My invention relates to windings for electrical apparatus and more particularly to the type of winding which is subdivided into a plurality of parallel connected strands to reduce eddy currents. If the current in a winding is great enough to require a rather large cross section of winding, the losses from eddy currents will be objectionably high if a single conductor winding is used.

Such a conductor is therefore usually subdivided into a plurality of parallel connected strands which are separately insulated to reduce the eddy currents and the losses which result from them. The strands of the conductor must also be arranged so that the current will divide equally among them and each strand be fully loaded without overloading others. This result may be attained by transposing the strands properly and at suitable intervals so that all strands have substantially the same resistance and reactance. Where the number of strands is only two or three, the problem of satisfactorily transposing them is rather simple but if the number of strands is four or more the problem of providing a simple but effective arrangement of transpositions becomes increasingly difficult. The general object of the present invention is to provide an electrical winding having a conductor of four or more strands with a simple arrangement of transposition of the strands to equalize the resistances and reactances of the several strands so that the current will divide equally among them.

The invention will be better understood from the following description taken in connection with the accompanying drawing in which Fig. 1 shows a winding such as may be used in a transformer, the conductor forming the winding comprising a plurality of transposed parallel connected strands.

Fig. 2 indicates diagrammatically how a conductor of five strands may be transposed in accordance with the invention and Fig. 3 indicates in a similar manner how a conductor of six strands may be transposed.

The invention will be described in connection with the winding 10 shown in Fig. 1 of the drawing, this being a type of winding often used in transformers. This winding 10 comprises a plurality of separately insulated parallel connected strands which are transposed at three points 11, 12 and 13, distributed at substantially equal intervals along the winding. The winding is in the form of a helix and, as is usual in this type of winding, the strands are arranged side by side in a flat layer at right angles to the axis of the helix so that the length of the helix is a minimum. The purpose of the transpositions is to arrange all the strands in such relative positions between the inner and outer edges of the conductor that all the strands will have substantially the same resistance and the same reactance with the result that the current will divide substantially equally among them.

In order to obtain an equal division of the current which is theoretically exact among the strands of the conductor, it is necessary that the conductor be formed with a sufficient number of properly located transpositions to divide the conductor into as many equal sections as there are strands and that the transpositions be so arranged that each strand will occupy every position between the inner and outer edge of the conductor. This means only one less transposition than there are strands and therefore a large number of transpositions if the number of strands is large. Such exact division of the current is not necessary, however, in the stranded winding of transformers, reactors and the like and the present invention provides a satisfactory transposition system in which only three transpositions are necessary for any number of strands above three. With a conductor divided into four strands, this system of transposition complies with the requirements already explained for an exact division of current. With a conductor divided into any reasonable number of strands above four, it may be shown theoretically and it has been shown by careful tests that the division of current is substantially equal and that the variation from an exactly equal division is negligible for all practical purposes.

The principles of the invention are illustrated in Figs. 2 and 3. Fig. 2 indicates a conductor of five parallel connected strands and shows how the invention is applied in the case of an odd number of strands. The conductor is divided into four substantially equal sections by three equally spaced transpositions 11, 12 and 13 which are of two kinds. The strands are numbered from 1
to 5 so that the course of each strand may be followed easily throughout its length when its position changes at a transposition. In the case of any odd number of strands, five in the present instance, one strand is in the center position throughout the length of the conductor, its position between the edges of the conductor not being changed by any of the transpositions. At each of the three transpositions, however, the two groups of strands at opposite sides of the center of the conductor are transposed in position, each group being carried over by the transposition to the opposite side of the center. In one of the two kinds of transpositions which is used, the individual strands of each group are transposed and the relative positions of these strands in the conductor reversed at the same time that the groups themselves are transposed. The center transposition of Fig. 2 is of this kind. In the other kind of transposition which is used, the individual strands of each group are not transposed but keep the same relative positions in the conductor as the two groups are transposed. The outer two transpositions 11 and 13 of Fig. 2 are of this kind.

Fig. 3 indicates a conductor of six parallel connected strands and shows how the invention is applied in the case of an even number of strands. There is, of course, no central strand, all the strands being in what may be considered as two groups at opposite sides of the center of the conductor. These two groups of strands and the individual strands of each group are transposed just as the two side groups and the individual strands of a conductor having an odd number of strands are transposed as has already been explained in connection with Fig. 2. That is, in the center transposition 12 of Fig. 3, the two groups of strands at opposite sides of the center of the conductor are transposed and the individual strands of each group are at the same time transposed so that their relative positions in the conductor are reversed. In the two outer transpositions 11 and 13 of Fig. 3, the two groups of strands are transposed but the individual strands of each group are not transposed but keep the same relative positions in the conductor.

As the invention has been described, the conductor forming the winding is divided into four substantially equal sections by three transpositions of its strands, the center transposition being of one type and the outer two transpositions being alike but of another type. Modifications of the specific arrangement of transpositions which have been described will be obvious, however, without departing from the spirit of the invention as defined in the appended claims. For instance, it will be clear that the lateral distribution of each strand between the edges of the conductor will be unchanged and the result will be the same if each transposition is changed to a transposition of the other type. That is, the central transposition may be formed by transposing the two groups of strands at the opposite sides of the center of the conductor but without relative transposition of the individual strands in each group and the two outer transpositions may be formed by transposing the two side groups of strands and also transposing the individual strands of each group so as to reverse their relative positions in the group. It is also clear that any desired portion of a stranded winding may be independently transposed as in the case, for instance, of a very long winding where it may be desirable to transpose the strands of each half of the winding separately.

What I claim as new and desire to secure by Letters Patent of the United States, is—

1. An electrical apparatus winding comprising a layer of at least four parallel connected strands, said strands being transposed at three points along the winding, two of the transpositions being alike and of one type and the third transposition being of a different type and located between said first two transpositions, one of said types of transposition comprising a transposition of the two groups of strands at opposite sides of the center of the winding and a transposition of the individual strands of each group to reverse their relative positions in the winding, and the other of said types of transposition comprising a transposition of the two groups of strands at opposite sides of the center of the winding with the relative positions of the individual strands of each group unchanged.

2. An electrical apparatus winding comprising a layer of at least four parallel connected strands, said strands being transposed at three points along the winding, the central transposition comprising a transposition of the two groups of strands at opposite sides of the center of the winding and a transposition of the individual strands of each group to reverse their relative positions in the winding, and each of the outer two transpositions comprising a transposition of the two groups of strands at opposite sides of the center of the winding with the relative positions of the individual strands of each group unchanged.

In witness whereof, I have hereunto set my hand this eleventh day of November, 1926.

Konstantin K. Palueff.