Aug. 8, 1944. W. M. ROBERDS 2,355,560

ELECTRICAL COUPLING DEVICE

Filed Feb. 27, 1943

FIG. 1.

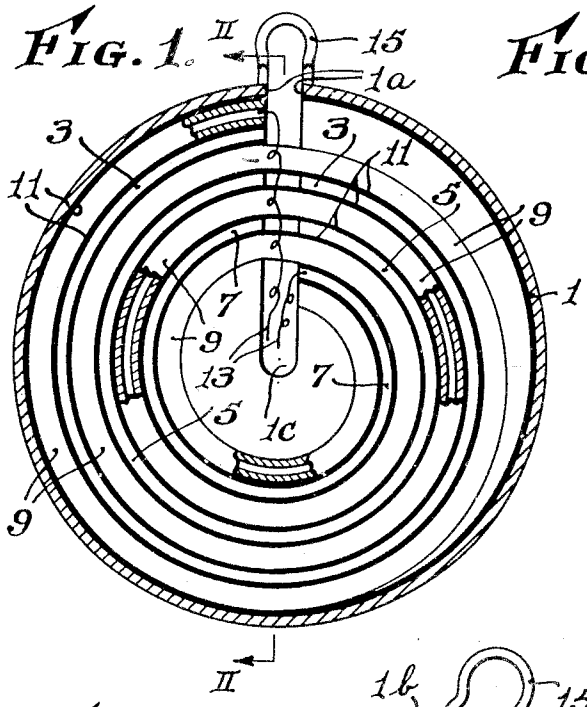


FIG. 2.

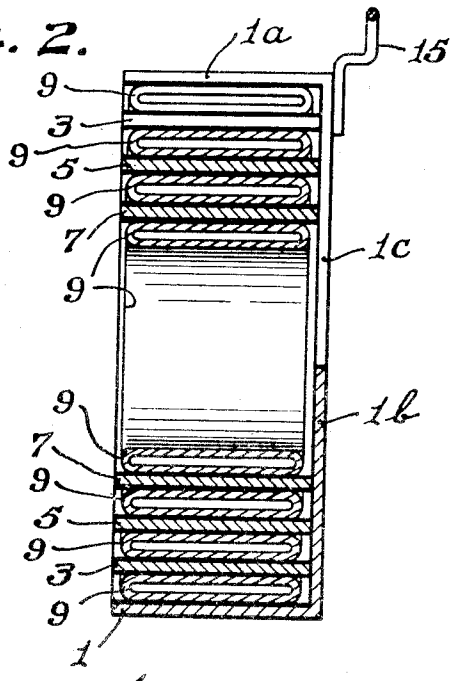


FIG. 3.

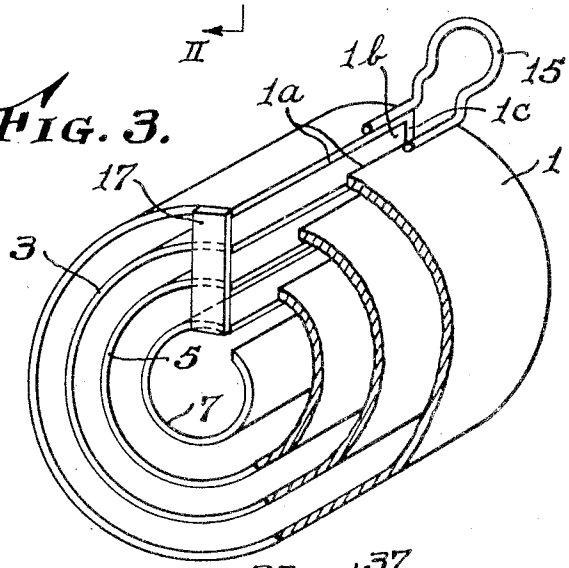


FIG. 4.

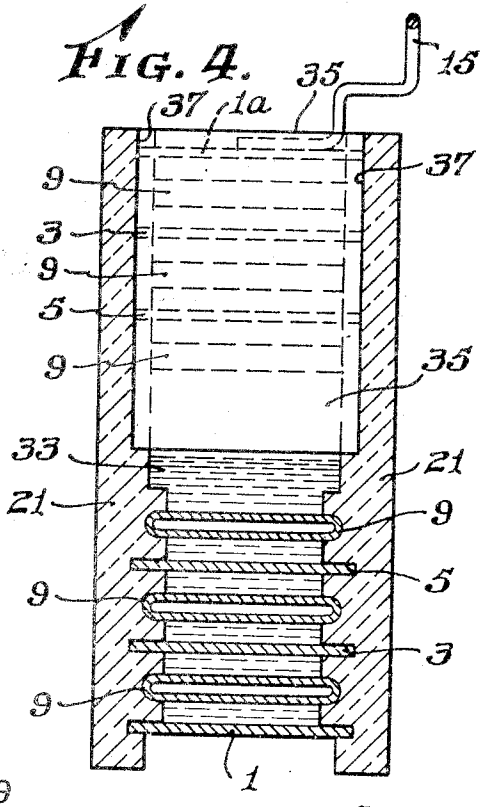
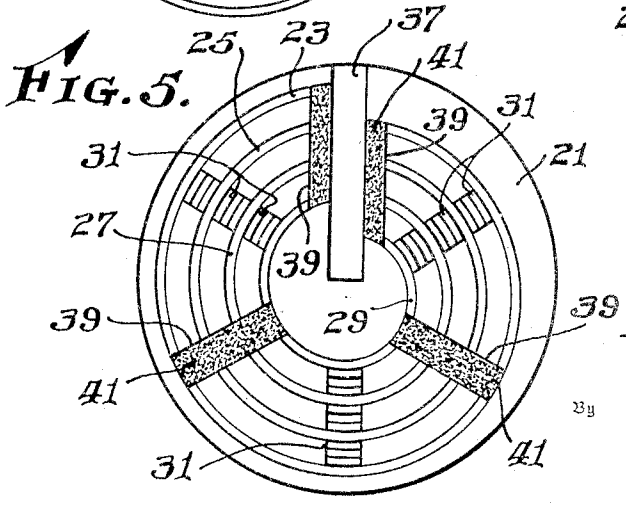


FIG. 5.



Inventor

Wesley M. Roberds

By

Attorney

UNITED STATES PATENT OFFICE

2,355,560

ELECTRICAL COUPLING DEVICE

Wesley M. Roberds, Collingswood, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application February 27, 1943, Serial No. 477,474

16 Claims. (Cl. 175—356)

This invention relates to electrical coupling devices, and more particularly to electrical transformers such as are useful in apparatus employed for the heat treatment of metals.

The heat treatment of metals for altering the hardness thereof is well known in the prior art. Among the proposals made heretofore for this purpose is that which includes subjecting the metal to a high frequency magnetic field which induces eddy currents therein. The field is supplied to the work by a suitable applicator which is coupled to a source of high frequency electrical energy, such as a vacuum tube oscillation generator, through a coupling transformer. Heretofore, transformers used for this purpose have generally included a secondary winding in the form of a single turn, relatively wide, copper sheet which surrounds the primary winding, the applicator usually being in the form of an induction coil connected directly to the terminals of the copper sheet. This type of transformer is not altogether satisfactory on account of the relatively poor coupling between the windings thereof with the resulting high leakage reactance which requires a relatively high primary voltage to produce the desired heating effect.

The primary object of my present invention is to provide an improved coupling transformer of the type set forth which will be free from the aforementioned and other similar objections found in prior art transformers.

More particularly, it is an object of my present invention to provide an improved coupling transformer wherein there will be close coupling between the primary and secondary windings thereof.

Otherwise stated, it is an object of my present invention to provide an improved coupling transformer as above set forth which has a low leakage reactance.

Another object of my present invention is to provide an improved coupling transformer which, for a desired or given heating effect, will require a much smaller primary voltage than is required in the case of transformers heretofore available for the purpose set forth above.

Still another and very important object of my present invention is to provide an improved transformer as above set forth which will provide an efficient means of coupling energy from the tank circuit of a high frequency oscillation generator to the part or work to be heated.

In accordance with this invention, the transformer is made of a pair of inductively related windings one of which comprises a plurality of parallel connected, substantially spiral, concentric sheets of conductive material, the sheets being arranged along progressively increasing radii. Preferably, these sheets are arranged in nested relation and are spaced from each other in radial directions. This assembly constitutes the secondary winding of the transformer. The primary winding of the transformer comprises a continuous, multi-turn, substantially spiral conductor arranged concentrically with the above mentioned spiral elements or sheets and each turn of the primary winding being disposed in the space between adjacent elements or turns of the secondary winding. The primary winding may be constituted by a tubular conductor through which a cooling fluid may be passed, if found necessary or desirable, and the two windings are separated from each other by a suitable insulating medium. The two windings are arranged in compact relation and are very closely coupled to each other. If desired, the windings may be arranged within a suitable casing of which at least a portion is of conductive material connected to the outer turn of the secondary winding. A suitable applicator in the form of an induction coil may be secured to the conductive part of the casing.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description of several embodiments thereof, when read in connection with the accompanying drawing, in which

Figure 1 is a view partly in end elevation and partly in section of one form of transformer according to the present invention,

Figure 2 is a sectional view thereof taken along the line II—II of Figure 1,

Figure 3 is a perspective view, partly in section, of a slightly modified form of secondary winding alone with a coupling coil secured thereto,

Figure 4 is a view similar to Figure 2 but showing a further modified form of the invention, and

Figure 5 is a top, plan view of one of the end closures of the form of my invention shown in Figure 4.

Referring more particularly to the drawing, wherein similar reference characters designate corresponding parts throughout, there is shown in Figures 1 and 2 a hollow, cylindrical casing 1 formed of a sheet of conductive material the lon-

gitudinal edges 1a of which are disposed in slightly spaced, adjacent relation. The casing 1 also includes an end plate 1b constituting a closure at one end thereof. The end plate 1b is provided with a radial slot 1c which communicates with the space between the longitudinal edges 1a of the casing.

Disposed within and electrically connected to the end plate 1b, as by soldering or the like, are a plurality of discrete, substantially spiral, conductive sheets 3, 5, and 7. These sheets, which may be made of copper or any other good conductive material, are preferably all of the same length and are arranged in nested relation relative to each other, being spaced from each other substantially uniformly in radial directions. The sheets or elements 3, 5 and 7 are of such length and are so disposed within the casing 1 that they extend from one of the radial edges defining the slot 1c (for example, the left hand edge as seen in Figure 1) around the axis of the casing 1, and clear around to the other radial edge of the closure 1b which defines the slot 1c. Thus, the longitudinal edges of each of the elements or conductive sheets 3 are spaced from each other. Furthermore, the trailing edge of each of the elements 3, 5 and 7 is substantially circumferentially aligned with the leading edge of the next innermost sheet or element of the group. Thus, commencing at the left hand edge of the slot 1c in Figure 1, and proceeding in a counterclockwise direction along the turn or sheet 3, it will be noted that the sheet 3 terminates adjacent the right hand radial edge defining the slot 1c. The adjacent, leading edge of the sheet or turn 5 then continues in substantially circumferential alignment with the end of the turn 3, although beginning, like the turn 3, at substantially the left hand radial edge of the slot 1c. The turn or sheet 5 then continues around to terminate adjacent the right hand radial edge of the slot 1c, and the sheet or turn 7 continues in substantially circumferential alignment with the trailing end of the sheet 5 but spaced therefrom substantially by the width of the slot 1c, and so on. The assembly thus far described constitutes the secondary winding of the transformer.

The primary winding of the transformer is constituted by a single, continuous, preferably hollow, conductor 9 which is also substantially spirally arranged and which is disposed in the spaces between the turns 1, 3, 5, 7 of the secondary winding. A pair of spirally formed insulated sheets 11 interposed between the primary winding 9 and secondary turns 1, 3, 5, 7 electrically insulates the two windings from each other. The primary winding 9 may commence at the left hand radial edge of the slot 1c, as viewed in Figure 1, between the outer shell or casing member 1 and the first spiral turn 3 of the secondary winding. The primary winding 9 continues around in spiral fashion, crossing the slot 1c, and then continues in between the turns 3 and 5 of the secondary winding, after which it continues on between the secondary winding turns 5 and 7, and finally terminates at the right hand radial edge of the slot 1c. A pair of leads 13 provide means for an external connection of the transformer to a source of high frequency energy (not shown), and a single turn or partial turn induction coil 15 connected to the casing 1 either along the longitudinal edges 1a thereof, or along the radial edges defining the slot 1c, as shown in Figure 2, affords means of applying the high frequency energy to the work.

A transformer as above described embodies a multi-turn primary and what is effectively a single turn secondary which are very closely coupled to each other and which will provide very efficient coupling from the tank circuit of the high frequency energy source to the part which is to be heated. In one embodiment constructed accordingly to the form of the invention described above, the casing 1 was made of a shallow pan about 3 inches deep and with a diameter of about 18 inches. The turns 3, 5, and 7 of the secondary winding were made of copper sheeting approximately $\frac{1}{16}$ inch thick, and the primary winding was made of flattened, ½ inch copper tubing. This transformer provided highly efficient coupling between the oscillation generator and the work, and a much lower primary voltage was required with this transformer to produce a desired heating effect in the work than was required with similar transformers of the prior art.

In Figure 3, there is shown a slightly modified form of secondary winding assembly. Here, the free ends of the secondary turns 1, 3, 5 and 7 are bridged by a conductive strip 17 to connect them in parallel relation, and it is, therefore, not necessary to solder or otherwise electrically connect the secondary turns to the end closure 1b. Also, the coupling coil 15 is shown connected to the longitudinal, terminal edges 1a of the casing member 1.

Where it is desired to operate the transformer with a very high primary voltage, the insulating strips 11 may not be adequate. For this purpose, the transformer may be constructed as shown in Figure 4. Here, the conductive casing member or sheet 1 has its ends closed by circular disks or end closures 21 of the insulating material. The closures 21 may be formed with spiral grooves 23, 25, 27, 29, etc., corresponding in number to the number of turns of the secondary winding and in which the respective turns of the secondary winding are received during assembly. The end closures 21 are also provided with grooved ridges or projections 31 in which the primary winding 9 is received and which serve to retain the primary winding in spaced relation to the several turns of the secondary winding. The space within the casing constituted by te electrically conductive sheet 1 and the insulated closures 21 which is not occupied by the primary and secondary windings of the transformer is filled with a suitable fluid 33 of insulating material, such as oil, an inert gas which may or may not be under pressure, or the like. To confine the fluid 33 within the casing, a suitable plug or closure 35 of insulating material may be inserted through the space between the longitudinal elges 1a of the sheet 1 and along a pair of aligned grooves 37 in the end closures 21 which communicate with the space between the edges 1a. To connect the several turns 1, 3, 5, etc. of the secondary winding electrically in parallel relation, one or both of the end closures 21 may be provided with one or more radial slots 39 which extend across all of the grooves 23, 25, 27 and 29. The groove or grooves 39, as the case may be, are coated with a conductive strip or layer 41 which corresponds to the bridging member 17 of Figure 3. With the last described form of my invention, high voltages may be applied to the primary winding without sparking taking place between the primary and secondary windings notwithstanding the fact that the two windings are very closely spaced and closely coupled magnetically.

From the foregoing description, it will be apparent to those skilled in the art that my improved transformer provides a much higher coefficient of coupling than similar transformers heretofore known. As a result, much more efficient coupling between the power source and the work can be obtained.

Although I have shown and described several forms of my invention, it will, no doubt, be apparent to those skilled in the art that many other forms thereof, as well as variations in the ones herein described, are possible. I therefore desire that my invention shall not be limited except insofar as is made necessary by the spirit of the appended claims.

I claim as my invention:

1. An electrical coupling device comprising a pair of inductively related windings, one of said windings comprising a plurality of parallel connected, substantially spiral, conductive elements physically spaced from each other, and the other of said windings comprising a continuous, substantially spiral conductor disposed in the spaces between said elements.

2. An elecrical coupling device comprising a pair of inductively related windings, one of said windings comprising a plurality of parallel connected, substantially spiral, concentric, conductive elements, said elements being physically spaced from each other, and the other of said windings comprising a continuous, substantially spiral conductor concentric with said spiral elements and disposed in the spaces between said elements.

3. An elecrical coupling device comprising a pair of inductively related windings, one of said windings comprising a plurality of parallel connected, substantially spiral, concentric, conductive elements of progressively increasing radii, said elements being physically spaced from each other, and the other of said windings comprising a continuous, substantially spiral conductor concentric with said spiral elements and disposed in the spaces between said elements.

4. An electrical coupling device comprising a pair of inductively related windings, one of said windings comprising a plurality of parallel connected, substantially spiral, concentric, conductive elements of progressively increasing radii, said elements being disposed in nested relation and being physically spaced from each other in radial directions, and the other of said windings comprising a continuous, multi-turn, substantially spiral conductor concentric with said spiral elements, each turn of said other winding being disposed in the space between adjacent elements of said first named winding.

5. A device according to claim 4 wherein each of said elements is constituted by an incomplete turn.

6. A device according to claim 4 wherein each of said elements has the same length in a direction axially of said device, and characterized further in that said elements are electrically connected in parallel relation at at least one end of said device.

7. A device according to claim 4 characterized by the addition of dielectric means interposed between the turns of said other winding and said elements for electrically insulating said windings from each other.

8. An electrical coupling device comprising a hollow casing member of conductive material, said member being constituted by an incomplete turn with its longitudinal edges in spaced, adjacent relation and including a closure at one end having a radial slot therein communicating with the space between said adjacent ends of said member, and a pair of inductively related windings within said casing member, one of said windings comprising a plurality of discrete, substantially spiral, concentric, conductive elements of progressively increasing radii disposed in nested relation and physically spaced from each other in radial directions, said elements being electrically connected to said closure whereby said elements are coupled to each other in parallel relation electrically, and the other of said windings comprising a single, continuous, multi-turn, substantially spiral conductor concentric with said spiral elements, each turn of said other winding being disposed in the space between adjacent elements of said first named winding, and said other winding also being spaced from said closure.

9. A device according to claim 8 characterized in that each of said elements is of such length and is so disposed within said casing member that it extends substantially from one of the edges of said closure which defines the slot therein around the axis of said device and substantially to the other edge of said closure which defines said slot.

10. A device according to claim 8 characterized in that each of said elements is of such length and is so disposed within said casing member that it extends substantially from one of the edges of said closure which defines the slot therein around the axis of said device and substantially to the other edge of said closure which defines said slot, and characterized further in that the trailing end of each of said elements along said second named slot edge is substantially in circumferential alignment with the leading edge of the next innermost element along said first named slot edge.

11. An electrical coupling device comprising a hollow casing constituted by an incomplete turn of a sheet of conductive material having its longitudinal edges arranged in spaced, adjacent relation and by non-conductive closures at the opposite and transverse ends of said turned sheet, a pair of inductively related windings within said casing, one of said windings comprising a plurality of discrete, substantially spiral, concentric, conductive elements of progressively increasing radii disposed in nested relation and physically spaced from each other in radial directions, and the other of said windings comprising a single, continuous, multi-turn, substantially spiral conductor concentric with said elements, each turn of said other winding being disposed in the space between adjacent elements of said first named winding but being spaced therefrom radially, means connecting said elements and said conductive sheet to each other in parallel relation electrically, a non-conductive fluid in said casing filling the space therein not occupied by said windings whereby to electrically insulate said windings from each other, and a third closure of non-conductive material extending into said casing through the space defined by the longitudinal edges of said sheet and said first named closures, said sheet and said three closures cooperating to confine said fluid therein.

12. A device according to claim 11 characterized in that said fluid is constituted by oil.

13. A device according to claim 11 characterized in that said end closures are provided with

spiral grooves in which said elements are supported.

14. A device according to claim 11 characterized in that said end closures are provided with spiral grooves in which said elements are supported, and characterized further in that at least one of said end closures is also provided with at least one additional groove extending across each of said elements and said casing sheet, said additional groove being provided with a conductive layer in engagement with said elements and said sheet whereby said sheet and said elements are connected in parallel relation electrically.

15. A device according to claim 11 characterized in that said end closures are both provided with aligned, radial slots communicating with the space between said longitudinal sheet edges, and characterized further in that said third closure extends into said space and said slots.

16. An electrical coupling device comprising a pair of inductively related windings, one of said windings comprising a plurality of concentric, conductive elements each of an incomplete single turn, said elements being spaced from each other and being connected in parallel relation electrically, and the other of said windings comprising a multi-turn, continuous conductor concentric with said elements, each turn of said other winding being a complete turn and being disposed in a separate one of the spaces between adjacent ones of said elements.

WESLEY M. ROBERDS.