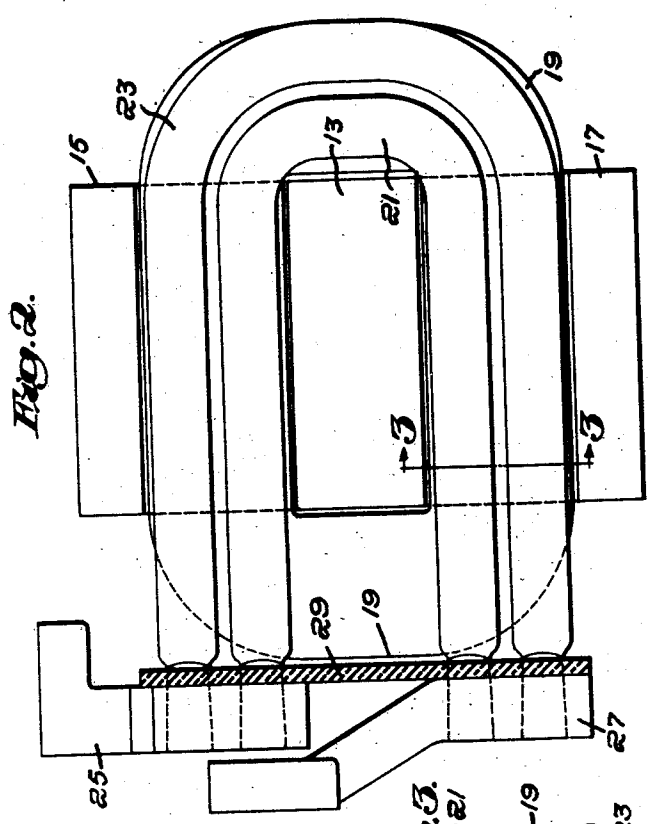
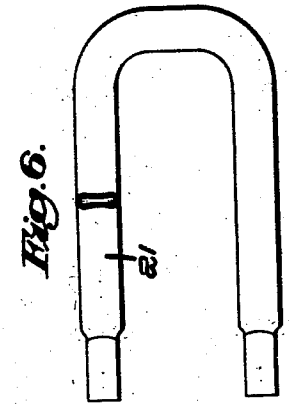
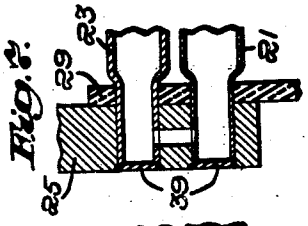
Nov. 28, 1939. C. E. SEIFERT 2,181,644

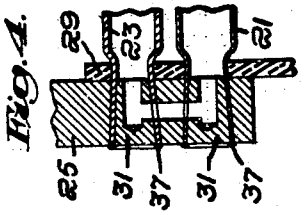
ELECTRIC TRANSFORMER

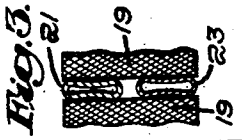
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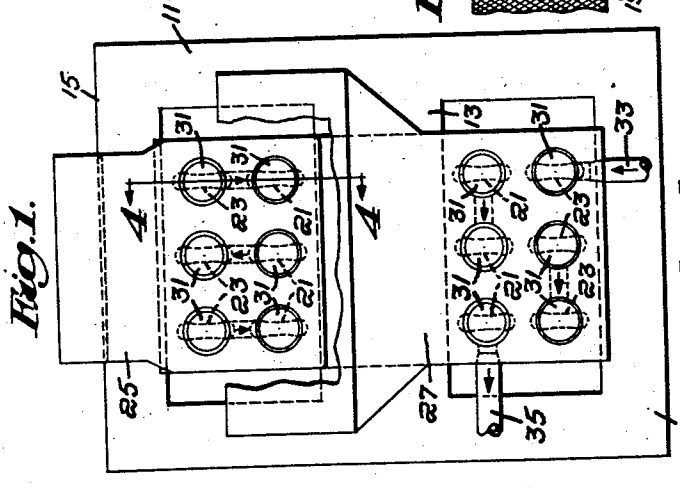


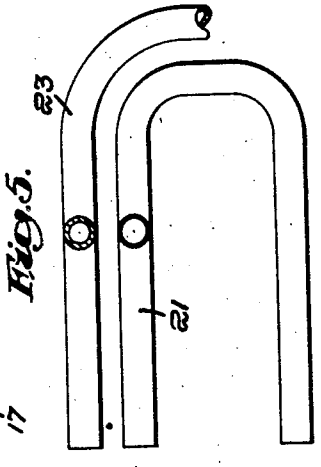












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Patented Nov. 28, 1939 2,181,644

UNITED STATES PATENT OFFICE

2,181,644

ELECTRIC TRANSFORMER

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Application June 2, 1938, Serial No. 211,375

6 Claims. (Cl. 175—356)

This invention relates to electric transformers for use where a secondary current of low voltage and high amperage is required, such, for example, as those employed for resistance welding, and particularly to transformers employing water-cooled tubular conductors for secondary windings. Such transformers, where the tubular conductors are given a flattened or elongated cross section, and when suitably designed and constructed, have the possibilities of marked advantages, in that cooling may be effected by a direct and highly efficient transfer of heat. A relatively great current carrying capacity for the amount of copper employed may be had, together with a reduction in eddy current losses and improvement in the power factor, as well as other advantages.

One object of the invention is the provision of such a transformer of simple form, such as lends itself to practical and relatively inexpensive manufacture, and is best adapted to develop the possible advantages referred to.

These and other objects of the invention will be best understood by reference to the following description when taken in connection with the accompanying illustration of one specific embodiment thereof, while its scope will be more particularly pointed out in the appended claims.

In the drawing:

Figure I is an elevation of a transformer embodying one form of the invention;

Fig. 2 is a side elevation of the same transformer;

Fig. 3 is a cross-sectional detail on the line 3—3 in Fig. 2, showing the shape of the tubular conductors and their relation to the adjoining primary windings;

Fig. 4 is a sectional detail on the line 4—4 in Fig. 1 and on a larger scale, showing one method of attaching the tubular conductor to its terminal;

Fig. 5 is a view showing the inner and outer conducting tubes after being bent but before being flattened;

Fig. 6 shows the inner tube after being flattened; and

Fig. 7 shows a modified form of attachment of the conducting tubes to the terminals.

Referring to the drawing, there is shown in Figs. 1 and 2, for illustrative purposes, one type of transformer embodying certain features of the invention. This is provided with the laminated iron core having the central core member or leg 13 about which are wound the primary and secondary conductors, and the outer yokes or legs 15 and 17. The primary high voltage windings 19 encircle the central leg 13 of the core. Also wound about the central leg of the core, and lying between and in close association with successive groups of the primary windings, are the low voltage secondary conductors 21 and 23, herein in the form of a plurality of hollow water-circulating tubes, preferably of drawn seamless copper tubing to secure the best conductivity. These may each be in the form of a plurality of convolutions, but herein they are each given a hairpin or U-shape form so that they partly encircle the core, leaving the protruding ends of each turn for connection to the terminals.

In the particular form of transformer illustrated, the tubular conductors comprise a series of tubular units 21, herein three in number, each of which constitutes a coil or turn of the secondary winding and has a relatively sharp radius of curvature to lie closely adjacent to but insulated from the central leg 13 of the core. They also comprise a series of three generally similar units 23, each having a larger radius of curvature and positioned to lie each one outside of but in the same plane with one of the tubes 21. Each set of the series constitutes inner and outer secondary turns. While each set comprises two such turns, the transformer, if desired, may be built up with one or more sets, each comprising three or more such turns.

The opposite ends of each of the tubes project out beyond the core and the primary, where each has connection to the secondary terminals 25 and 27 and to water circulating means, as will be more fully described.

These tubular conductors 21 and 23 are so formed that the cross-section of each is elongated or flattened with its longer dimension lying parallel to the plane of the deformed unit and at right angles to the axis of the windings, as indicated in Figs. 3 and 6, while the opposite extreme projecting ends of each tubular unit are left round.

The formation of such unit may be best achieved by first bending the required length of round copper tube, as shown in Fig. 5, with the desired curvature and spacing between the legs, dependent on the size of the transformer and the design of core. In its initial form of rounded cross-section it may be readily given any curved shape required. The tube or coil, after being thus bent, is then subjected to pressure to deform it into a more or less flattened shape, as indicated in Fig. 6, the round cross-sectional shape of the tubular member at and near its extreme ends,

however, being preserved. This cross-section of the ends may be left unflattened and round by inserting in the end of each tube a closely fitting plug before the flattening pressure is applied. The result is a flattened tube bent on its edge with the ends still left round, and presenting an elongated narrow water passage. With the described method of forming the unit, the compressed outer side walls of the tube actually assume a slightly concaved or dished appearance, as indicated in Fig. 3, thereby stiffening the tube against magnetic side thrusts due to magnetic reactions of the primary and secondary currents.

The tubular coil unit flattened in its own plane increases the efficiency of the body of circulating cooling water by bringing it into closer contact with the inner walls of the tube and reduces eddy currents and reactance, while at the same time stiffening the unit against magnetic repulsion set up between the legs of the tube. The round ends of the tube where they project beyond the core and the primary windings, and before connection to the terminals, pass through an insulating yoke 29 which serves as a tie piece to hold them together in their assigned relation, to oppose the effect of magnetic repulsion, tending to force them outwardly, and at the same time provides an insulating support for the terminals.

By providing terminals of suitable form, and cross connected if desired, the described tubular units may be connected in various ways, in either series or multiple relation, both with respect to the path of the secondary current and the path of the circulating water. In the illustrated embodiment of the invention, the upper ends of all the tubes are connected in multiple to a single terminal header 25 of conductive metal and the opposite ends to a second terminal header 27.

The method of connection indicated in Fig. 4 provides a mechanically simple and electrically effective connection in multiple for the ends of the tubes, as well as providing a simple series water circulating system, as will be described. In this construction each terminal has formed in it an outwardly tapered opening, one for the projecting end of each tube, the smaller end of which opening is of a diameter adapted to have inserted therein and receive the rounded end of the tube. A tapered plug 31 is then driven into the open rounded end of the tube, forcibly expanding the walls of the tube into close contact with the walls of the tapered opening in the terminal. This provides a metal to metal joint of good conductivity without the necessity of brazing, and affords an adequate, permanent, mechanical connection between the terminal and the tubular conductor.

Connecting water circulating passages are formed in the walls of the terminals, the plugs and the tubes, as, for example, in the manner indicated in Figs. 1 and 4, where the water is shown as circulating through the tubes in series. As there indicated, the cooling water enters from the bottom of the terminal 27 from the water supply pipe 33 and passes into and through the outer tube 23 of the first set to the upper terminal 25. There it has connection to the end of the inner tube 21 and passes thence through and around the tube 21 to the lower terminal, where it passes to the inner tube 21 of the next pair, thence around the latter tube to the upper terminal, where it passes into the outer tube of the second pair, thence again to the lower terminal where it enters the outer tube of the third pair, thence again to the upper terminal to the inner tube of the third pair, and finally to the lower terminal, where it passes out of the discharge pipe 35.

While the described method of fastening the ends of the tubes to the terminals by means of the tapered plug 31 effectively seals the internal passages against the escape of water, as an additional precaution the joints between the tubes, terminals and plugs may be sealed by an external application of solder, as represented at 37.

By varying the shape and arrangement of the terminals, the tubular turns of the secondary may be connected in multiple, in series or in series multiple as may be required, and by a suitable arrangement of the water passages the cooling water may pass through the separate tubes either in multiple, in series or in series multiple.

Where the secondary comprises an inner turn and one or more successive outer turns, all connected in multiple, each outer turn is preferably formed from a tube having a wall thickness greater than that of the next adjoining inner turn, as indicated in Fig. 5, so as to equalize the resistance of the several turns in multiple and thereby secure uniform heating, current flow and reduce the internal circulating currents.

It will be observed that as assembled the primary windings, which are not shown in Fig. 1 but are indicated in Fig. 3, are arranged in sets or groups, each group being on opposite sides of a single water-carrying tubular secondary, so that the latter has both of its opposite, lateral, flattened sides facing and in close relation to adjacent primary windings.

In Fig. 7 there is illustrated a modified form of attachment for the round ends of the conductor tubes to the terminals. In this case the terminal has formed in it an untapered hole in which the round end of the tubular conductor fits tightly, the open end of the tube being closed by any suitable means, as by the disc-shaped cap piece 39 brazed or soldered in place. The round ends of the tubes may be shrunk in place in the terminals or may be soldered or brazed thereto.

While I have herein shown and described one specific embodiment of the invention, it is to be understood that the same principles may be applied to transformers of various types, sizes and intended for various purposes, and that extensive modifications may be made in the details herein shown of the terminals, the secondary windings, and their connections to the terminals, all without departing from the spirit of the invention.

I claim:

1. In a transformer, a secondary winding having inner and outer turns connected in multiple, each comprising a water-cooled tubular conductor, a conductor constituting an outer turn having walls of greater thickness than the walls of a conductor constituting an inner turn.

2. A transformer having a secondary winding, comprising a fluid-cooled tubular conductor of a hairpin shape consisting of a single unitary length of tubing flattened to provide an internal fluid passage, cross-sectionally elongated in one direction and having ends of round cross-section, primary windings next to and on both opposite flattened sides of the legs of said con-

ductor, separate conductive terminals each having a hole of round cross-section in which the round end of one of the respective legs of said conductor fits and with which it has electrical contact, means for closing each open end of the tube, and means by which cooling fluid is circulated to said tubular conductor through said terminals.

3. A transformer having a secondary winding, comprising a plurality of separate fluid-cooled tubular conductors each of a hairpin shape and consisting each of a single unitary length of tubing, each conductor being flattened to provide an internal fluid passage cross-sectionally elongated in one direction and having ends of round cross-section, the legs of said hairpin tubes being arranged in substantial parallelism, primary windings closely adjacent the flattened sides of the legs of each tubular conductor, a pair of separate conductive terminals to one of which tubular ends of one set of legs are connected and to the other of which tubular ends of the remaining set of legs are electrically connected, and means for supplying cooling fluid to circulate through said conductors.

4. A transformer having a secondary winding, comprising a fluid-cooled tubular conductor of a hairpin shape consisting of a single unitary length of tubing flattened to provide an internal fluid passage, cross-sectionally elongated in one direction and having ends of round cross-section, primary windings closely adjacent the flattened sides of the legs of said conductor, electrically separate secondary conductive terminals each having a hole of round cross-section in which the resepctive free opposite round end of said tubular conductor fits and with the wall of which it has electrical contact, and means for supplying cooling fluid to the said conductor.

5. A transformer having a secondary winding, comprising a fluid-cooled tubular conductor of a hairpin shape, flattened to provide an internal fluid passage cross-sectionally elongated in one direction and having ends of round cross-section, primary windings closely adjacent the flattened sides of the legs of said conductor, electrically separate conductive terminals each having a tapered hole of round cross-section in which the respective round opposite free end of said tubular conductor is secured and in which it closely fits, and means for expanding the open end of the tube in said hole comprising a tapered plug in the end of the tube for forcing the walls of the latter into close fitting conductivity with said terminal, and means for circulating cooling fluid through the interior of said tubular conductor.

6. A transformer having a secondary winding, comprising a fluid-cooled tubular conductor of a hairpin shape, flattened to provide an internal fluid passage cross-sectionally elongated in one direction and having ends of round cross-section, primary windings closely adjacent the flattened sides of the legs of said conductor, electrically separate conductive terminals each having a hole of round cross-section in which the respective end of said tubular conductor is secured and in which it closely fits, and means for closing the open ends of the tube comprising a cap piece fastened over said open end.

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