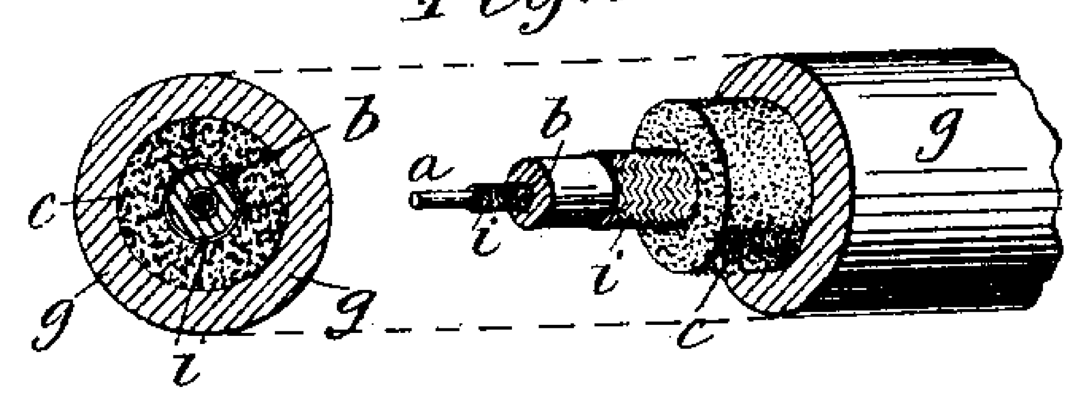


Fig: 12.

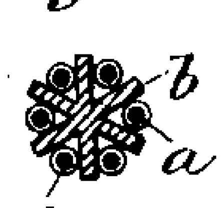
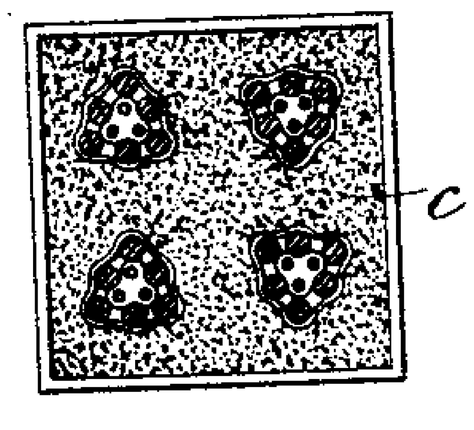


Fig: 13.



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(No Model.) 2 Sheets—Sheet 2.

G. & A. PFANNKUCHE.

ELECTRIC CONVERTER.

No. 476,816. Patented June 14, 1892.

Fig: 14.

Fig: 15.

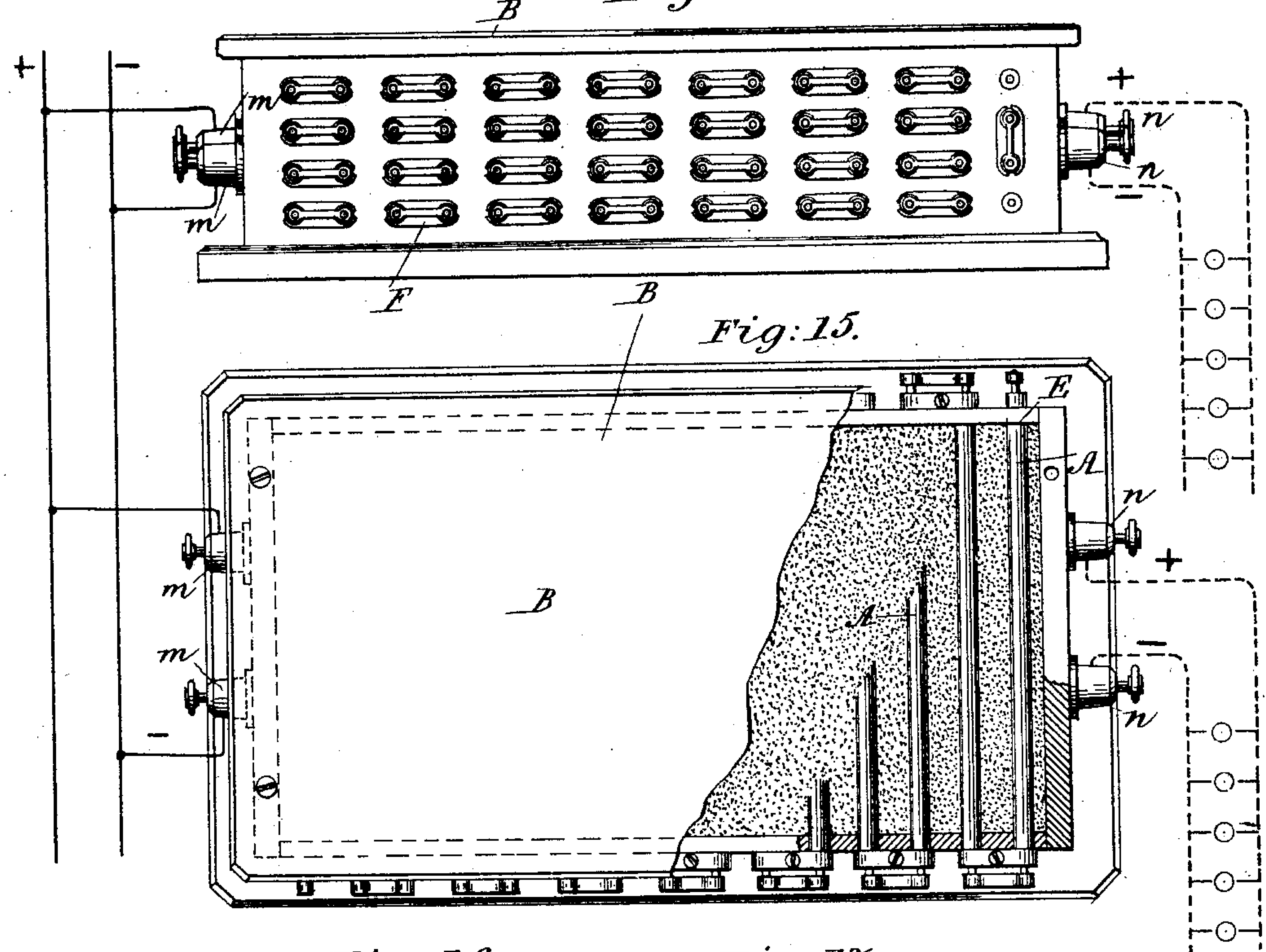


Fig: 16.

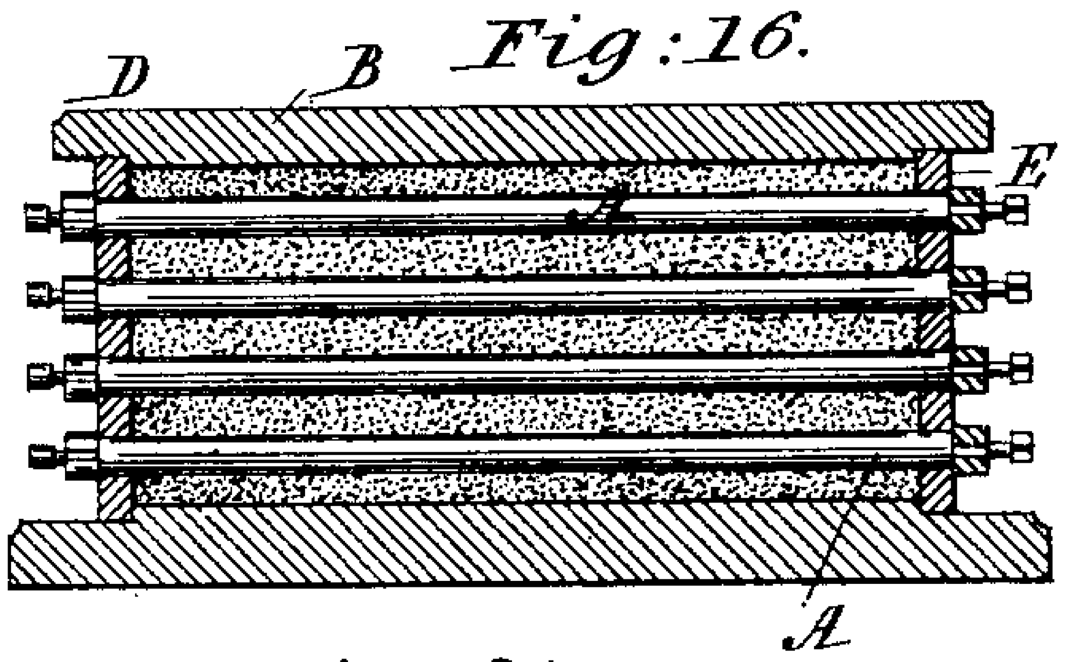


Fig: 17.

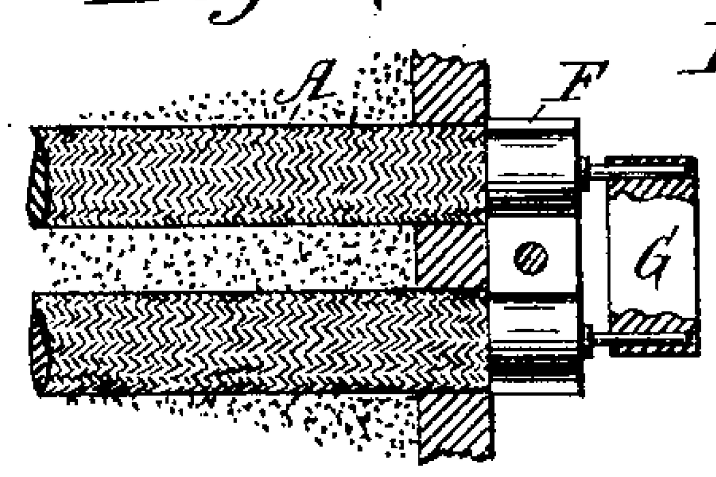


Fig: 18.

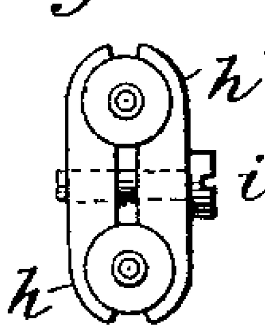


Fig: 19.

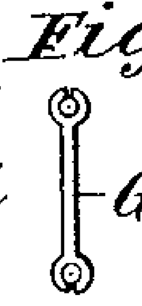


Fig: 21.

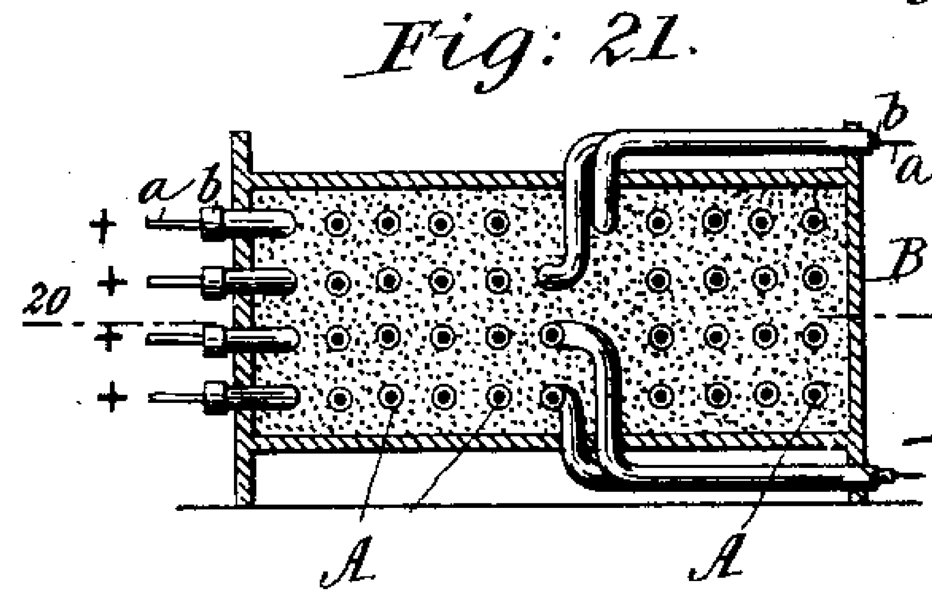


Fig: 20.

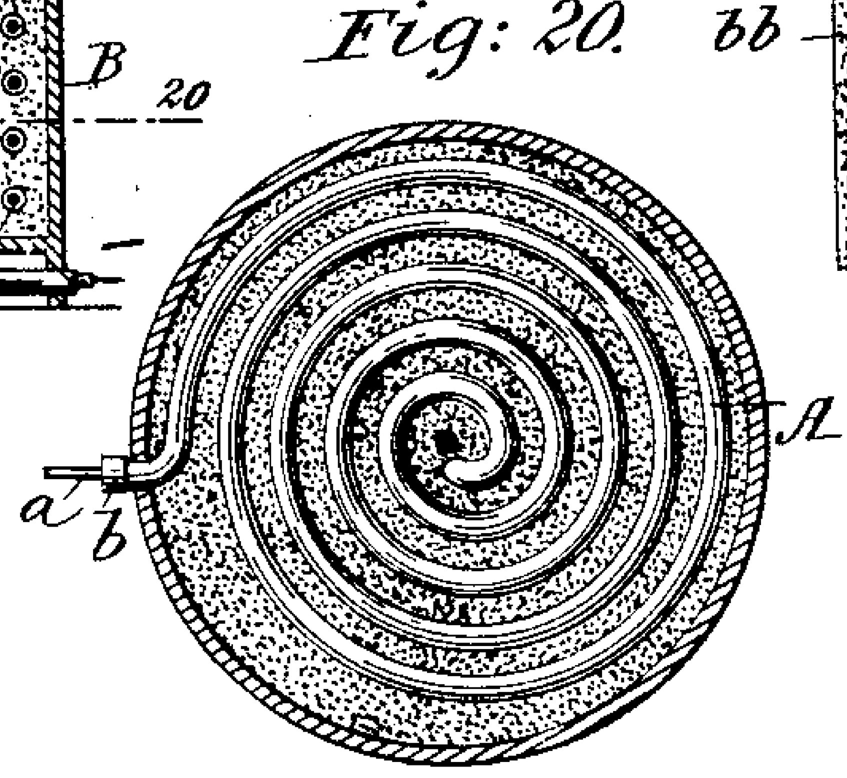
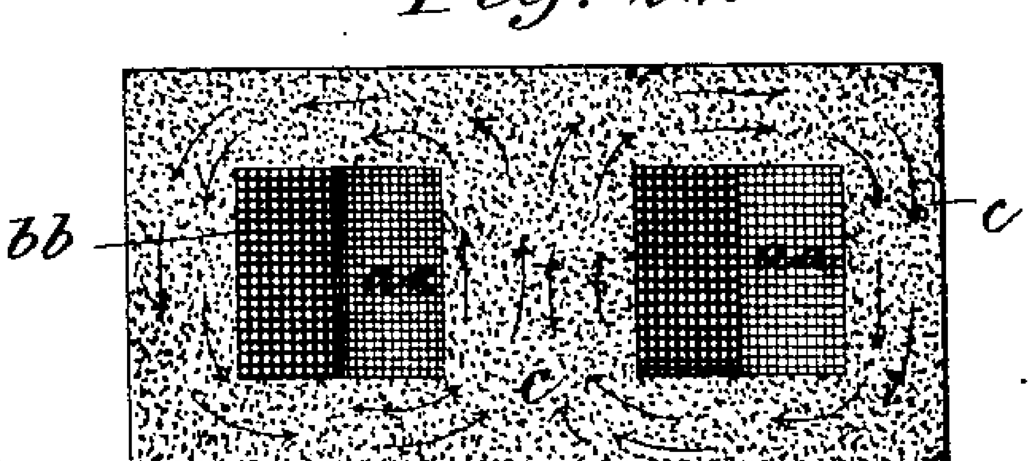


Fig: 22.



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UNITED STATES PATENT OFFICE.

GUSTAV PFANNKUCHE, OF EXETER, NEW HAMPSHIRE, AND ALFRED PFANNKUCHE, OF CLEVELAND, OHIO, ASSIGNORS TO THE BRUSH ELECTRIC COMPANY, OF CLEVELAND, OHIO.

ELECTRIC CONVERTER.

SPECIFICATION forming part of Letters Patent No. 476,816, dated June 14, 1892.

Application filed May 14, 1887. Serial No. 238,205. (No model.)

To all whom it may concern:

Be it known that we, GUSTAV PFANNKUCHE, a resident of Exeter, Rockingham county, in the State of New Hampshire, and ALFRED PFANNKUCHE, a resident of Cleveland, in the county of Cuyahoga and State of Ohio, have invented certain new and useful Improvements in Electric Converters or Inductoriums, of which the following is a specification.

This invention has reference to inductoriums or induction-coils, and particularly to such as are employed for transforming or converting an electric current of one character (such as of high potential and slight density) on a main or primary circuit into a current of a different character (such as of low potential and considerable density) on a local or secondary circuit, such inductoriums being commonly known as "electric converters" or "transformators" or "inductive translators." Such electric converters are chiefly employed in those systems of electric distribution wherein an alternating, intermittent, or pulsatory current of high electro-motive force is transmitted to a distance over a line-circuit which includes the primary wire of the converter, and a current of considerable density and of low electro-motive force is induced in the secondary wire of the converter, which is connected with a local circuit in which incandescent electric lamps or other consuming devices are installed usually in multiple arc. Such inductive systems of distribution possess the well-known advantages of enabling the electric energy to be transmitted over long circuits with but little loss of potential, of enabling a small and consequently cheap conductor to be used for the line-circuit, and of enabling a current from one generating-station to be translated into currents of different characters at several different consuming-stations.

Our invention has for its object to improve, simplify, and cheapen the construction of inductive converters for use with such a system of distribution, and for other purposes, and to increase the efficiency thereof by preventing waste of electric energy therein.

Before proceeding to describe our invention we will, in order that its principle may be better understood, rehearse some of the well-known laws pertaining to the inductive action of electric currents and the relations which exist between electrical and magnetic forces which have a bearing thereon. For this purpose we will make reference to Figs. 1 to 7 of the accompanying drawings, which are cross-sections of electrical conductors in different arrangements and illustrating the respective fields of force. When an electric current is passing through a wire, the wire becomes surrounded by a tubular field of force, known as the "magnetic whirl," which consists of lines of magnetic force which revolve around the wire-like wheels on a shaft and in a direction depending on the direction in which the current is flowing through the wire.

Figure 1 is a cross-section of a wire, (shown in solid black,) through which a current is passing, thereby developing lines of force, which are indicated by the arrows circling around the wire. If another wire be brought into close proximity with the excited wire, so that the lines of force generated by the current in the excited wire cut the second wire, as shown in Fig. 2, (where the black circle designates the primary and the tinted circle the secondary wire,) a momentary current will be induced in the secondary wire in the opposite direction to that of the current in the primary. If the current in the primary wire is stopped, another momentary current is induced in the secondary wire, but of opposite direction to the first. The same result ensues upon a rise or fall of potential in the current traversing the primary wire, a rising potential inducing a secondary current in one direction and a falling potential inducing one in the opposite direction.

In induction-coils as commonly made a primary wire is wound into a coil of numerous convolutions, the separate convolutions of which are arranged close to and parallel with one another, and the secondary wire is also wound into a similar coil, which is arranged either outside of or inside of the primary coil or otherwise in inductive proximity to it. In some special constructions of induction-coils the primaries and secondaries have been more or less subdivided, in order to bring the individual primary and secondary wires into closer proximity with one another. The most perfect construction embodying this principle of which we are aware is the one illustrated in our Letters Patent, No. 343,602, dated June 15, 1886, wherein the primary and secondary wires are coiled in layers alternately superposed upon one another.

In induction-coils wherein the primary and secondary wires are wound in separate coils there is but a low inductive efficiency on account of the distance at which the greater portion of the convolutions of the respective wires are from one another. In order to produce the best inductive effect, the secondary wires should be arranged in the densest portion of the magnetic field surrounding the primary wires. This ideal is somewhat more nearly approximated in the subdivided coils. Such coils are, however, subject to the disadvantage that the parallel currents in the adjoining primary wires or convolutions tend by self-induction to weaken one another, and thereby to reduce their effect on the secondary wires. The same disadvantage is also inherent in the undivided coils. To make this self-induction more clear, let us consider the case of two parallel wires through which currents are passing in the same direction, as shown in Fig. 3. The fields of force of the two wires coalesce in their outer portion to the same effect as though there were but one wire carrying a current; but in the denser portions of the fields of force the lines of force oppose each other in the manner more clearly shown in Fig. 4, where only the opposing lines of force are indicated. The result is that the wires tend to repel each other, and if freely suspended will move apart to some extent in the direction of the straight arrows in Fig. 4, or if rigidly mounted and unable to move the effect of the opposing lines of force is to diminish the current in the wires. The same action may be expressed in another way by saying that the current in each wire tends by its magnetic whirl to set up a counter magnetic whirl in the other wire and to produce at each rise and fall of potential a secondary current therein, the potential of which is opposed to that of the main current.

It is one of the objects of our invention to so construct an inductorium as to suppress this self-induction of the primary wires or convolutions, and thereby to avoid the loss of electric energy resulting therefrom and to concentrate in the secondary conductor the entire inductive effect due to the primary current. To this end we interpose a magnetic sheath or envelope between the respective primary wires or convolutions thereof or between successive groups of primary wires. We do this by inclosing or partially inclosing each primary wire or group thereof in a tubular or approximately tubular envelope of magnetic material.

Fig. 5 is a cross-section of two primary wires, each inclosed in an iron tube and indicating the lines of magnetic force around the respective wires. It is well known that the magnetic conductivity of soft iron is about eight hundred times greater than that of air. It follows that when the primary wire is thus inclosed in an iron tube the magnetic lines of force circling around it will find a much easier path through the iron than through the intervening air or the external air. The lines of force will therefore to a great extent find their way into the iron envelope and will circle therein in preference to passing through the air. The result is twofold: first, the field of force around the conductor will be intensified by the lowering of the magnetic resistance, and, second, the straying of lines of force over a large area will be prevented and they will be restrained within the area of the magnetic envelope. Hence the lines of force revolving around two adjacent conductors will not interfere with one another for the reason that they will not reach one another. This effect is clearly indicated in Fig. 5. If now we place within each of the magnetic sheaths or envelopes one or more secondary conductors, the latter will be powerfully acted upon, since they receive the full effect of the lines of force generated by the respective primary conductors and since these lines of force are not diminished by mutual induction.

Fig. 6 is a cross-section of two primary and secondary conductors with two magnetic envelopes, each surrounding one primary and one secondary conductor. *a a* are the primary conductors, *b b* the secondary conductors, and *c c* the iron tubes or magnetic envelopes. This figure is introduced to illustrate the most elementary form of our invention, the mechanical construction being immaterial. The primary and secondary wires *a b* should be insulated not only from each other, but also from the magnetic envelope, which latter may be applied to them in a great variety of ways. For example, the magnetic envelope may be an iron tube into which the primary and secondary conductors may be drawn, or the iron tube may be longitudinally subdivided into two or more parts which may be put together around the conductors, or the magnetic envelope may be made by winding iron wire around the primary and secondary conductors. We have not deemed it necessary to illustrate these constructions, partly because of their extreme simplicity and partly because in another application for patent which we have prepared to be filed simultaneously herewith we have illustrated a number of constructions of iron envelopes which are applicable in carrying out our present invention.

Either the primary conductor or the secondary conductor, or both, may be subdivided into two distinct wires, all of which will be inclosed within the one magnetic envelope. We will presently describe several different constructions involving this idea. It is by no means essential to our invention that every primary wire or convolution should be magnetically insulated or shielded from the neighboring primary wires or convolutions; but the advantages of our invention may be in great part availed of if the primary wires or convolutions are divided up into groups and those of each group are insulated from those of each other group by being inclosed in a magnetic envelope. Nor is it essential to our invention that a separate magnetic envelope be employed for each primary wire or group of primary wires or that the respective magnetic envelopes be in any way separated from one another. It is not necessary to leave a space between the adjacent magnetic envelopes nor to separate them by interposing insulating material. In fact, the magnetic envelopes surrounding adjoining wires or groups of wires may all be, mechanically considered, one single body or substance.

Fig. 7 is a cross-section of two groups of wires with a magnetic envelope inclosing them and separating them magnetically from one another. This magnetic envelope is all of one piece instead of there being a distant magnetic envelope for each group of wires. The magnetic envelope may be formed thus in various ways—as, for example, by molding or casting a plastic composition around the groups of wires.

Another important feature of our present invention relates to the construction of the magnetic envelope in such manner as to prevent or suppress the Foucault currents which are liable to be generated in it. These currents are believed to be true electrical currents which flow perpendicularly to the encircling lines constituting the magnetic whirl, or, in other words, longitudinally of and parallel with the primary conductors. The Foucault current thus induced flows in one direction along the inner portion of the magnetic envelope, where the inducing field of force is most dense, and being unable to form a complete circuit in any other way is forced to return along the outer portion of the envelope, where the field of force is less dense, thereby encountering and opposing this outer portion of the field of force. The result is a great loss of energy by the heating of the magnetic material, due not only to the resistance which it opposes by reason of its low conductivity to the passage of the current, but also to the opposition which the returning current encounters from the field of force.

Efforts have been made in the construction of induction-coils to prevent the formation of these Foucault currents by subdividing the iron core upon which the coils of wire have been wound; or, in other words, by building up a core of iron wires slightly separated or insulated from one another. In the only inductoriums of which we are aware, wherein in place of a central iron core inclosed by the wires there is an external iron envelope inclosing the wires, the efforts which have been made toward the suppression of Foucault currents in this envelope have been directed toward the subdivision of the envelope by lamination, as by building it up of thin plates or washers occupying planes perpendicular to the direction of the inclosed wires or by forming the envelope of windings of iron wire, the convolutions of which are insulated from one another. Both of these methods are very crude and imperfect and result in only a partial subdivision of the envelope, and consequently in only a partial suppression of the Foucault currents.

According to our invention we provide a magnetic envelope which is minutely subdivided and the minute subdivisions of which are very perfectly insulated from one another, whereby an almost ideal suppression of Foucault currents is accomplished. The subdivision of the magnetic envelope is attained by forming it of iron filings or minute particles of iron—such as chippings, turnings, &c.—and the respective particles of iron are insulated from one another by being coated with some insulating material—such, by preference, as can be applied in a liquid state and afterward hardens or dries upon the surface of the particles. There are many insulating substances that will answer this purpose—such, for example, as shellac, varnish, or other solutions of gummy matters in volatile solvents. We prefer, however, the employment of paraffine or other similar waxy material by reason of the superior facility with which the insulation may be effected by its use. It is only necessary to dip a mass of the iron filings or particles in a bath of melted paraffine and then to drain them. Upon the cooling of the paraffine a very thin film will be found around each of the particles of iron, in most cases perfectly covering and inclosing it. Some little irregularity in the application of the coating—such, for example, as the failure of the paraffine to cover one side or portion of a particle—is of slight consequence, since in the massing together of the paraffined particles to form the magnetic envelope it will usually happen that any such uninsulated portion of one particle will come against an insulated portion of the next; but even if two uninsulated portions happen to come into contact the result is merely the same as though a single larger particle had been employed instead of the two, the precise minuteness of the subdivision of the iron being merely a matter of degree and not material.

The iron filings or particles may be applied in various ways around the conductors in order to form the magnetic envelope. For example, the conductors may be placed in some suitable receptacle, and the iron filings may be poured thereinto or packed therein in such manner as to surround the conductor or group of conductors on all sides, or the insulated iron filings may be made into a paste with some suitable plastic material as a binding agent, and the paste or dough thus made may be molded around the conductors or groups of conductors, so that it shall harden into a solid body.

Having thus described the principal distinguishing features of our invention, we will now proceed to describe some of the constructions which we have designed for embodying the same and which are shown in the remaining figures of the accompanying drawings, wherein Fig. 8 includes a cross-section and a dissected side view of a construction of inductive conductors and their inclosing magnetic envelope embodying our invention. Figs. 9, 10, and 11 each include a section and dissected side view, each showing a different construction. Fig. 12 is a cross-section of another construction. Fig. 13 is a cross-section of still another construction. Fig. 14 is a side elevation of a complete inductive battery embodying our entire invention. Fig. 15 is a plan thereof partly broken away to show the internal construction and arrangement. Fig. 16 is a vertical transverse section thereof cut on the line 16 16 in Figs. 14 and 15. Fig. 17 is a fragmentary view, on a larger scale, illustrating the method of connecting or coupling the ends of successive conductors. Fig. 18 is an end view of one of the couplings shown in Fig. 17, and Fig. 19 is an end view of the other coupling. Fig. 20 is a plan of another construction of inductive battery in horizontal section on line 20 20, and Fig. 21 is a transverse section thereof. Fig. 22 is a similar section showing another construction of inductive converter embodying a portion of our invention.

It is to be observed that in all the drawings the primary wires or conductors wherever they appear in section are shaded in solid black and the secondary conductors are shaded with a tint or section shading.

The dotted portions designate the subdivided iron envelope or iron filings.

In all the figures, *a* designates the primary conductor; *b*, the secondary conductor; *c*, the magnetic envelope, and *i i* insulating coatings or wrappings around the conducting-wires.

In Fig. 8 the primary wire *a* is shown as completely surrounded by the secondary conductor *b*, which is in the form of a copper tube. This is a very advantageous construction, since it brings the area of the secondary conductor symmetrically on all sides of the primary and into the densest portion of the field of force that it is possible for the secondary conductor to occupy. The advantage of this symmetrical arrangement may be realized by comparing Fig. 8 with Fig. 6, wherein the secondary conductor is entirely on one side of the primary, so that it is necessary for the field of force to be strained to that side by an eccentric arrangement of the magnetic envelope. The gain in inductive efficiency resulting from the arrangement of the secondary conductor in the very densest portion of the field of force is too obvious to require explanation.

The construction of the conductors here shown may be accomplished in various ways—as, for instance, by drawing the primary wire *a*, with its insulation *i*, through the copper tube *b*, and then, if desired, compacting the copper tube closely around the wire by drawing through a die or passing between grooved rollers. We prefer, however, what we consider the cheaper and more practical method of construction, which consists in forming the secondary conductor of **U** shape in cross-section, placing the insulated primary wire in the hollow or groove, and closing the **U**-shaped bar or strip around the primary wire by passing between grooved rollers or by drawing through successive dies, as may be found most efficient. When thus constructed, the tubular secondary conductor exhibits a slit or joint *d* along one side. It is afterward covered with insulating material *i*. The magnetic envelope *c*, of insulated iron particles, is in this construction of cylindrical form, concentrically inclosing the conductors and covered by an outer wrapping *e*, of any suitable material—as, for example, a braided tube of textile fabric or a wrapping of tape. In the case of a braided covering the iron filings may be filled into the covering as the latter is made in the braiding-machine; or the iron filings may be made into a dough and molded round the conductors, being afterward wrapped with a protective tape.

Fig. 9 shows a construction wherein the secondary conductor *b* is made up of a group of wires arranged around the insulated primary wire and bound together by an outer wrapping of insulation. The conductors thus formed are placed concentrically within a paper tube *e*, and the intervening space is filled with the insulated iron filings.

Fig. 10 shows a transposed arrangement of conductors, the secondary conductor *b* being arranged within a number of primary conductors *a a*. The secondary conductor is made up of several wires, which may be in contact with one another or insulated from one another, as preferred. If they are insulated from one another, they may be coupled either in series or multiple arc, or they may be arranged in different secondary circuits. We have shown six primary wires *a a*, each wrapped with a separate insulation and arranged equidistantly around the secondary wires. All the wires are bound firmly together by a wrapping *f*, of fine wire or of thread. A wrapping of iron wire may be used with advantage; but in such case its convolutions should be out of contact with one another. The magnetic envelope *c* is made into a paste and molded around the group of wires, being given a hexagonal form.

We do not recommend the arrangment of the secondary conductor within the primary, as we believe this arrangement to be less efficient than that first described.

Fig. 10 may also be regarded as an illustration of a construction that may be used in case primary currents of great density but low potential are used to induce secondary currents of high potential but slight density, in which case the inner-course wires will carry the primary current and the outer fine wires the secondary current.

Fig. 11 shows a construction wherein a central primary wire *a* is inclosed in a tubular secondary conductor *b*, as in Fig. 8, and these are surrounded by a magnetic envelope *c* of insulated-iron particles, the whole being inclosed in an iron tube *g*. This iron tube may form a portion of the magnetic envelope, in such case serving to collect any lines of magnetic force that may pass outside of the envelope *c* of subdivided iron. We prefer, however, not to employ an outer tube of magnetic material, except in case the envelope *c* be made thick enough to collect within itself substantially all of the lines of force, as otherwise there will be a waste due to the generation of Foucault currents in the outer tube.

Fig. 12 shows a construction of the primary and secondary conductors, which is a modification of that shown in Fig. 10. The secondary conductor *b* is star-shaped in cross-section or formed with deep longitudinal grooves, and the primary wires *a a*, each being separately insulated, are laid into these grooves. The secondary conductor need not be insulated except by a winding around the whole, which is applied after the primary wires are in place.

Fig. 13 is a transverse section of a construction wherein four groups of conductors are all inclosed within a single magnetic envelope, being so far separated from one another that the lines of force circling around each group shall find free passage within the magnetic envelope without being brought so close to one another as to suffer loss by mutual induction. In the precise construction shown each group consists of three primary wires and six secondary wires, either or both of which may be coupled in multiple arc or series, or according to any intermediate arrangement. The magnetic envelope consists of insulated iron particles deposited in a suitable box or outer casing, in which they are packed closely around the groups of conductors.

We will now proceed to describe how we construct what we term an "inductive battery," or a collection of inductive conductors or groups thereof connected together according to whatever electrical arrangement may be desired. Figs. 14 to 19 illustrate the preferred construction of such a battery. It consists, in general, of a box B, in which the compound conductors or inductive elements A A are placed, suitably separated from one another and with the intervening spaces filled with insulated iron particles to form a magnetic envelope. The box B consists of a bottom board or base C, a top board or cover D, and an intervening frame E, consisting of the sides and end pieces of the box. The three parts C, D, and E are separable from one another, and may be provided with any suitable means of securing them together—such, for example, as screws in the top and bottom boards screwing into the frame E. Coinciding holes are bored through the opposite sides of the frame E at suitable regular intervals, and in these holes are placed the inductive elements A A, the opposite ends of which protrude slightly from the opposite sides of the frame, as shown in Fig. 16. Each of the inductive elements A A consists of a primary conductor *a*, its insulation *i*, and a tubular secondary conductor *b* around the primary, with an insulation *i* around it. The construction is thus the same as in Fig. 8, except that the magnetic envelope is omitted. There may be two or more primary conductors; but for simplicity we have shown but one, and the secondary conductor may be composed of a group of wires, as shown in Fig. 9, for example, or in Fig. 13; but as this would entail some complication in the terminal connections or couplings we prefer to make the secondary as a simple tube. This construction has also the advantage that it brings the greatest area of the secondary conductor into the densest portion of the magnetic field. Each of the elements A is made with its secondary conductor protruding somewhat beyond the outer sides of the frame E, and this protruding portion is bared of insulation, in order that it may make metallic contact with a coupling F, (shown best in Figs. 17 and 18,) which consists of two yokes or pieces *h h*, which engage the ends of the secondary conductor on opposite sides and are drawn together by a screw *i*. In this manner the secondary conductors of two successive elements are joined together in series. The ends of the primary conductors protrude beyond the ends of the secondary conductors, are bared of insulation, and are coupled together in pairs by couplings or yokes G G, as best shown in Figs. 17 and 19. Thus the primary conductors are joined, also, in series. Either primaries or secondaries, however, may be coupled in multiple or according to any desired electrical arrangement. We propose to so proportion the inductive elements A A that when used with a primary current of given electro-motive force each one shall develop at the opposite terminals of its secondary conductor a certain standard difference of potential which shall be easily computed—such, for example, as one or two volts. Assuming that one-volt elements are used and that it is desired to construct a battery which shall develop a potential in its secondary of, say, sixty volts, it is obviously only necessary to combine sixty elements connecting their secondaries together in series. In the battery shown in Figs. 14, 15, and 16 we have illustrated four horizontal tiers of elements with fifteen elements in each tier. If a higher potential is desired, more tiers may be added or a greater number of elements may be arranged in each tier. The battery is put together by inserting the elements A A through the holes in the frame E and then applying the couplings F and G, the former of which, by coming close against the sides of the frame, prevent any longitudinal displacement of the elements, then placing the frame E on the bottom board C and filling it with the insulated iron filings up to a level with the top of the frame, after which the cover D is fastened on. The opposite terminals of the primary conductors are carried to binding-posts *m m* and those of the secondary conductors to binding-posts *n n*. The former binding-posts are connected by leading-in wires to the positive and negative wires of the line-circuit, and the latter binding-posts are connected to the respective leads of the local or consumption circuit, all as indicated in the diagrams forming part of Figs. 14 and 15.

Figs. 20 and 21 show a different construction of battery. A circular box B is employed in which are arranged four (more or less) inductive elements coiled spirally and having their opposite ends led out to opposite sides of the box into position for coupling together. Each spiral occupies a flat or horizontal plane and the adjacent convolutions of each spiral and the respective spirals are spaced far enough apart to avoid mutual induction, the intervening space being filled with the insulated iron filings to form a magnetic envelope. The proportions will be such as to suit the work to be done. For example, if a secondary current having a potential of eighty volts is desired, the battery may be made of four spiral elements, each of which, with a primary current of standard potential, will generate a secondary potential of twenty volts.

Fig. 22 illustrates a construction of converter which embodies a portion of our invention. The primary and secondary wires are all wound in one coil without any intervening magnetic material, and the coil thus formed is laid in a box B and surrounded on all sides by a magnetic envelope of insulated iron particles such as our invention provides. This construction departs from that portion of our invention whereby we avoid the loss due to mutual induction of the primary current by surrounding each primary wire or group of wires with a magnetic envelope for the lines of force.

The construction of the inductive conductors or elements with the secondary in the form of a tube inclosing the primary is claimed in another application which we have executed, and we therefore make no claim to such construction in this specification except in combination with an exterior magnetic envelope.

What we claim as our invention, and desire to secure by Letters Patent, is, in inductoriums or electric converters, the following-defined novel features or combinations, namely:

1. In an inductorium, the combination, with the primary and secondary conductors, of a magnetic envelope surrounding or inclosing them and consisting of iron particles insulated from one another.

2. In an inductorium, the combination, with the primary and secondary conductors, of a magnetic envelope surrounding them, consisting of iron filings separated from one another by insulating material.

3. In an inductorium, the combination, with the primary and secondary conductors, of a magnetic envelope surrounding them, consisting of particles of iron coated with insulating material and massed together.

4. In an inductorium, the combination, with the primary and secondary conductors, of a magnetic envelope surrounding them, consisting of particles of iron coated with paraffine and massed together.

5. The combination of a primary conductor, a secondary conductor laid parallel therewith, and a magnetic envelope consisting of insulated iron particles formed to inclose said conductors.

6. The combination of a primary conductor, a secondary conductor inclosing the primary, a winding around said secondary conductor, and a magnetic envelope inclosing the same and consisting of insulated iron particles.

7. The combination of a primary and secondary conductor laid parallel, a magnetic envelope consisting of insulated iron particles formed to inclose said conductors, and an exterior covering for said envelope.

8. In an inductorium, two or more primary conductors or convolutions thereof arranged at a little distance from one another, in combination with secondary conductors or convolutions arranged in close proximity to the respective primaries and a filling between and around said conductors, consisting of insulated iron particles.

9. The combination of an inclosing box, a filling of insulated iron particles therein, and a series of inductive conductors or convolutions thereof arranged within said box at a little distance from one another and surrounded by the magnetic filling, whereby the latter forms a closed magnetic circuit around each inductive conductor or convolution thereof.

10. An inductive battery consisting of the combination of a number of inductive elements, each consisting of a primary and secondary conductor arranged in close proximity to one another and the several elements disposed at a little distance apart, with a box in which said elements are placed, a filling of insulated iron particles in said box between and around the respective elements, and electrical connections between the respective conductors at the opposite ends of the elements.

11. An inductive battery consisting of the combination of a box formed with holes in its opposite sides, a number of inductive elements, each consisting of a primary and secondary conductor arranged in close proximity to one another and the several elements arranged in said box with their opposite ends

projecting through the holes therein, electrical connections between the respective conductors at the opposite protruding ends of the elements, and a filling of insulated iron particles in said box between and around the respective elements.

12. An inductive battery consisting of the combination of a box formed with holes in its opposite sides, a number of inductive elements, each consisting of a tubular secondary conductor and a primary conductor inclosed thereby, with its opposite ends protruding beyond the ends thereof, the several elements arranged in said box with their opposite ends projecting through the holes therein, electrical conducting-couplings between the projecting ends of successive secondary conductors, electrical conducting-couplings between the protruding ends of successive primary conductors, and a filling of insulated iron particles in said box between and around the respective elements.

In witness whereof we have hereunto signed our names each in the presence of two subscribing witnesses.

GUSTAV PFANNKUCHE.
ALFRED PFANNKUCHE.

Witnesses to the signature of Gustav Pfannkuche:

ARTHUR C. FRASER,
GEORGE H. FRASER.

Witnesses to the signature of Alfred Pfannkuche:

FREDK. SEIGER,
C. M. WALES.