H. K. McINTYRE.
ELECTRICAL CONDUCTOR.
APPLICATION FILED MAR. 27, 1906.

1,008,423. Patented Nov. 14, 1911.

8 SHEETS—SHEET 1.

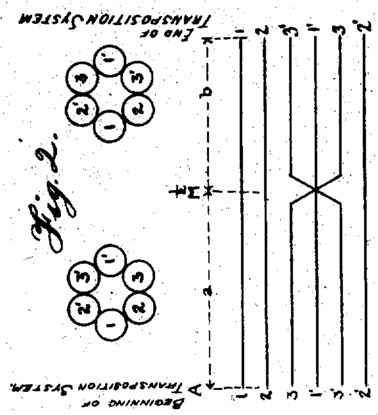


Fig. 2.

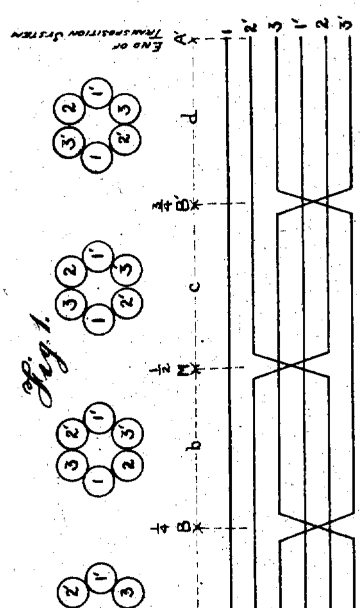


Fig. 1.

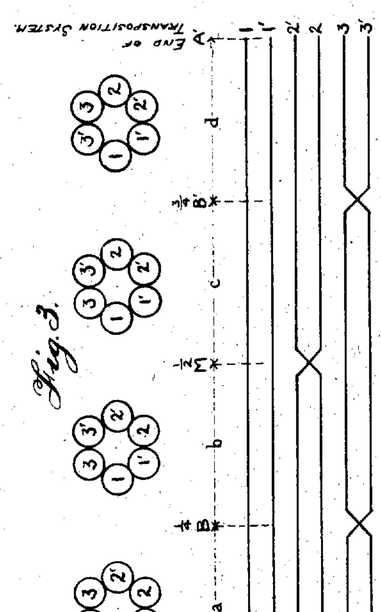


Fig. 3.

WITNESSES:
George L. Pafort
Harry H. Walton.

INVENTOR
Henry K. McIntyre
BY
Alexander P. Proudfit ATTORNEY

H. K. McINTYRE.

ELECTRICAL CONDUCTOR.

APPLICATION FILED MAR. 27, 1906.

1,008,423.

Patented Nov. 14, 1911.

3 SHEETS—SHEET 2.

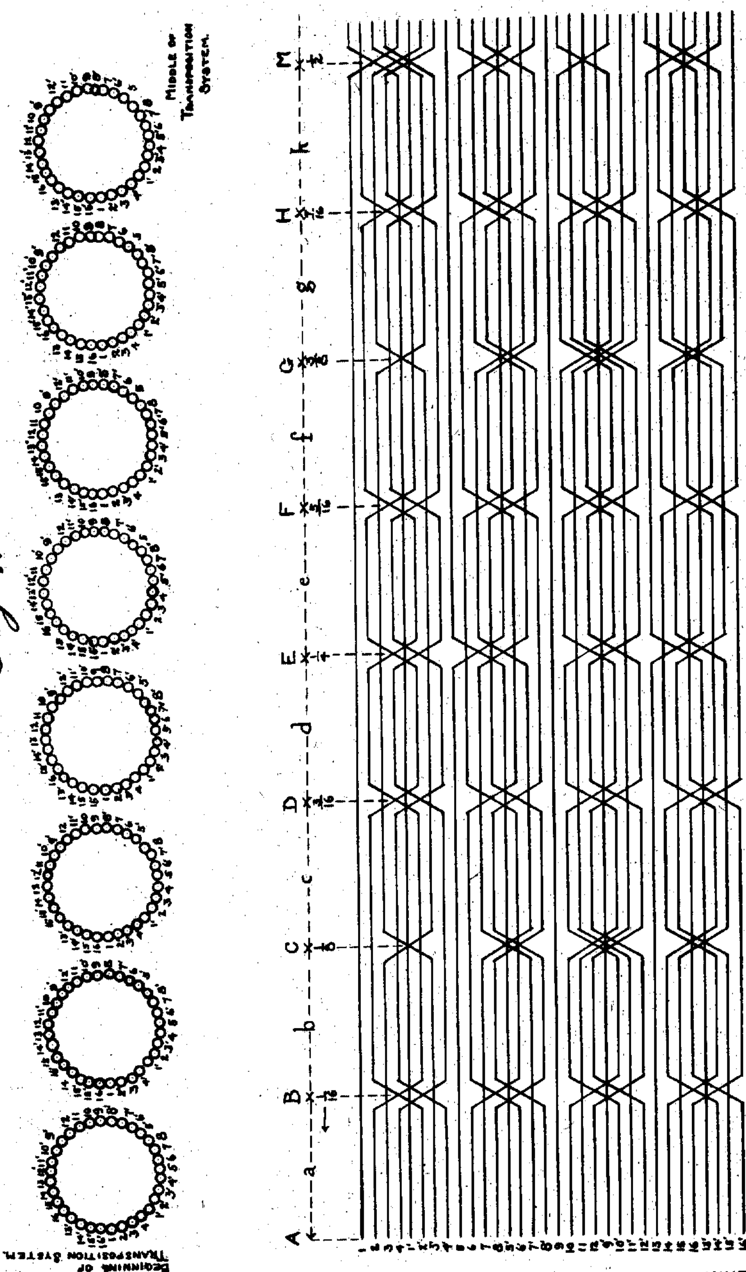


Fig. 4.

WITNESSES:

George L. Pafort

Harry H. Walton

INVENTOR

Henry K. McIntyre

BY

Alexander C. Proudfit ATTORNEY

H. K. McINTYRE.

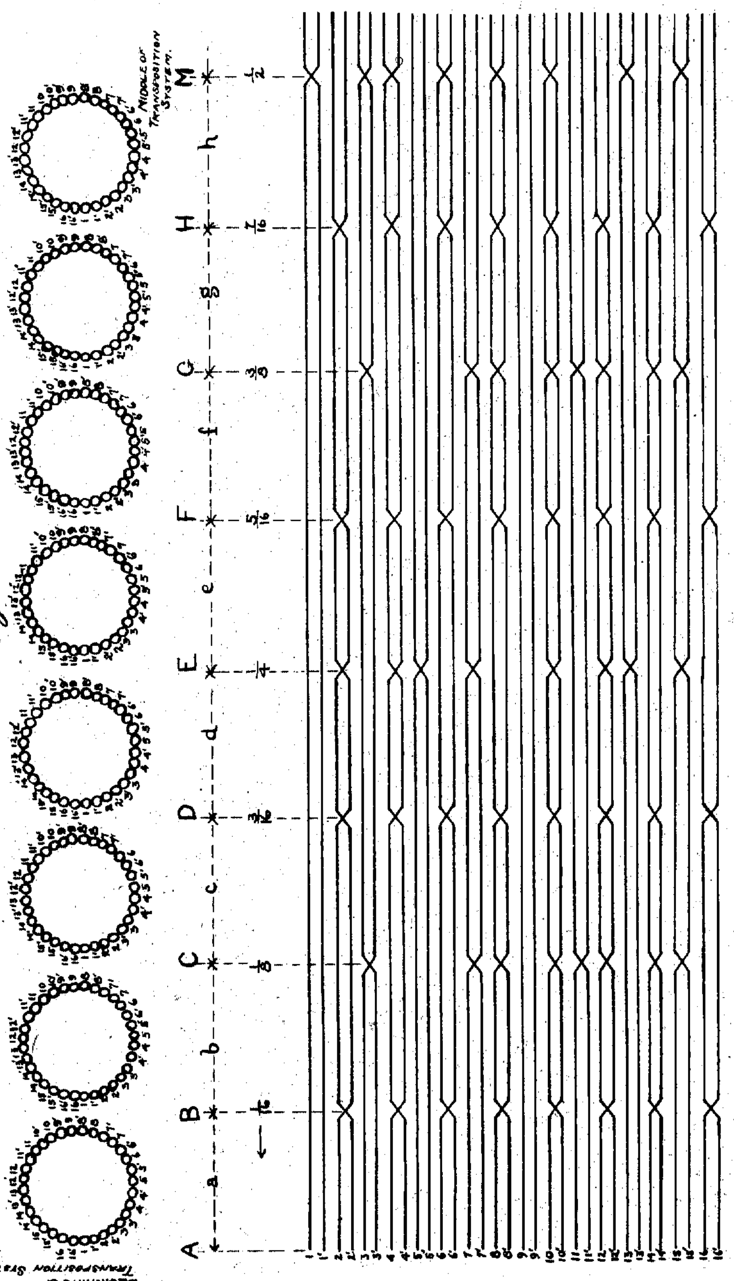
ELECTRICAL CONDUCTOR.

APPLICATION FILED MAR. 27, 1906.

1,008,423. Patented Nov. 14, 1911.

8 SHEETS—SHEET 3.

Fig. 5.



WITNESSES:

George L. Pafort

Harry H. Walton

Henry K. McIntyre INVENTOR

BY

Alexander C. Proudfit, ATTORNEY

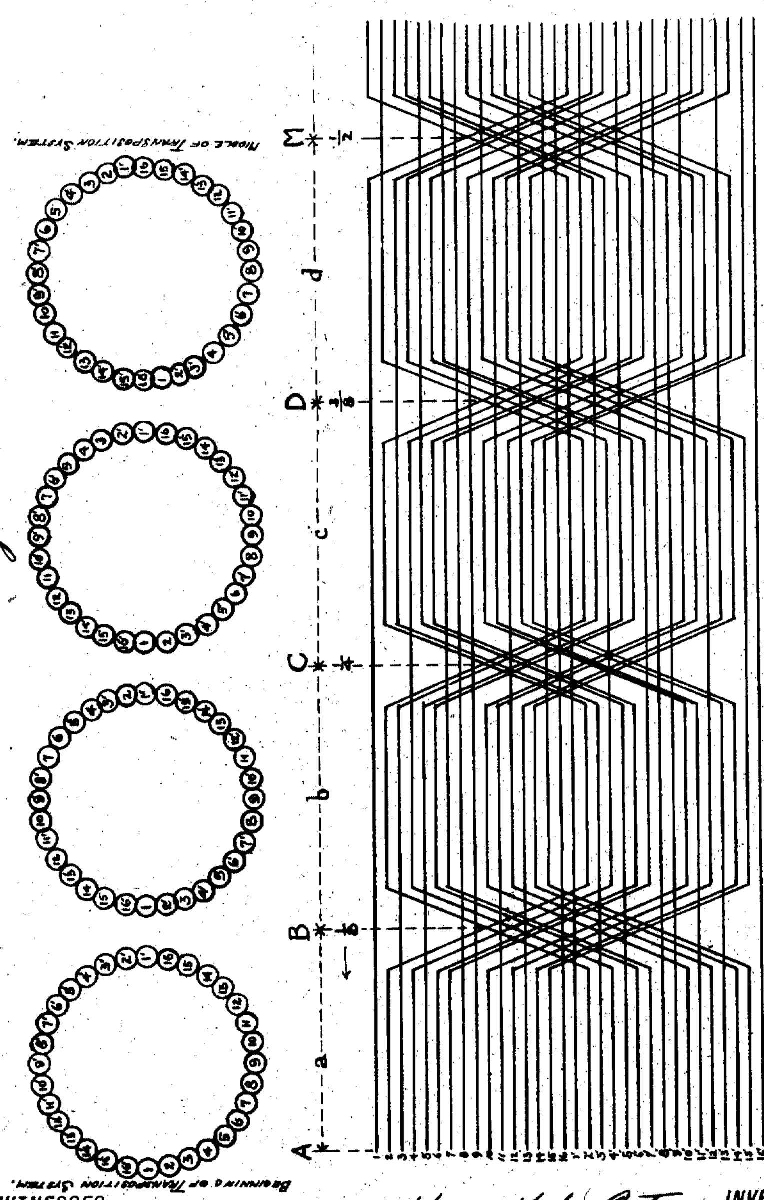
H. K. McINTYRE.
ELECTRICAL CONDUCTOR.
APPLICATION FILED MAR. 27, 1906.

1,008,423.

Patented Nov. 14, 1911.

8 SHEETS—SHEET 4.

Fig. 6.



WITNESSES:
George L. Pafort
Harry H. Walton

Henry K. McIntyre INVENTOR

BY

Alexander C. Proudfit, ATTORNEY

H. K. McINTYRE.

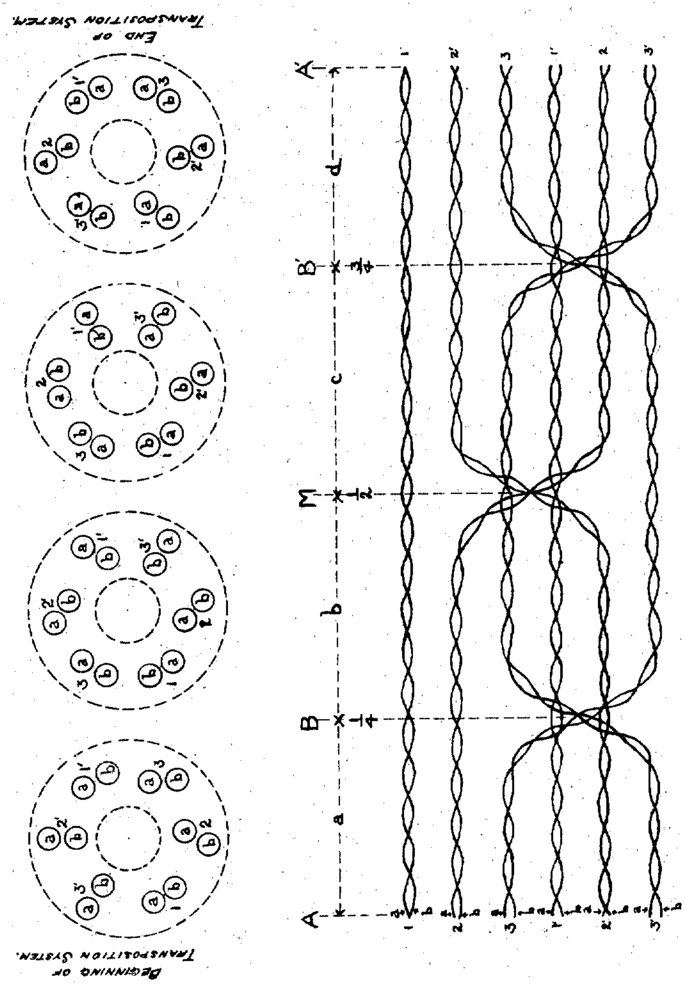
ELECTRICAL CONDUCTOR.

APPLICATION FILED MAR. 27, 1906.

1,008,423. Patented Nov. 14, 1911.

8 SHEETS—SHEET 5.

Fig. 7.



WITNESSES:

George L. Pafort

Harry H. Walton.

Henry K. McIntyre INVENTOR

BY

Alexander C. Proudfit, ATTORNEY

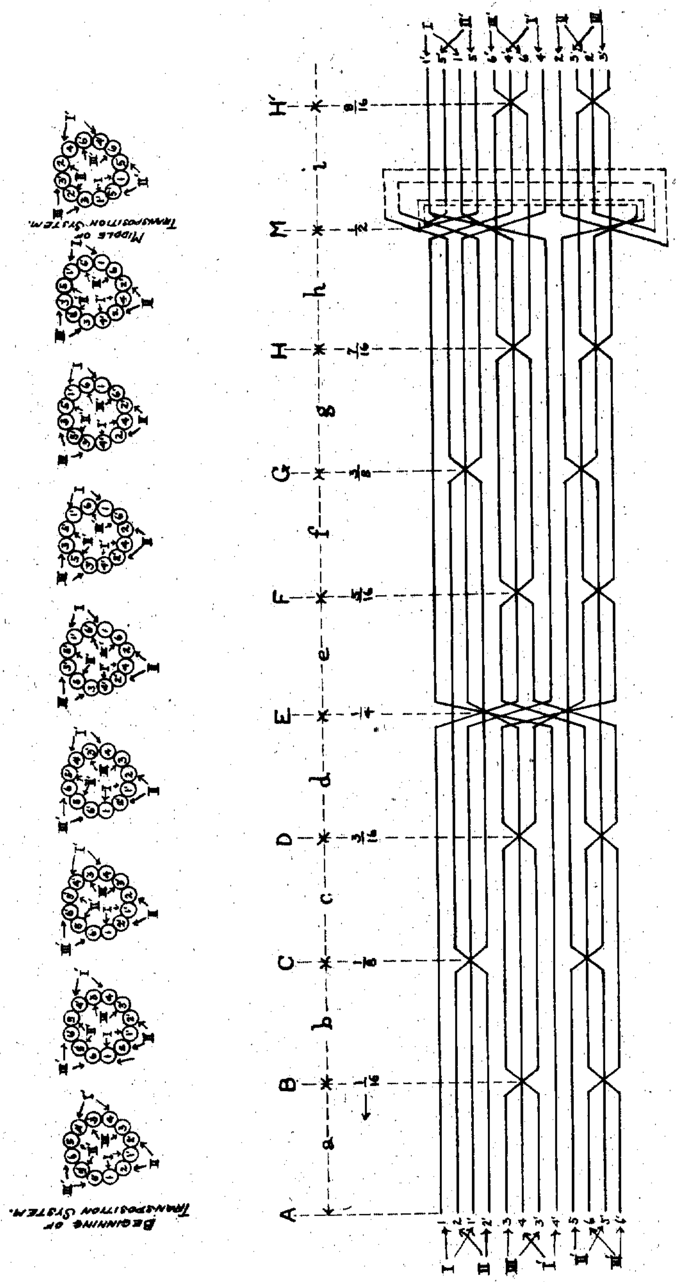


Fig. 8.

WITNESSES:
George L. Pafort
Harry H. Walton

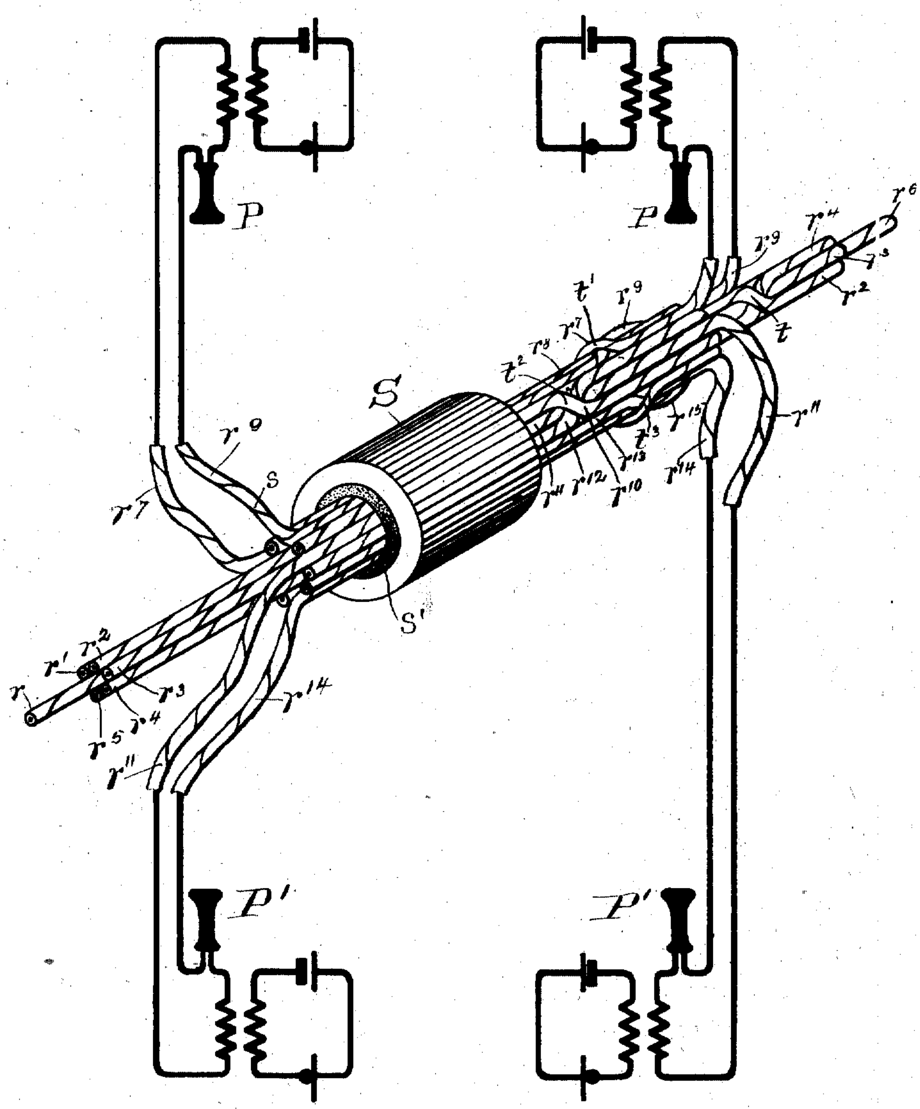
Henry K. McIntyre INVENTOR
BY
Alexander C. Proudfit, ATTORNEY

H. K. McINTYRE.
ELECTRICAL CONDUCTOR.
APPLICATION FILED MAR. 27, 1906.

1,008,423. Patented Nov. 14, 1911.

8 SHEETS—SHEET 7.

Fig. 9.



WITNESSES:
Alex Scott
Francis S. Allen

Henry K. McIntyre INVENTOR.
BY
Alexander C. Proudfit
ATTORNEY.

H. K. McINTYRE.
ELECTRICAL CONDUCTOR.
APPLICATION FILED MAR. 27, 1906.

1,008,423.

Patented Nov. 14, 1911.

8 SHEETS—SHEET 8.

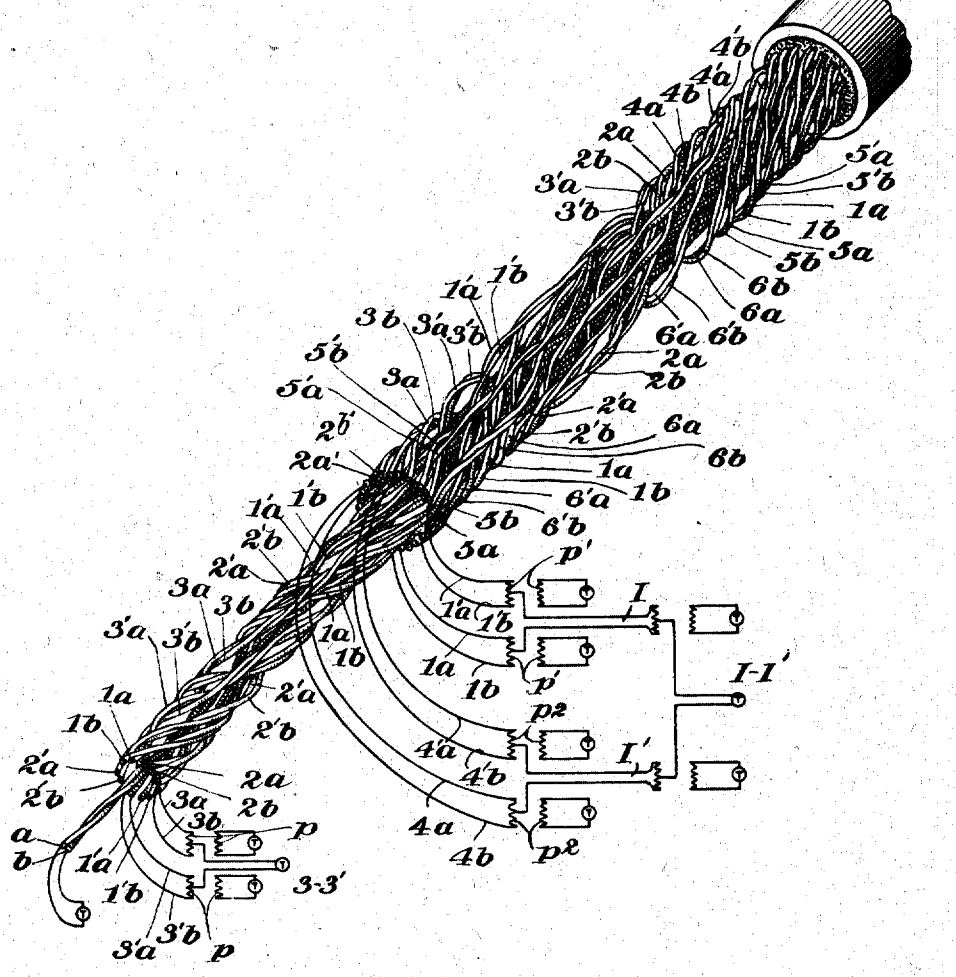


Fig. 10.

Witnesses:
D. W. Edelin.
C. K. Bergmann

Inventor:
Henry K. Mc Intyre
by his attorney
Alexander C. Proudfit.

UNITED STATES PATENT OFFICE.

HENRY K. McINTYRE, OF NEW YORK, N. Y.

ELECTRICAL CONDUCTOR.

1,008,423. Specification of Letters Patent. Patented Nov. 14, 1911.

Application filed March 27, 1906. Serial No. 308,285

To all whom it may concern:

Be it known that I, HENRY K. McINTYRE, of New York, N. Y., have invented certain Improvements in Electrical Conductors, of which the following description, in connection with the accompanying drawings, is a specification, like letters on the drawings designating like parts.

This invention relates to electrical conductors and is particularly applicable to polycircuit cables for telephone and similar installations, although I contemplate its utilization in any field to which my improvements may be adapted by their nature.

Briefly stated, the primary purpose of my invention is to provide a polycircuit cable in which the conductors forming a pair or circuit are not twisted in the usual manner, (except in cases where one or more conductors of a twisted pair may form part of a "phantom" circuit or circuits) but are laid up in such a manner that the mate conductors are at a greater distance from one another than if they were so twisted, thereby improving transmission, as will be hereinafter fully explained; at the same time I transpose the conductors in such a manner that inductive disturbances, known in telephonic parlance as "cross-talk", and analogous undesirable disturbances, are avoided.

The twist of mate conductors is ordinarily employed to secure equal and countervailing exposure of each to inductive influences, but by increasing the separation of the conductors forming pairs, I reduce the electro-static capacity and increase the inductance of the mate conductors, relatively to each other. Decrease in capacity and, within certain limits, increase of mutual induction, are beneficial to transmission. As peripheral area is also a factor in static capacity, this unfavorable influence is lessened by anything which enables the use of conductors of smaller size. By increasing the separation of mate conductors therefore, I improve the transmission without increasing the size of conductors employed; or, I obtain the same efficiency in transmission with a smaller conductor, and thereby effect very considerable economy in copper, especially in the long distance cables now being laid down in place of open wire pole lines. As previously mentioned, the cross-talk which would result from the conductors not being twisted, is prevented by the transpositions, examples of which are subsequently described.

The principle of my invention may be applied to so-called "phantom" or "duplex" circuits, by simply regarding the single mate conductors of a cable constructed in accordance with my invention, shown in the drawings, and hereinafter described, as each comprising a twisted pair of conductors, instead of a single conductor, and forming the mate pairs or opposite sides of phantom circuits.

In the foregoing discussion I have described the underlying principles of my invention. In applying these principles it is obviously desirable that the labor of making the transpositions should be as small as possible. This condition can be greatly aided by laying up the conductors of the cable in helical layers. Neighboring layers should preferably be given a different length of lay, while layers which are adjacent should preferably be laid up in reverse directions. In this way inductive disturbances between pairs in different layers is avoided. Inductive disturbances between pairs in the same layer may be prevented by transposing the pairs in the same layer at intervals, as will be fully described in connection with the accompanying drawings. Since the method of laying up the conductors helically in layers presents the least difficulty in practically transposing them, I have adopted this method of transposition in certain of the drawings which are referred to in this specification, although I do not limit myself to the helical lay.

The various features of my invention will be illustrated and described fully in the accompanying drawings and specification and pointed out in the claims.

In the drawings, Figure 1 illustrates diagrammatically a layer containing three pairs of conductors, in which the mate-conductors are separated by two other conductors; Fig. 2 is a similar diagram illustrating the principles applied to a layer containing three pairs, in which the conductors are so arranged that fewer transpositions are required, than would be required by the system of Fig. 1; Fig. 3 illustrates the principle applied to a layer containing three pairs, in which the mate-conductors are adjacent; Fig. 4 represents a layer containing sixteen pairs, and is analogous to Fig. 1, except that the mate-conductors, instead of being separated by two other conductors, are separated by three other conductors; Fig. 5 represents a layer containing sixteen pairs, and is analogous to Fig. 3, in which the mate-conductors are adjacent; Fig. 6 shows a layer containing sixteen pairs in which all of the mate-conductors are diametrically opposite. Fig. 7 shows a layer comprising six pairs twisted in the usual manner, the pairs being so arranged that three phantom circuits are obtained; Fig. 8 shows a layer containing twelve conductors, from which are obtained six single pairs and three phantom pairs. Fig. 9 shows in perspective part of a cable constructed in accordance with my invention, and comprising a core wire and two layers of conductors, paired to form 9 metallic circuits, transposed to eliminate cross-talk from the cable. Fig. 10 illustrates in perspective a cable, constructed in accordance with my invention, comprising two helical layers, of six and twelve twisted pairs of conductors respectively, paired to form 18 metallic circuits, 9 phantom circuits and 3 second derived phantom circuits, the pairs being transposed in accordance with my invention following the diagrams in Figs. 2 and 8, to eliminate cross-talk from the cable. In the upper portion of Figs. 1 to 8 inclusive are shown diagrammatic cross sections of the table between each transposition, while the lower portion in each figure shows the transpositions in development, or the relative position of conductors respectively before and after each transposition. In each of the diagrams, the mate conductors, or mate pairs, in the case of phantom circuits, are designated by the same number, for example the mate conductors of pair 1, Fig. 1, are 1 and 1′; similarly the mate pairs of phantom circuit I are I and I′.

In the preferred embodiments of my invention selected for illustration and description herein, the lengths *a*, *b*, *c*, &c, are indicated as equal or as nearly so as possible, and each of the conductors, 1, 1′, 2, 2′, is shown laid up at equal distances, but while in most cases it will be found most convenient and practicable to follow this practice I do not limit myself thereto.

In the drawings I have endeavored to give conductors which are closest to one another the most frequent transpositions. It is probable that in practice the more neighboring pairs may be advantageously transposed more frequently and the more distant pairs less frequently relatively to one another than I have indicated.

In each of the diagrams I have shown a complete or partially complete transposition system for the layer under consideration. The method of applying the transposition may be any of those subsequently described under *a*, *b* or *c*, that is, the transposition system shown in each diagram may extend over a fraction of a cable section, a whole or several cable sections.

It is understood that throughout the drawings the ends of mates are joined in any suitable fashion, to form a metallic circuit for each pair of mates, including telephonic or any other desired and suitable apparatus, as in Fig. 9, this applying also to the phantom circuits.

In accordance with my invention, with reference to Figs. 1–6, and 9 and 10 the mate-conductors 1 and 1′, 2 and 2′, 3 and 3′, are laid up singly in layers, the lay of adjacent layers being preferably helical in reverse directions as indicated in Fig. 10, to be hereafter described, but no twisted except in the case of phantoms, and neighboring layers being given such different lengths of lay as experience may indicate; the lengths of lay may conveniently be in the neighborhood of three feet.

Examples of how mate-conductors in a layer containing three single pairs may be given equal exposure to one another are shown in Figs. 1, 2 and 3. In Fig. 1, the mate-conductors are separated by two other conductors. The mate conductors of pair 3 are interchanged at the quarter points B and B′, and the mate-conductors of pair 2 are interchanged at the middle point M only. The conductors of pair 1 are not interchanged. An examination of Fig. 1 will make it clear that if the conductors in the cable are carefully and symmetrically laid up there will be no cross-talk between pairs 1, 2 and 3, because they have an equal electrical exposure to one another; nor will there be any cross-talk between pairs in different layers similarly transposed, owing to the helical lay, and their resultant equal exposure to one another. In Fig. 2 the mate-conductors of pair 1 are at any section, at the extremities of the diameter of a circle and the mate-conductors of pairs 2 and 3 are at the extremities of chords of the same circle, perpendicular to the diameter. The exposure of either conductors of pair 1 to both conductors of pair 2, and to both conductors of pair 3 is the same. There will therefore be no cross-talk or other inductive disturbances between pair 1 and pairs 2 or 3; pair 3 is transposed at the middle point M to prevent cross-talk with pair 2. It is seen that by selecting mate-conductors in this way there is a saving in the number of transpositions and transposition points, and at the same time the pairs are all balanced with respect to one another. In Fig. 3 the mate-conductors are adjacent, otherwise the scheme of tranposition is exactly similar to that of Fig. 1, and the same explanation applies.

For the purpose of showing how transpositions in a layer containing a considerable number of conductors may be made without introducing an impracticable number of transpositions, I have shown three examples (Figs. 4, 5 and 6), of how conductors in a layer containing sixteen pairs may be transposed. In each of these figures the transposition illustrated between A and M is one-half a complete actual transposition, the remainder of the transposition being symmetrical with the part A—M. The relative position of the mate-conductors of Fig. 4 is analogous to the position of the mate-conductors in Fig. 1, except that the mate-conductors are separated by three other conductors instead of two. An examination of Fig. 4 will show that all the conductors there shown are transposed with respect to one another. Fig. 5, in which the mate conductors are adjacent, is analogous to Fig. 3. The system of transposition is the same as that used in Fig. 4. I have shown no exact parallel of Fig. 2, for a layer containing sixteen pairs. If mate conductors are chosen at the extremities of chords perpendicular to a common diameter, mate-conductors at the extremities of the diameter need not be transposed with respect to conductors located at the extremities of the same chord; and if several such groups are made, a substantial saving in transposition will result over the number required by the systems of Figs. 4 and 5. Fig. 6 illustrates how transpositions may be saved by selecting the mate-conductors diametrically opposite to one another. If this is done pairs whose mate-conductors are at the extremities of diagonals of the same square need not be transposed with respect to one another since they are already balanced. Such pairs may therefore be transposed at the same points, which reduces the transpositions and transposition points to about a half the number shown in the system of Figs. 4 and 5. A further examination of Fig. 6 will show that if the cable is carefully and symmetrically laid up there will be no cross-talk between any of the pairs of Fig. 6.

In Fig. 7 I have shown diagrammatically a layer containing six pairs twisted together in the usual manner similarly to that illustrated in Fig. 10, preferably laid up helically to prevent cross-talk or other inductive disturbances between phantom pairs in different layers similarly transposed. The pairs are so arranged that three "phantom"-circuits are obtained from them, which are transposed to meet the requirements already explained for preventing inductive disturbances between circuits intended for this class of service. Single pair 1, Fig. 7, is composed of two conductors *a* and *b*, twisted together. Single pair 1′ is composed similarly of two other twisted conductors, *a* and *b*. The remaining phantom pairs 2—2′, 3—3′, etc., are similarly each composed of two twisted conductors *a* and *b*. It is seen that the phantom pairs 1, 2 and 3 are transposed with respect to one another, while the twist of the original pairs prevents inductive disturbances both between the original pairs and between the original and derived pairs. Furthermore the mutual capacity of the derived pairs 1, 2 and 3 will be materially less and the induction will be materially greater than if the two pairs forming the phantom pair were twisted together. The transmission is therefore improved in the same way as is the case when each side of the circuit is a single conductor.

By considering each of the conductors 1—1′, 2—2′, etc., of Figs. 1 to 6 inclusive, as formed of two conductors twisted together, as *a* and *b* in Fig. 7, to form a pair, the transposition of these diagrams may be extended to phantom circuits as well; also to the second derived phantoms of Fig. 8. In Fig. 8 my method of separating mate-conductors is applied to both phantom and component pairs, with the resulting benefit in transmission to each already pointed out. A layer is shown, containing twelve conductors, preferably laid up helically according to the mode of construction illustrated in Fig. 10, to prevent cross-talk or other inductive disturbances between all the circuits, phantom and single. The phantom pair I—I′ is made up of the two single pairs 1—1′ and 4—4′, and the phantom pairs II—II′ and III—III′ are similarly made up of the single pairs 2—2′ and 5—5′, and 3—3′ and 6—6′ respectively. In this diagram one-half a complete transposition system is shown, from the point A to the point M, the other half being symmetrical thereto. Phantom pair I—I′ is transposed at the quarter points E and E′, and at the middle point M; phantom pair II—II′ is transposed at the middle point M only; and phantom pair III—III′ is transposed at the quarter points E and E′ only. In addition to the phantom circuits being transposed at the points E, M and E′, the component pairs are also transposed at these points, each with respect to its phantom mate. Further transpositions for the purpose of preventing cross-talk or other inductive disturbances between the single circuits themselves and between the single and phantom circuits are shown at the points B, C, D, F, G, H, H′, etc. Six single pairs and three phantom pairs therefore result, which are completely transposed and at the same time the benefits of improved transmission are obtained over the original single circuits as well as over the derived phantom circuits.

In Fig. 9 I have shown in perspective a portion of a section of cable as it may be constructed in accordance with my invention, the conductors being transposed within the section. The conductors may be built up, as shown, in two layers, formed in the instance illustrated of six and twelve conductors respectively, around a single core wire r, insulation of paper or the like s being provided for the several conductors individually, while an outer sheath S of suitable insulating material such as gutta-percha or the like may be furnished, and supplemented by an intervening protective layer s' of paper, felt or cotton to prevent the wires from rubbing against the sheath at the transpositions. The sheath is omitted from the drawing except at the middle, to show the method of transposing the conductors. The single core wire r has no mate, but can be used for a grounded telephone, telegraph or other circuit without inducing disturbances in the pairs in the next layer, if they are properly transposed. Its place may be taken, if desired, by any suitable core or filling. The next layer, shown as having six conductors r', r^2, r^3, r^4, r^5, and r^6 the same size as the middle one, will exactly fit around it, and at the point t (near the extreme right of the sheet) the pair of mated conductors r^2 and r^4 are shown as transposed, their position being thereby reversed with respect to the intermediate conductor r^3, and all the other conductors. In the outermost layer, containing twelve conductors r^7–r^{18} inclusive, (r^{16}, r^{17} and r^{18} not being shown), three transpositions, t', t^2 and t^3 are in view, and there is a fourth transposition t^4, diametrically opposite, and similar to t^2, but not in view, so that no two adjacent conductors continue without transposition, but every fourth conductor, r^8, r^{11}, r^{14}, r^{17} (not shown) continues unaltered in position. It will thus be clear that the pair of conductors mated to form the circuit P, but segregated and untwisted, will by its transposition at t' be freed from cross-talk and like inductive disturbances, with other pairs, as for example the pair P', formed of the conductors r^{11} and r^{14}, whose position continues undisturbed, and this will hold good throughout the cable, all of the space being utilized.

Fig. 10 is a view in perspective of a cable made up in accordance with the above described principles of my invention. The core may consist, as shown, of a single twisted pair a, b, used in the illustration simply as a core about which the layers are laid up. The reference letters T, indicate telephone or similar instruments. The first layer contains six twisted pairs, transposed in accordance with the diagram illustrating the transposition of single conductors shown in Fig. 2, the transposition being applied to the pairs as units. In the following description, the twisted mate wires are in each instance designated by the letters a and b, while the preceding numeral indicates that one of the conductors shown in Fig. 2 to which the twisted pair corresponds; thus, 1^a and 1^b constitute one pair of a phantom; $1'^a$ and $1'^b$, constituting the other component pair of the same phantom circuit; and similarly with 2^a and 2^b, $2'^a$ and $2'^b$, &c. By means of the twist and the transposition, six ordinary twisted pair circuits, and three phantom circuits are derived from the twelve conductors. Phantom coils p, p, and instruments T, T, are shown connected to the twisted pairs respectively as illustrated in the case of two of the pairs, viz., 3^a, 3^b, and $3'^a$, $3'^b$, and it will be understood that the phantom pair 3—3' derived therefrom will be free from cross-talk with the other two phantom pairs (not shown), derived respectively from the pairs 1^a, 1^b, $1'^a$, $1'^b$, and from the pairs 2^a, 2^b, $2'^a$, $2'^b$, as well as free from cross-talk with the twisted pairs; and that the several phantom pairs in addition will have a lower capacity than if the component mate pairs were twisted. The second layer contains 24 conductors, arranged to form twelve twisted pairs, lettered 1^a, 1^b, and $1'^a$, $1'^b$, &c. up to $6'^a$ and $6'^b$ inclusive, the twisted pairs being transposed as units at the middle region of that portion of the second layer which is illustrated and in accordance with the diagram showing the transposition of twelve single conductors of Fig. 8. From the 24 conductors are derived twelve ordinary twisted pairs; six first derived phantom pairs, of which those numbered I and I', are shown connected to telephone instruments T; also three second derived phantom pairs, derived from the six first derived phantom pairs, and of which that numbered I—I' is shown connected. The transposition shown is the middle one of Fig. 8, and with the transposition of Fig. 8 carried throughout the cable, all of the twenty-one circuits will be free from cross-talk with one another, and at the same time the phantom pairs will have the benefit of reduced capacity, obtained by separation, over what the capacity would be, were the two sides of each circuit twisted together.

In considering the embodiment of my invention selected for illustration and description as a convenient form to enable ready and complete understanding of my improvements, summarizing the above discussion, it is to be borne in mind that by my improved method of construction, the static capacity of mate wires in a poly-circuit cable is reduced, and their mutual induction increased, as compared with an ordinarily twisted pair of conductors of the same gage; and each pair presents substantially net equal exposure with respect to external as well as neighboring circuits, thus obviating cross-talk and noise to the extent required by modern practice.

With the conductors laid up according to my invention as already described, (see for example Fig. 1), the mean distance of any conductor in any layer, from either of any two other conductors in any other layer, is the same, except where certain of the helical transpositions may not be completed at the ends; but there will be certain conductors on each layer which are completely transposed with respect to certain conductors on other layers. Accordingly, there will be substantially no cross-talk between pairs in different layers, the unbalance resulting from the non-completion of certain helical transpositions being small in comparison with the entire length of the cable, and the elimination of inductive disturbances between pairs in different layers being further aided by the transpositions, which are primarily for the purpose of taking care of inductive disturbances between pairs in the same layer.

Having described the general principle of transposing pairs in the same layer, it may be applied in any of the several ways described below.

a. Each of the lengths in the drawings may represent a complete cable section, or several cable sections if desired. The transpositions would then be made at the splices. It would of course, be desirable that the conductor wrappings should be differently colored or otherwise marked in order that the splicer might be able to follow the transposition diagram which would be furnished him. It would be of course difficult to arrange that all of the lengths *a*, *b*, *c*, &c., should be the same or of the proper length. In the long run however, the average of these lengths would be approximately the same or of the proper length, which is substantially the case with pole line transpositions.

b. Each section of cable during its manufacture may be divided into equal transposition lengths *a*, *b*, *c*, etc., and the transpositions there applied during the manufacture of the cable. If desired the transposition may be repeated a number of times in each section. If repeated at frequent intervals, the transposition would take the form of a braid, which might be a desirable result.

c. A portion of the transpositions may be made within the cable section, while the remainder may be made at the splices.

What I claim and desire to secure by Letters Patent is:—

1. In a polycircuit cable for telephone and like systems, a plurality of conductors laid in closely adjacent relation and mated to form three or more metallic circuits; said mate conductors being laid up in untwisted relation, and certain of said conductors being segregated to reduce static capacity and to increase induction between said mates, and transposed to avoid cross talk and like inductive disturbances throughout said circuits, substantially as described.

2. In a polycircuit cable for telephone and like systems, a large number of conductors closely arranged throughout said cable, and mated to form three or more metallic circuits, certain conductors in said circuits being transposed relatively to conductors in other circuits, to avoid cross-talk and like inductive disturbances between said circuits and between pairs in each circuit throughout said cable, and the individual mated conductors separated from each other by a distance greater than that between any of said mate conductors and the nearest conductor not its mate; substantially as described.

3. A polycircuit cable for telephone and like systems, comprising a large number of conductors closely arranged in a plurality of series throughout said cable, and mated to form three or more metallic circuits, a conductor in each of said series being transposed relatively to the conductors in the other series, to avoid cross-talk and like inductive disturbances between said series and between pairs in each series throughout said cable, and the individual mated conductors separated from each other by a distance greater than that between one or any of said mate conductors and the nearest conductor not its mate; substantially as described.

4. In a polycircuit cable for telephone and like systems, a plurality of conductors laid in closely adjacent relation and mated to form three or more circuits, mated conductors throughout said cable being separated from each other by a distance greater than that between one or any of said mate conductors and a conductor not its mate, and certain of said conductors being transposed to locate each of three or more pairs on an average midway between another pair, to avoid crosstalk and like inductive disturbances throughout said circuits, substantially as described.

Signed at New York city in the county of New York and State of New York this 20th day of March A. D. 1906.

HENRY K. McINTYRE.

Witnesses:
ROBT. E. J. CORCORAN,
FRANCIS L. PATTON, Jr.