March 21, 1939. T. R. KENNEDY 2,151,035

TRANSFORMER

Filed Dec. 11, 1937

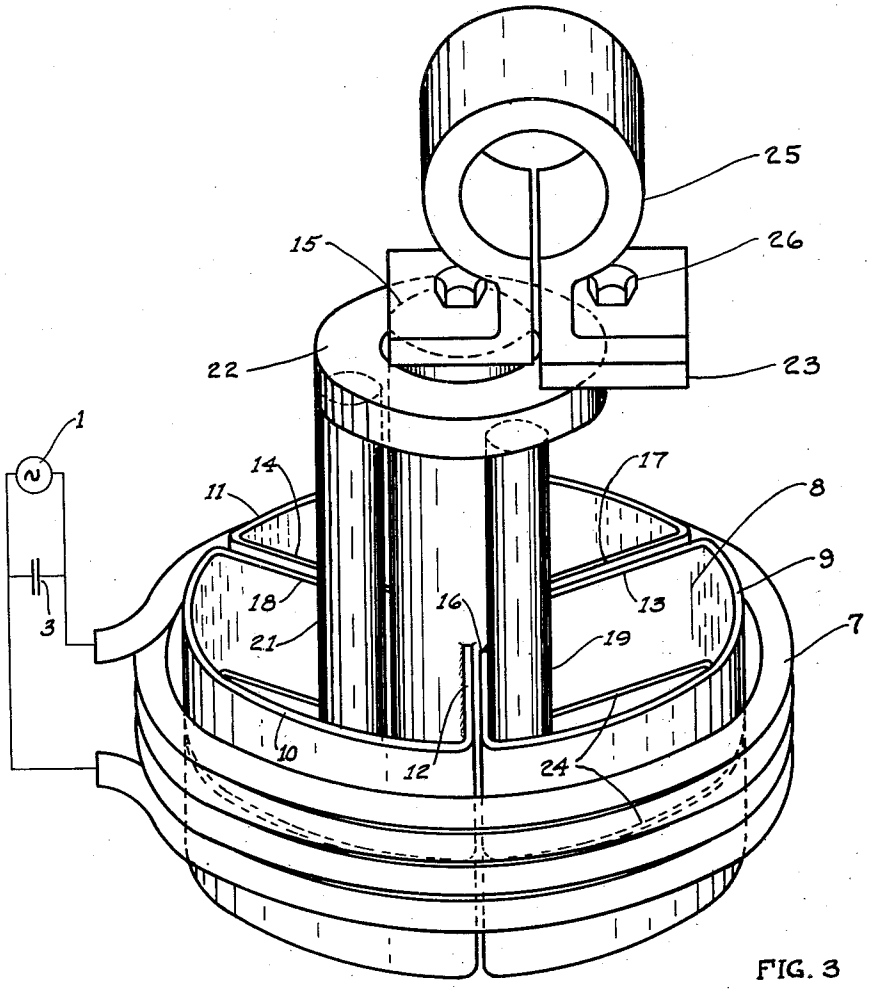


FIG. 3

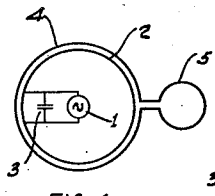


FIG. 1

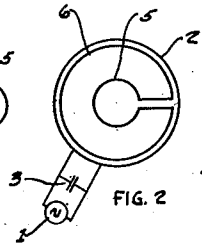


FIG. 2

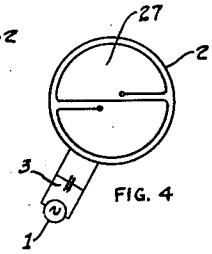


FIG. 4

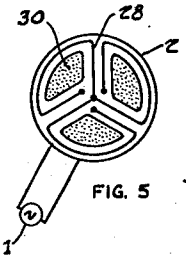


FIG. 5

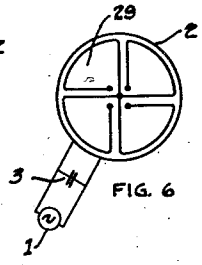


FIG. 6

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TRANSFORMER

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Application December 11, 1937, Serial No. 179,219

7 Claims. (Cl. 219—47)

This invention deals with transformers and specifically those transformers which are used or useful in rapid inductive heating apparatus.

An object of the invention is to provide a transformer in which the ratio of turns between primary and secondary is high, yet in which the impedance of the secondary is low.

A further object is to provide a focus inductor transformer wherein the impedance of the power collecting portion is matched against the impedance of the distributing inductor.

A further object is to provide a transformer with a secondary winding comprising fractional parts of a single turn.

A further object is to provide a method for increasing the current flow in a focus inductor distributing block without materially increasing the primary voltage.

Further purposes will appear in or be evident from the specification.

Attention is directed to applicant's copending application, Serial No. 252,906, filed January 26, 1939, which is a continuation in part of this application and in which are claimed certain features of applicant's invention referred to, but not claimed herein.

Applicant has chosen six figures by way of illustration.

Figures 1 and 2 are diagrammatic views of focus inductor circuits showing the use of inside and outside primary coils with one turn secondary coils.

Figure 3 is an isometric view of an inductive heating device embodying applicant's invention. Diagrammatically shown in connection with this figure is an alternating current power source and power factor correction therefor.

Figures 4, 5 and 6 are diagrammatic views of transformer circuits according to this invention, showing respectively half turn, third turn and quarter turn secondary windings. In Figure 5 is shown how an iron core might be placed in a transformer of the type described.

The focus inductor as described in Northrup U. S. Patent 1,378,187, and elsewhere, is well known. It comprises a transformer and distributing inductor for concentrating a large block of power into a comparatively small charge piece. The primary of the transformer, like most heating inductors, usually comprises a single layer helical coil of hollow copper tubing arranged for water cooling. The turns usually are edge wound to get a large number of turns into a small space. The secondary usually comprises a single electrical turn closely coupled with the primary and lying either inside or just outside of same. If the secondary is of broad width it usually is subdivided with circumferentially directed openings to cut down eddy current losses. The distributing inductor, like the secondary, is usually of one turn, but may be of several turns. Ordinarily it comprises a single loop, usually a hollow casting of rugged construction and small size, adapted in form to lie closely within or around the charge to be heated. It is connected in series with the secondary and usually is adapted to carry an extremely heavy high frequency alternating current. Because of the high frequency of the current used in a focus inductor assembly an iron core usually is not used. It may be used either in the main transformer or in the distributing inductor, or in both if desired.

The value of a focus inductor heating assembly lies in its ability to perform intricate, fast or unusual heating, although its efficiency is relatively low with respect to other methods of heating. Assuming that the best efficiency in ordinary induction heating is from 50 to 70 per cent, the focus inductor efficiency is of the order of 15 to 30 per cent, and since many applications to which the focus inductor may be applied are not of the type offering good electrical coupling, efficiencies have been known to be as low as 5 per cent. While efficiency is of general, it is not of essential importance; and even in cases where the efficiency is as low as 5 per cent the use of a focus inductor is sometimes considered commercially sound. This is true because many of the applications to which the focus inductor is applied can be handled in no other way. The present invention describes a method of improving the efficiency of certain types of focus inductor equipment.

Applicant has found that as the coupling between the distributing inductor and the charge piece becomes poor, due to the small size of the charge piece or to its irregularity or physical make-up, the efficiency of the system falls off. This he attributed to the fact that with a focus inductor assembly of the usual construction the distributing inductor, instead of transmitting power to the load, forms substantially a short circuit on the secondary winding of the transformer; and because of the poor coupling between the primary and secondary windings, causes the voltage of the secondary to fall off. Applicant devised his present construction to gain a better voltage ratio under load conditions between primary and secondary.

By dividing the one turn secondary into a

plurality of symmetrical fractional turn windings, each in parallel with the other, and in series with the distributing inductor, he was able to decrease the resistance, and hence the impedance of the secondary, without sacrificing the total current flow in the distributing inductor. In fact, because of the lower secondary impedance, the current as a whole was increased, with an accompanying better regulation and higher overall efficiency.

Assuming that each segment of the fractional turn secondary has induced in it $1/n$th of the current which would be induced in a full turn secondary (n being the total number of segments), then all n turns operating in parallel would supply the same current as with the one turn secondary. Forgetting that the reentrant portions of each segment have resistance, the resistance of the total n segments, operating in parallel is reduced to $1/n^2$th of the resistance of the single turn. Thus by applicant's method, even considering some resistance in the reentrant portions of the secondary segments, the total impedance is greatly reduced over what it would have been using a complete turn.

Applicant has found that the number of parts into which he can divide a focus inductor secondary with constructive results is dependent upon the ultimate load conditions. As a general rule, if the diameter of the charge piece is small the number of segments in the secondary to obtain the best results will be large, and vice versa. Applicant believes that the impedance of the distributing inductor, including the load, should be equal to the transformer secondary reactance for the best results, and he has effectively checked his conclusions with a number of experiments involving commercial size equipment. In his tests secondary coils having from one to four segments were experimented with and these were compared with the more common type focus inductor assemblies for efficiency and practical operation data. Improvements in efficiency up to 30 per cent were recorded.

In Figure 1 applicant has shown a focus inductor assembly of the usual construction. In this figure an alternating current source 1, feeds the primary coil of a focus inductor transformer 2. Capacitors 3 are used to resonate the coil. The secondary of the transformer 4, is shown in this case as surrounding the primary. The distributing inductor is shown by the loop 5.

The assembly shown in Figure 2 is similar to that of Figure 1 with the exception that the primary 2 surrounds the secondary 6. Figures 1 and 2 are used by way of illustration to show for comparison some of the features of the older type focus inductor assemblies. The matter of internal and external coils is considered to be old, and can be applied equally well to applicant's present invention.

Applicant's invention is best illustrated by Figure 3 in which a focus inductor assembly is shown having a transformer secondary, each section of which comprises a third part of a turn. In this figure a high frequency power source 1 is connected, as in Figure 1, to the primary of the transformer 7. The primary comprises a single layer helical coil closely coupled to the secondary 8. Insulation, not shown, would be placed between primary and secondary windings.

The secondary 8, comprises three parts, 9, 10 and 11, which together make one complete electrical turn, and each part is connected in parallel with the other two. For instance, re-entrant parts 12, 13 and 14 are connected to the center connecting block 15, while parts 16, 17 and 18 are connected through connecting studs 19, 20 (not shown) and 21 to connecting blocks 22 and 23. The parts of the secondary are divided circumferentially by spaces 24. Insulation, not shown, would be placed between re-entrant portions 12—16, 13—17 and 14—18, and also between the central connecting piece 15 and the other connecting studs 19, 20 and 21.

The distributing inductor block 25 is adapted with bolts 26 for use in clamping same to the connecting blocks 15 and 23 of the transformer secondary.

In Figures 4, 5 and 6 applicant has shown primary windings 2 surrounding two, three and four part secondaries 27, 28 and 29 respectively. In each of these figures one end of each secondary section is connected to a common junction, and it is assumed that the free ends would be similarly connected together as shown in Figure 3. In Figure 5 applicant has shown how an iron core 30 might be applied to a transformer of the type described.

Theoretically, there is no limit to the number of segments which can be used in a transformer of this type if the load condition justifies the degree of subdivision; and for this reason applicant does not wish to be limited to the half, third and quarter turn examples used for illustration.

Applicant has described his invention with particular reference to inductive heating apparatus, but believes it to be equally applicable to the design of transformers for other uses.

What is claimed follows:

1. A transformer comprising a winding with a plurality of electrical turns, and a winding with a plurality of conductors connected in parallel at their extremities each coupled only fractionally with the circumferential part of said first mentioned winding but as a group substantially fully coupled with same.

2. A transformer comprising a winding with a plurality of electrical turns and a winding comprising one physical turn divided into a plurality of arc like sections, said sections being electrically connected in parallel and each being coupled with a different circumferential portion of said first winding.

3. A transformer winding comprising substantially a single layer hollow cylinder divided circumferentially to limit eddy currents and longitudinally to effect a plurality of fractional turns, the fractional turns being electrically connected in current additive parallel relation.

4. In a focus inductor assembly a transformer primary, a transformer secondary comprising a plurality of fractional turns each inductively coupled with a different circumferential portion of the primary circuit and connected in parallel to a distributing inductor.

5. A transformer comprising a primary winding having turns of substantially 360 degrees of arc and a secondary winding comprising a plurality of conductors, connected in parallel at their extremities, each electrically insulated from the others and inductively coupled with the primary only over from 20 to 50 per cent of its circumferential length, these conductors as a group being inductively coupled with the primary over substantially in its full circumferential length,

6. A transformer comprising one winding having a substantially annular turn and a second winding comprising a plurality of conductors,

connected in parallel at their extremities, each inductively coupled with said primary turn only over a portion of its annular length but as a group inductively coupled with said turn over substantially its full length.

7. A transformer having a helical type primary winding, a secondary comprising a plurality of conductors each inductively coupled with the same longitudinal but a different circumferential portion of the primary circuit and connected in parallel to a distributing inductor, the number of conductors in said secondary, together with their physical characteristics, being so chosen as to make their combined impedance substantially equal to the impedance of the distributing inductor.

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