

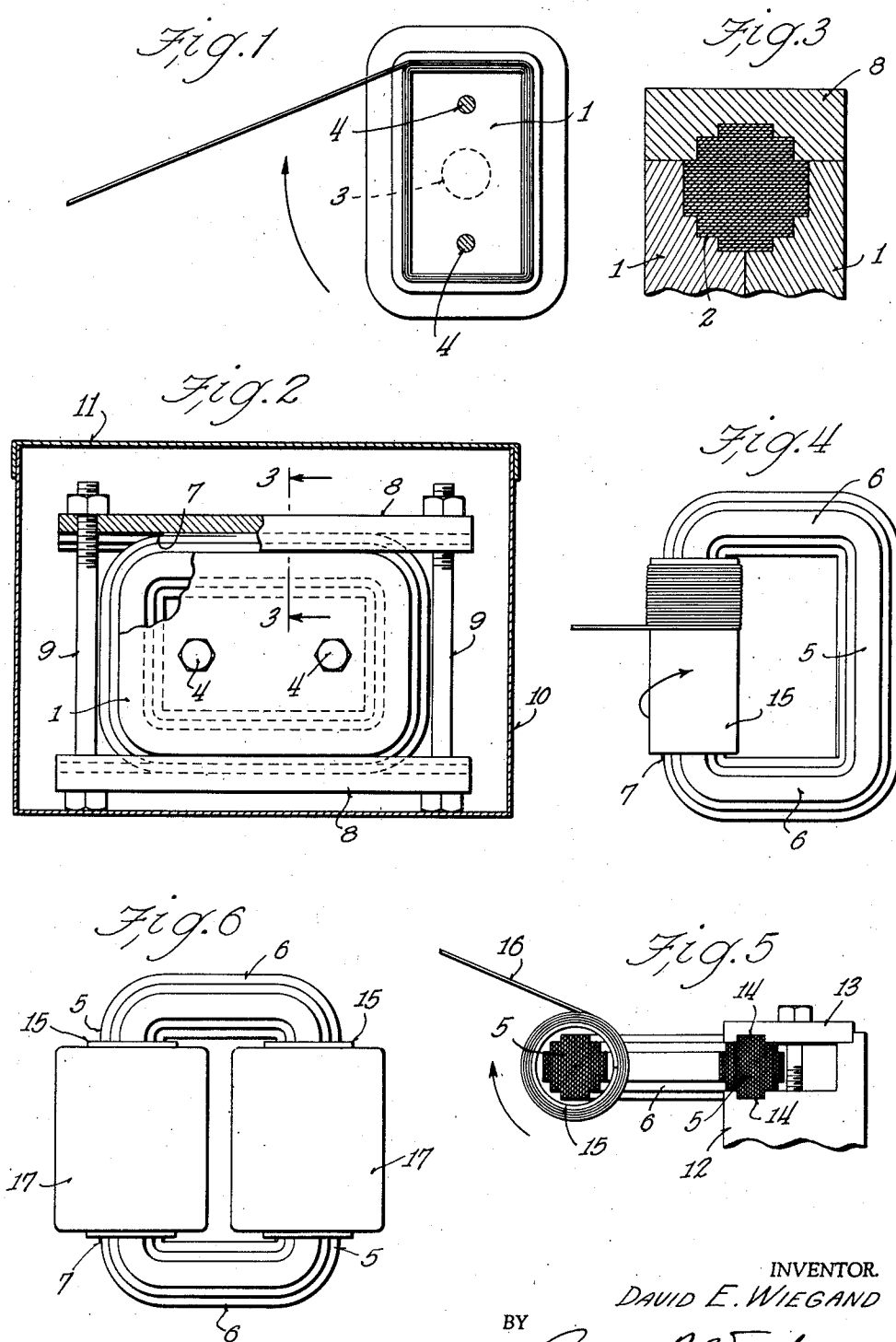
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METHOD OF MAKING TRANSFORMERS

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METHOD OF MAKING TRANSFORMERS

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This invention relates to the method of making a transformer or the like.

Objects of this invention are to provide a novel method of making a transformer or the like whereby the number of steps in the construction or assembly of the transformer is materially reduced and whereby a very simple process results.

In greater detail, objects of this invention are to provide a novel method of making a transformer whereby an elongated magnetic member, such for example as a ribbon or wire or member of other cross-sectional shape, is wound to form a closed core, the elongated magnetic member being formed either of a continuous strip or of a plurality of strips, but in all instances being wound to form a continuous closed core.

The method further contemplates the producing of a transformer having a closed core of wound magnetic material which is unstressed when the coil construction is wound on the core so that there is not any reworking of the core at the time the coil is assembled or formed on the core. This method, therefore, provides for the construction of a transformer in which the finished transformer has an unstressed core, thus materially improving its electrical characteristics.

Further objects are to provide a novel method of winding a coil on a closed core without requiring reworking of the core and without requiring machining of the core, but in which the core is allowed to remain in its finished form prior to and during the forming of the coil on the core so that there are no resultant stresses left in the core in the finished transformer, the core preferably having been annealed after having been formed and prior to the winding of the coil thereon.

Attempts have heretofore been made to produce a transformer with a closed wound core and in these attempts the coil was first wound and completed and thereafter the core was threaded through the coil to form a loosely wound core and thereafter was contracted. Several undesirable results were produced by this method in that the core was stressed by this reworking and consequently the efficiency of the finished transformer was reduced as there was no way in which the stresses, whenever they occurred, could be removed from the core after the transformer had been completed. In addition to this defect, it is apparent that the portion of the core which passed through the coil was curved and consequently required a larger opening in the coil and thus required a greater length of wire for the same number of turns for the coil, thus also reducing the efficiency of the transformer.

In the prior constructions, in order to keep

the stress in the core at a small value, the most accurate workmanship was required and very little or practically no tolerance could be allowed and variation from strict accuracy resulted in a material increase in the stresses remaining in the core. In other words, in the prior construction, the core was wound and annealed, then simultaneously unwound, rewound to a much larger size while it was being passed through the preformed coil, and was subsequently contracted. If the assembled core varied in diameter even a small fraction of an inch from its initial diameter, harmful stresses were set up that materially lowered the efficiency of the completed transformer.

This invention does not require such accuracy in the manufacture of the transformer in order to avoid stress in the finished core as the core of a transformer constructed in accordance with this invention is not reworked at all after annealing.

This invention, therefore, has the further object to provide a method of making a transformer in which, in addition to providing an unstressed finished core in the completed transformer, it also minimizes the amount of wire required for the coil because the opening in the coil does not have to be excessively large to accommodate the core, the core being formed with a straight portion at the point where it passes through the coil, and thus the length of wire required for a coil of a given number of turns and given size of wire is reduced, thus again improving the electrical efficiency of the transformer.

When preformed conductive coils are employed with a ribbon like core of magnetic material threaded therethrough to form the magnetic core, the preformed finished conductive windings are made rectangular with a rectangular window through which the flat, ribbon of magnetic material is threaded. These rectangular shaped windings are not as strong mechanically as circular windings and can, therefore, be more easily damaged by the large stresses that are imposed on the winding when an accidental short circuit occurs. Under these conditions, the stresses are suddenly imposed on the windings and are frequently very severe mechanically.

When insulated wire is wound to form a rectangular coil, the wire has to be sharply bent around the corners and this working of the wire tends to damage it and has a tendency to crack or otherwise injure the insulation. This frequently causes failures and shortens the life of the transformer. This invention, therefore, employs a coil or winding of the strongest shape, namely, circular,—one in which the chances of failure are reduced to a minimum.

A further object of this invention is to provide a method of making a transformer in which reactance is reduced although a wound core is employed. This result is attained by having the straight portion of the structure, not in the winding, but in the core itself. The core and the winding always interlink and if the core is wound on a preformed winding, it is obvious that the core must be circular as it cannot be shaped after assembly without producing prohibitive stresses as it cannot then be annealed.

Where a circular core is employed, the winding will have to be relatively thick, or in other words, will have to have a relatively great depth in comparison to its length. With this invention, however, it is possible to shape the wound core to provide a straight portion and remove the stresses by annealing and thereafter wind a coil or winding on the straight portion. It is possible, therefore, with this invention, to wind the coil on the straight portion in such a manner as to produce a coil or winding that is relatively thin with respect to its length and thus to provide a transformer which has little reactance though a wound core is employed, thus further improving the electrical characteristics.

In this invention, the core is preferably shaped in cross-section by stepping the core, that is to say, by using ribbon like material of different widths so that the core approximates a circle in cross-section. Obviously, other magnetic members of other shapes, such as magnetic wire, could be employed and the core wound to give an approximately circular cross-section. Producing the cross-sectionally shaped core is readily possible with this invention but would be very difficult if the core were wound on a preformed coil.

This invention has for its further object a method of making a transformer, in which a circular coil or winding is employed and in which the straight portion of the structure is the magnetic core which has at least one straight leg or portion passing through the circular conductive winding.

Reference is to be had to the drawing which shows diagrammatically successive steps in the making of the transformer.

In the drawing, Figure 1 shows the first step which consists in winding a ribbon or other shaped elongated magnetic member on a form to produce a closed wound core.

Figure 2 is a sectional view through a box showing the transformer core clamped in position and ready for annealing.

Figure 3 is a sectional view on the line 3-3 of Figure 2.

Figure 4 is a plan view showing the manner in which the coil is wound on the finished core.

Figure 5 is a transverse sectional view showing one way of holding the core while it is being wound.

Figure 6 shows the finished transformer, the mounting brackets, terminal block or other accessories being omitted for the sake of clearness.

Referring to the drawing, it will be seen that the first step in the manufacture of the transformer is the winding of an elongated magnetic member upon a form of the desired shape. This magnetic member may have any desired cross-section. For example, it may be a round wire or an elongated ribbon or may have other shapes. The form on which it is wound may be of any desired contour. Preferably the form is rec-

tangular as shown in Figure 1 so as to provide the elongated side portions for the wound closed core, thus economizing in the required size of opening in the coil which is subsequently formed directly on the finished core.

In Figure 1 the form is indicated by the reference character 1. This form may be of metal and may be made in many different ways, one of which is shown in section in Figure 3 from which it will be seen that in this particular illustration the form is made of two halves which are provided with stepped portions 2 so that ribbon of different widths may be successively wound on the form to provide a cruciform cross-section for the core, as shown most clearly in Figure 3.

The form is carried in any suitable manner by a revolving member 3 by means of which the form is rotated during the winding of the core. The elements composing the form are removably held together by means of bolts 4 or in any other suitable manner. The core takes the shape of the form on which it is wound. By using a rectangular form as illustrated, the core is provided with elongated side portions 5 and end portions 6 so that a substantially rectangular window through the form is provided which is defined by these side portions 5 and end portions 6.

After the core has been wound, the final end or convolution is secured in place in any suitable manner by wiring it down or by welding or brazing at the point indicated by the reference character 7 in Figures 2 and 4. Thereafter the shaped core is clamped in place either upon the form 1 as shown in Figure 3, or merely clamped in shape with the form removed. Preferably it is clamped on the form to prevent sagging or change of shape during annealing and also to hold the successive convolutions or layers close together on the flat elongated sides.

Any suitable type of clamping structure may be employed. A simple type is indicated in Figures 2 and 3 in which upper and lower members 8 are drawn into binding engagement with the wound core by means of the bolts 9. This insures the holding of the side legs of the core straight and the legs of the annealed core remain straight and compact after annealing when the clamping means is removed. The shaped core is placed in an annealing oven and is annealed, preferably substantially shielded from the direct action of the flame. This is easily accomplished by placing the clamped core in a box 10 having a removable cover 11, or if desired the core may be placed in the box and packed with flaked mica.

The magnetic ribbon or material may be either cold rolled or hot rolled, but is in each instance preferably annealed in a reducing atmosphere. The annealing of the shaped core while held in its shaped form removes all stresses due to the working of the core and thus enhances the electrical characteristics of the finished transformer. Additionally, the straight leg or legs of the core, depending upon the shape of the form on which it is wound, retain their straight shape and allow a circular coil or conductive winding to be wound on the straight leg or straight legs of the core. This circular coil or conductive winding has very desirable characteristics as will appear hereinafter.

After annealing, the form is removed and the core is clamped in a holder in any suitable manner. For example as shown in Figure 5, during the winding of the first coil one of the elongated

sides may be clamped to the support 12 by means of the clamping plate 13. For greater security each of the members, namely, the support 12 and clamping plate 13, may be shaped to receive a portion of the core and to thereby get a better grip on the core. As shown in Figure 5, each of these members may be provided with a notched out or grooved out portion indicated at 14, though this is not absolutely necessary. Thereafter the coil is wound on the core without reworking the core as the coil is rotated while it is being wound in any suitable manner, either by hand or by machine, preferably the latter. The winding of the coil on the closed core is made possible by causing relative rotation to occur between the coil and the core. For example, while the core is clamped as shown in Figure 5, the coil is formed by actually rotating such coil during its formation. An easy way of accomplishing this is to provide a sleeve 15 preferably of suitable insulating material which encircles one of the legs 5 of the transformer core and is preferably out of contact therewith, though in the broader aspect of this invention it may contact loosely with the core provided free rotation of the sleeve is secured.

The sleeve may take any of several forms. For example, it may be somewhat resilient and may be split as shown in Figure 5 and sprung over the core, or it may be made of removable sections is so desired. Any suitable means may be provided for rotating the sleeve as stated, or it may be rotated by hand, and while the sleeve is being rotated, the coil is formed thereon by winding the wire 16 on the rotating sleeve.

The sleeve, as stated, is preferably of insulating material though it may be of metal, in which case it would be either removable in sections or would have the edges adjacent the split out of contact with each other if it is to form a permanent part of the transformer.

The machine for winding the coil on the closed finished core is disclosed in the copending application of Alwin G. Steinmayer and William E. Krueger, Serial No. 342,524, filed June 26, 1940, for Method and machine for winding coils.

It is obvious that this process can be followed for the production of transformers or chokes or other similar electromagnetic devices and it is also to be distinctly understood that where the expression "coil" appears it is intended to cover any coil structure whether it includes a single coil or whether it includes either a primary or a secondary or both a primary and a secondary. The expression "coil" is used merely for the purpose of simplicity in the description and claims.

It is obvious that the clamping means 12 and 13, Figure 5, could be applied to the side 5 or end portion 6 if so desired. Also if applied to the end portion 6, it would be advantageous for relatively heavy cores to employ a clamping member at each end of the core.

The transformer may be formed either with a single coil, which is shown as being wound in Figure 4, or with a pair of coils as shown in Figure 6 and indicated by the reference character 17. It is also obvious that the transformer could be constructed by employing two cores with the elongated portion 5 of each core passing through a centrally arranged coil. Under these conditions, the core would only be wound for a half section of that shown in Figure 3 so that when the two half sections were placed side by side where they passed through the centrally located coil, they would together form the shape shown in Figure 3.

However, it is believed that the disclosure of the single core is sufficient for illustrating this invention, though other forms could be employed.

It will be seen that by following this invention that a transformer is produced in which there is a closed wound core which is not reworked and which, in the finished transformer, is unstressed and in which the coil is wound directly on the core by causing relative rotation of the coil and core while the coil is being wound.

It will also be seen that by following this method, the elongated, straight side portions of the wound core are secured, thus reducing the size of the opening through the coil, as has been pointed out hereinabove, and consequently reducing the length of wire required for a given size of wire and for a given number of turns and securing an excellent space factor.

These features outlined hereinabove materially improve the electrical characteristics of the transformer.

It is of course to be understood that the coils are taped, tied, or otherwise finished in the usual manner and that wedging blocks or any other suitable means are employed for holding the finished coils against motion with respect to the core, though these well known features have not been illustrated.

Also it is to be understood that suitable mounting brackets are employed in accordance with the usual practice, though these mounting brackets, as well as other accessories, have been omitted for the sake of clearness.

It will be seen that several of the various steps heretofore found necessary in the construction of transformers are avoided. For example, it is not necessary to punch and stack the separate elements making up the cores. Also the step of removing the wire edges resulting from stamping the separate elements of the core as heretofore practiced is avoided. Additionally, there is no machining of the core after it has been wound to shape and consequently there are no burrs or sharp edges left on the core layers. Also there is no reworking of the wound core after it has been annealed and consequently there is no chance whatsoever of any stresses remaining in the core in the finished transformer.

The amount of work required in producing a transformer in accordance with this invention is materially reduced and the resulting transformer has been found to have excellent electrical characteristics.

It is to be understood that although a single length of magnetic member has been illustrated, that the invention contemplates the use of either a single elongated strip of magnetic material or a plurality of such strips. However, the core is wound in a closed shape irrespective of whether a single strip or a plurality of strips are employed in producing the core. Obviously where a plurality of different widths are employed as shown in Figure 3, it is preferable to use different strips of material for these different portions of the core, the ends of such strips being either left free or welded to each other.

It is also to be understood that other forms of sleeves on which the coil is wound may be employed without departing from the spirit of this invention.

The circular coil or conductive winding is mechanically stronger than a preformed winding which has a rectangular window. The circular coil will resist forces tending to distort or move

the coil, or component parts thereof, better than a rectangular preformed coil with its relatively long straight sides. The distorting forces are frequently very severe under certain conditions as when an accidental short circuiting of a transformer occurs. This additional mechanical strength, together with an actual reduction in the amount of wire required, is obtained when a circular coil is employed in conjunction with a rectangular core or a core having a straight side or leg passing through the coil.

Another advantage resulting from the use of a circular coil, or winding, is that it eliminates the problem of bending insulated wire around corners. This eliminates, to a great extent, the possibility of damaging magnet wire and the insulation thereof in the winding of the coil. The net results of this are fewer failures and longer life and a more uniform high impulse strength.

By having the core formed with one or more straight sides and winding the coil around the core by rotating the coil about one of the straight sides, it is clear that the internal diameter of the coil is less than if the coil were wound on a circular core, as in this latter case the internal diameter of the coil would have to be sufficiently large to accommodate the curved or circular core.

If a circular core is used and is threaded or wound into a preformed coil or conductive winding, it is obvious that if a fairly good space factor is attempted, that it is necessary to have the winding or coil cruciform in cross-section. This results in a winding or coil which has a large thickness or depth as compared with its length which results in a high reactance. By following this invention and employing a preformed core having one or more straight sides and winding the coil on the preformed core, that a coil which is thin or of small depth as compared with its axial length is produced, which results in a low reactance.

This invention produces a transformer in which the air gap is reduced to a minimum as there is, in effect, only one air gap which has a very small effect as compared with the multiplicity of air gaps in the ordinary transformers where individual sections are assembled. There is considerable economy both in material used in the manufacture of the transformer and in the expense of operation thereof, for with this reduction in air gaps there is a material lessening in the value of exciting current. Additionally, with this invention it is possible to efficiently use a high grade steel and have a higher flux density therein as the reluctance of the magnetic path has been greatly reduced by the reduction in air gaps. If, on the other hand, it were attempted to have a high flux density in the magnet core and yet have a number of air gaps, it is obvious that this high flux density would also exist at the air gaps and consequently a very inefficient transformer would result as the exciting current would be very high.

Also by using a high grade steel and substantially eliminating the majority of air gaps, it is possible to effect a real economy in material in practicing this invention.

In addition to preventing the core from sagging by clamping it while it is being annealed, there is the further advantage of holding the successive layers on the long straight sides compacted

so that the finished core, which retains its shape after annealing, will have successive layers well compacted and thus minimize the spacing or air gap between the successive layers. Further, by holding the core clamped during annealing, the resulting annealed core more accurately conforms to its desired dimensions and there is, consequently, less variation during manufacture.

It is to be understood that other types of forms may be employed on which the core is wound. For example, if it is desired, the core may be wound on a single rectangular block without any of the stepped portions as shown in Figure 3 and the clamping structure may be different from that shown in Figure 2. For example, it may merely consist of two straight bars on opposite sides of the wound core.

Wherever the term "coil" appears, such expression is intended to include either a single coil or winding or the coil structure as employed in transformers, that is to say, a coil structure including both a primary and a secondary, either wound as one assembly with one coil wound on or adjacent the other or with the two coils physically separated but interlooped by the core.

It is also obvious that the invention is equally applicable to the manufacture of chokes when a closed core is employed and a coil or coils wound on a portion of such core.

Although this invention has been described in considerable detail, it is to be understood that such description is intended as illustrative rather than limiting, as the invention may be variously embodied and is to be interpreted as claimed.

I claim:

1. The method of making a transformer or the like comprising winding a closed core of magnetic ribbon around a shaping form having at least one straight side with the magnetic core surrounding the shaping form in successively closely compacted convolutions, holding the wound core on the form so that it does not change its shape and annealing the wound core while it is held against change of shape to cause the core to take a permanent finished shape and to insure that successive convolutions of the core remain closely compacted during and after annealing, removing the form and winding a circular coil structure around the straight side of the core by causing relative rotation between the coil and the core while the coil is being wound, the core being free from any working or machining after annealing.

2. The method of making a transformer or the like comprising winding a closed core of magnetic ribbon of different widths around a shaping form having at least one straight side to thereby provide a straight-sided core stepped in cross-section, holding the wound core in shape on the form and annealing the wound core while it is held in shape to cause the core to take a permanent finished shape and to insure that successive convolutions of the core remain closely compacted during and after annealing, removing the form and winding a circular coil structure around the straight side of the core by causing relative rotation between the coil and the core while the coil is being wound, the core being free from any working or machining after annealing.

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