Dec. 18, 1945. F. R. D'ENTREMONT 2,391,229

ELECTRIC INDUCTION APPARATUS

Filed Nov. 27, 1943 2 Sheets-Sheet 1

Fig. 1.

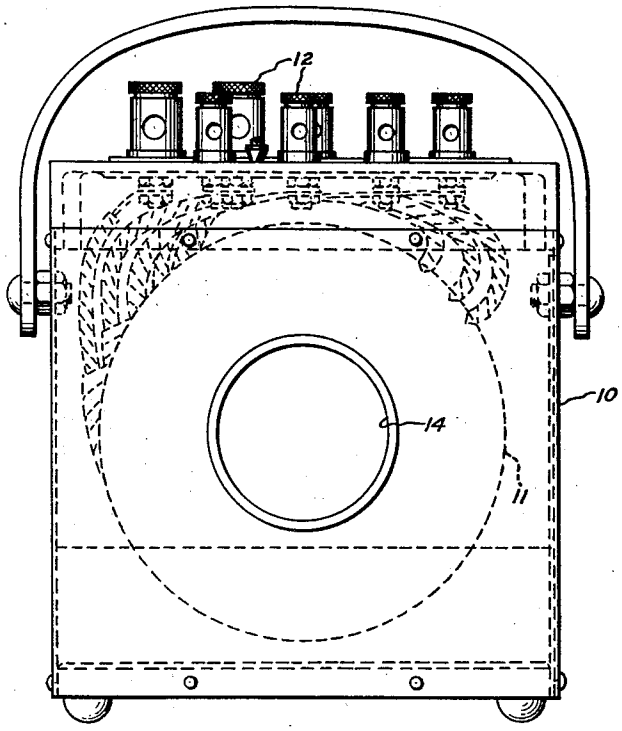
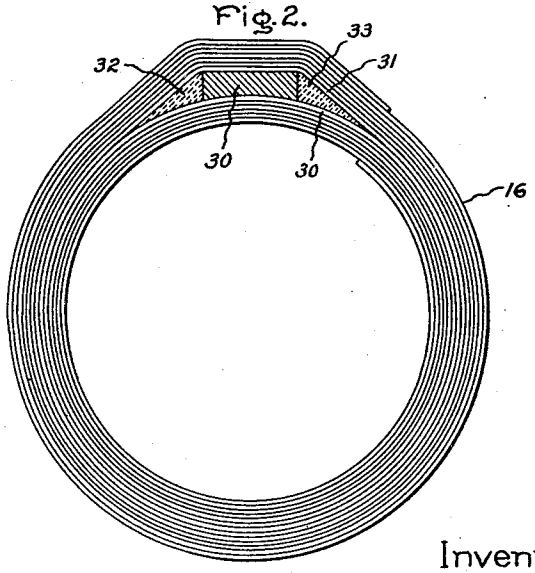


Fig. 2.



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Fig.3.

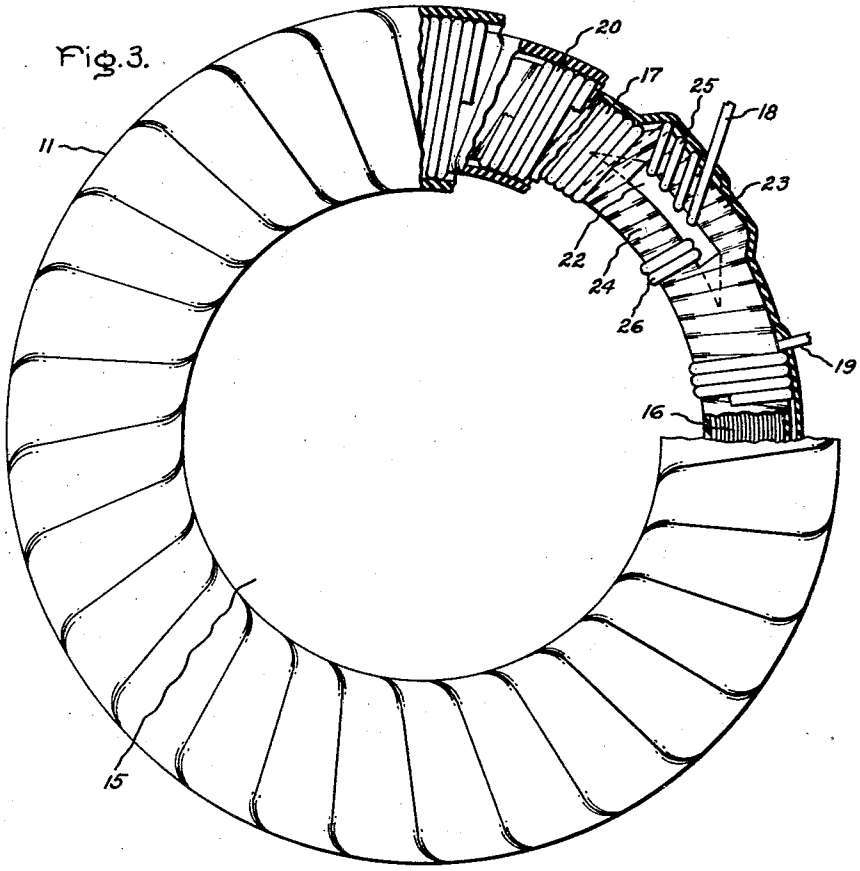


Fig.4.

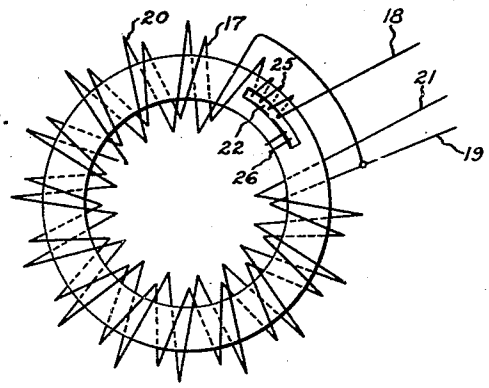
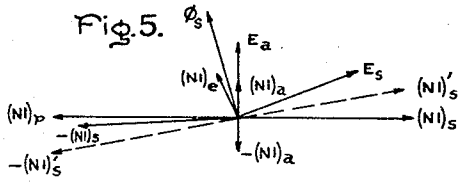


Fig.5.



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Patented Dec. 18, 1945

2,391,229

UNITED STATES PATENT OFFICE

2,391,229

ELECTRIC INDUCTION APPARATUS

Franklin R. D'Entremont, Lynn, Mass., assignor to General Electric Company, a corporation of New York

Application November 27, 1943, Serial No. 511,972

1 Claim. (Cl. 29—155.57)

My invention relates to electric induction apparatus, and more particularly to a transformer with compensating arrangement for obtaining the desired transformation ratio and phase angle, and to a core for an electrical induction apparatus and to a method of making the core.

An object of my invention is to provide an improved electrical induction apparatus with a magnetic core which facilitates the provision of suitable compensating arrangement for producing the desired ratio of transformation and phase angle between the primary and secondary windings thereof.

A further object of my invention is to provide an electric induction apparatus with an improved curved iron type core which is simple in construction and easy to manufacture.

A further object of my invention is to provide an improved method of forming and maintaining a curved iron type of core.

Further objects and advantages of my invention will become apparent from the following description referring to the accompanying drawings, and the features of novelty which characterize my invention will be pointed out with particularity in the claim annexed to and forming a part of this specification.

In the drawings Fig. 1 is a side elevation illustrating an instrument transformer which is provided with an embodiment of my invention; Fig. 2 is a sectional side elevation of the core employed in the construction of Fig. 1 during a step in the manufacture thereof; Fig. 3 is an end view in partial section illustrating the core and coils employed in the transformer construction shown in Fig. 1; Fig. 4 illustrates somewhat diagrammatically the arrangement of the secondary winding and turn construction employed in Fig. 3, and Fig. 5 is a vector diagram of the flux in the core and current of the primary and secondary windings of the transformer construction illustrated in Fig. 3.

Referring to the drawings, I have illustrated a transformer construction which includes an enclosing casing 10 within which is provided a core and coil construction 11 which is illustrated in further detail in Figs. 2 and 3. A plurality of terminals 12 are provided for connection to the various ends of the primary and secondary coils. In order to provide a primary winding for larger currents an opening 14 is provided in the casing which is in registry with the opening 15 of the core and coil construction and through this opening may be provided a conductor bar or cable which acts as the primary winding of the transformer construction.

The electric induction apparatus construction as is illustrated in the drawings has particular application as an instrument current transformer and in order to provide a suitable core and coil construction I provide a core construction 16 which includes magnetic strip material curved in any suitable manner so as to provide a doughnut- or rectangular-shaped core. In the construction as illustrated in Fig. 2 it will be seen that the strip is wound or formed with a plurality of layers or convolutions to provide an annular-shaped core. As will be seen more particularly in Fig. 3 a secondary winding is provided which includes a first layer 17 which includes a plurality of turns of the wire distributed around the toroidal-shaped core 16 and having terminal ends 18 and 19. Any suitable number of conductor layers may be provided and in the construction as illustrated in Figs. 3 and 4 a second conductor layer 20 is provided which has one end connected to the terminal 19 and the opposite end being connected to a terminal 21.

In the ideal transformer, the ratio of transformation of primary to secondary voltage is equal to the ratio of the primary and secondary turns. However, due to the exciting current drawn by the transformer occasioned by the internal drop and losses such as core losses, the true ratio of transformation does not in fact equal the turn ratio. A method of compensating current transformers therefor includes the provision of a few turns in series with the secondary winding which turns link only a portion of the magnetic circuit, such a circuit being described and claimed in Patent 1,722,167, Wilson, issued July 23, 1929, and which is assigned to the same assignee as this present invention. In order therefore to obtain compensation to adjust turn ratio, I provide an opening 22 in the transformer core by spreading adjacent layers so as to provide a pair of parallel flux paths 23 and 24. In series with the secondary winding layer 17, I therefore provide a plurality of turns 25, four being shown which pass through the opening 22 and link the parallel flux path 23.

In order to correct for phase angle error I also provide a short circuited turn 26 which includes bands of conducting metal passing through the opening 22 and linking the flux path 24 of the core.

The effect of such short-circuited turns may be shown by the vector diagram of Fig. 5. In an ideal transformer the secondary current and

therefore the secondary ampere-turns $(NI)_s$ would be equal to and 180 degrees out of phase with the primary current or primary ampere-turns $(NI)_p$. Without the short-circuit winding (26) the secondary ampere-turns reversed would be as shown by the vector $-(NI)_s'$ in Fig. 5. In this case the secondary ampere-turns $(NI)_s'$ are not 180 degrees out of phase with the primary ampere-turns $(NI)_p$. With the short-circuited winding (26), current will flow in this winding, substantially in quadrature with the primary current. The reversed secondary ampere-turns $-(NI)_s$ under this condition, are equal to the primary ampere-turns $(NI)_p$ minus the exciting ampere-turns $(NI)_e$ minus the reversed short-circuit winding ampere-turns $-(NI)_a$. The secondary current is substantially opposite the primary current due to the current required by the short-circuited winding (26). The idea of providing short-circuited turns so as to correct for phase angle is also described and claimed in the above mentioned Wilson patent.

In order to provide a convenient method of producing a core which is particularly suitable for such instrument transformers, I form the core by curving or bending magnetic strip in any suitable manner such as by winding a plurality of turns of magnetic strip material until any suitable number such as approximately half the number of layers are provided. In order to produce the opening, I then place a spacing bar 30 of suitable material which will withstand the annealing temperature, such as metal, and then wind the remainder of the layers of magnetic material until a sufficient number are provided. Between adjacent layers 30 and 31 on either side of the spacer bar I then introduce any suitable cement material such as a mixture of sodium-silicate and china clay. However, I may also use a magnetic cement, such as sodium silicate mixed with iron powder. The core may then be placed in a conventional annealing oven and during anneal the sodium silicate binder becomes hard so as to provide spacer portions 32 and 33. The spacing wedge may then be forced out from between the adjacent layers, thus leaving an opening 22 as is illustrated in Fig. 3. It is to be understood that any suitable number of openings may be provided in this manner. In order to produce a core construction which will not only have predictable characteristics but the characteristics of which will also be constant, it is desirable that the opening be maintained at a constant size and it will be seen that with the relatively hard spacer inserts 32 and 33 at either end of the opening, that the opening will be maintained at substantially constant size.

Although I have shown and described particular embodiments of my invention, I do not desire to be limited to the particular embodiments described, and I intend in the appended claims to cover all modifications which do not depart from the spirit and scope of my invention.

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

The method of forming a core for an electrical induction apparatus including the steps of bending magnetic strip material to form a plurality of layers of a core, providing a spacer bar between adjacent layers, placing cement material hardenable during a subsequent annealing step between said adjacent layers at the sides of said spacer bar, annealing the core, and removing the spacer bar so that the cement will hold the adjacent layers spaced with an opening where the bar had been removed.

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