Aug. 10, 1965 W. OLSEN ETAL 3,200,357

TRANSFORMER COIL CONSTRUCTION

Filed Aug. 23, 1962 2 Sheets-Sheet 1

FIG. 1

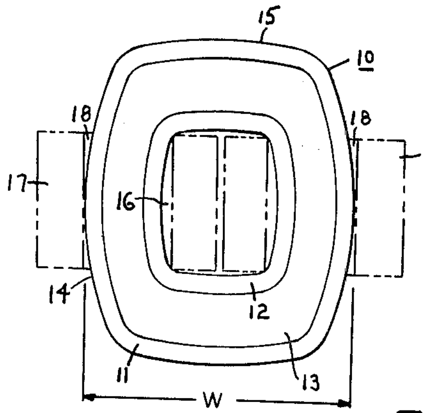


FIG. 2

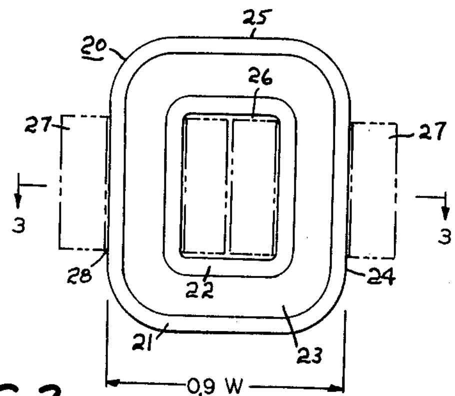


FIG. 3

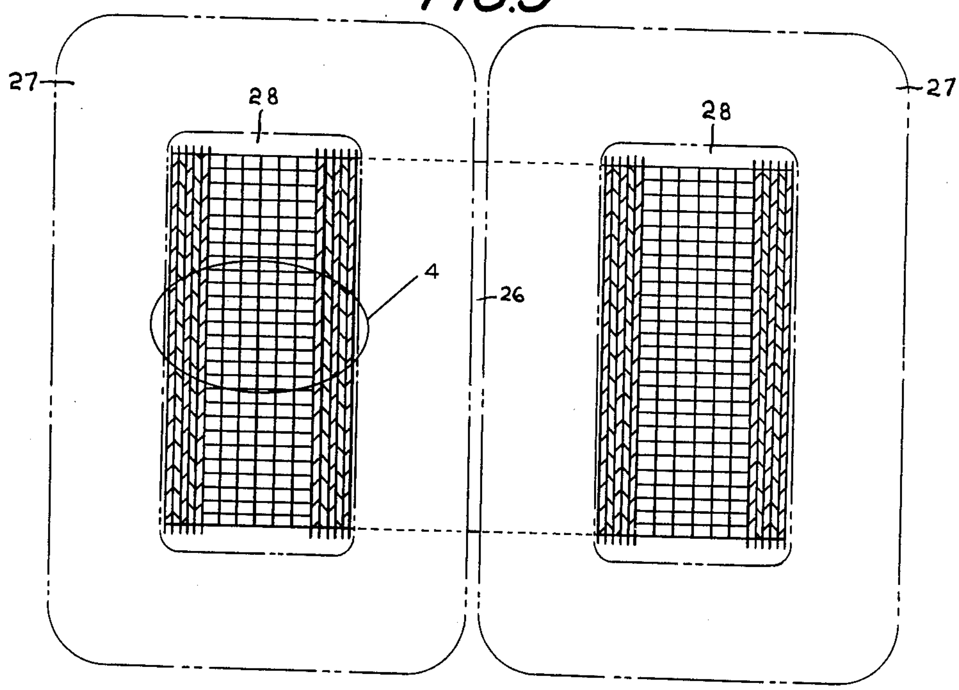
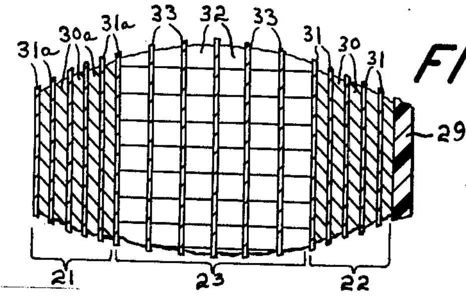


FIG. 4



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2 Sheets-Sheet 2

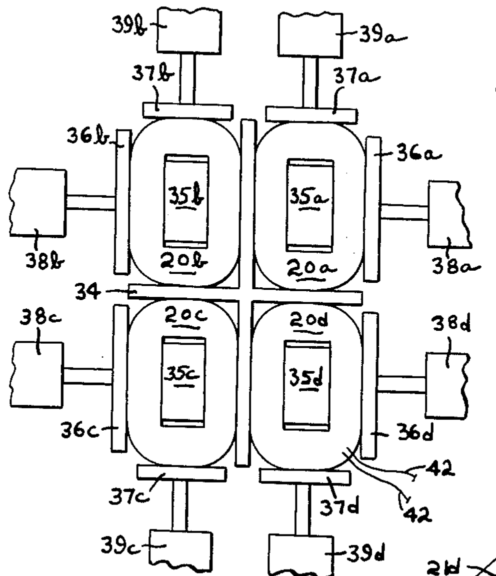


FIG. 5

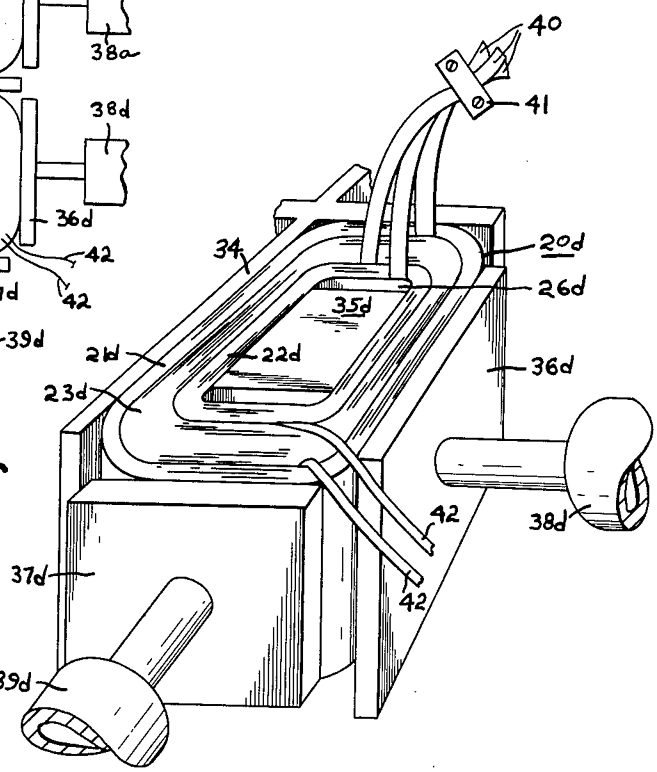
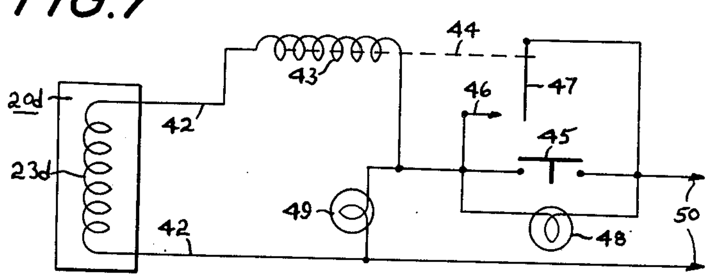


FIG. 6

FIG. 7



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TRANSFORMER COIL CONSTRUCTION

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1 Claim. (Cl. 336—205)

This invention relates generally to the electrical coil structures of inductive devices, and more particularly, relates to pre-formed coil structures having windows therethrough which are normally combined with magnetic core assemblies in which one or more core legs are disposed within the coil window. The composite core and coil assembly may in some cases be a transformer and in other cases be a reactor. Devices of this general type which are suitable for relatively high-power use are usually of some appreciable size and therefore include in their physical make-up a substantial amount of core and coil materials, and in most cases also include an enclosing casework together with an insulating oil bath. Reductions in the size and weight of such inductive devices due to decreases in the amount of material required for manufacture of the device without impairment of the operating characteristics thereof are very important since such reductions represent manufacturing economies.

The instant invention results in such economy by providing a coil structure which is approximately 10 percent narrower in width than conventional coil structures having the same electrical ratings and usable window size. This in turn permits the magnetic cores used with the coil to be somewhat smaller in size, lower in weight and magnetic reluctance by permitting reduction in the amount of core material required, all of which make possible the use of a smaller enclosing tank and reduced volume of insulating oil. Accordingly, it is a primary object of this invention to provide a pre-formed coil structure of substantially reduced width than heretofore to thereby permit the construction of inductive devices of smaller size and weight.

Another object of this invention is to provide a novel method of making the improved coil structure as aforesaid which contemplates modification of the shape of a pre-formed coil structure by subjecting such structure to heat and forming pressure.

Still another object of this invention is to provide a novel pre-formed coil structure for inductive devices which is fabricated with a thermosetting bonding agent between layers of turns and which when subject to heat and forming pressure hold the coil structure in the final shape to which it is pressed.

The foregoing and other objects of the invention will become clear from a reading of the following specification in conjunction with an examination of the appended drawings, wherein:

FIGURE 1 illustrates a centrally windowed coil structure about the side legs of which and through the window thereof are disposed a pair of magnetic cores, the coil legs and yokes being bowed in the manner typical of coils manufactured in the usual way;

FIGURE 2 is similar to FIGURE 1 excepting that the illustrated coil is substantially rectangular in shape as a consequence of formation according to the invention;

FIGURE 3 is a cross-sectional view through the coil and cores of FIGURE 2 as would be seen when viewed along the line 3—3 thereof;

FIGURE 4 is an enlarged fragmentary view of the coil cross-section shown within the phantom ellipse of FIGURE 3 to more clearly illustrate the arrangement of the winding and insulation layers thereof;

FIGURE 5 illustrates in diagrammatic form the press apparatus used for forming the coil structures while subjecting the same to a heating process;

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FIGURE 6 is an enlarged perspective view of one of the coils and part of the press structure seen in diagrammatic plan view in the showing of FIGURE 5; and

FIGURE 7 is an electrical schematic diagram of a relatively simple apparatus for controlling the heating cycle of a pre-formed coil structure which is clamped in the press arrangement of FIGURES 5 and 6.

In these several figures, like elements are denoted by like reference characters.

Considering first FIGURE 1, there will be seen a coil structure generally designated as **10** having outer and inner low voltage windings designated respectively as **11** and **12** separated by a high voltage winding **13**. It is observed that the coil legs **14** and coil yokes **15** are generally bowed out so that the coil window **16** is also somewhat bowed. The non-rectangular shape of the coil **10** requires that the cores **17** be made with windows **18** which are wider than would be necessary if the coil legs **14** were perfectly straight instead of being bowed. FIGURE 2 illustrates a coil **20** similar to the coil **10** in that it also has low voltage windings **21** and **22**, a high voltage winding **23**, and coil legs **24** and yokes **25** which bound an interior central window **26**. The cores **27** shown in phantom are disposed with respect to the coil **20** in the same manner as the cores **17** of FIGURE 1 are disposed with respect to coil **10**. Coil **20**, however differs from coil **10** in that the coil legs **24** and yokes **25** are substantially straight and are not bowed in the manner of the coil legs **14** and yokes **15** of coil **10** shown in FIGURE 1. As a consequence, the cores **27** are of smaller size by virtue of the fact that the windows **28** are smaller than the windows **18** of the cores **17** of FIGURE 1. The rectangular shape of the coil **20** is much preferable to the bowed shape of the coil **10** since the cores **27** can therefore be made smaller and lighter than the comparable cores **17** due to the reduction of about 10 percent in the dimension W as shown.

The narrow width rectangular coil **20** is seen in cross-section in FIGURES 3 and 4, to which reference should now be made, and is built up in the following manner. The low voltage winding **22** closest to the coil window **26** is built up of aluminum strip material **30** interleaved with shellac impregnated paper **31** and wound together upon a coil form **29** of electrically insulating material. The high voltage coil **23** is then wound directly over the low voltage winding **22** and consists of layers of copper wire **32** with the layers separated by insulating paper **33**. The outer low voltage winding **21** is then built right over the high voltage winding **23** in the same manner as for the inner low voltage winding **22**. That is, the aluminum strip **30***a* and shellac impregnated paper **31***a* are interleaved and wound together to form the outer winding **21**. Conductor leads are of course connected to the individual coils at appropriate points and are led out of the winding structure for ultimate connection in the finished inductive device. The finished wound coil has a certain bulkiness due to the springiness of the aluminum strip and copper wire and generally resembles the core **10** shown in FIGURE 1. This non-optimum coil configuration is transformed into the compact rectangular desirable shape of the coil **20** of FIGURE 2 in the manner to be now described in connection with the showings of FIGURES 5, 6 and 7 to which reference should be now made.

The method according to the invention and which is to be described in connection with the apparatus of FIGURES 5 through 7, consists essentially of heating the coil structure to a temperature of approximately 295° F., and while so heated to press the coil to the desired shape and then allow the coil structure to cool while physically held in the press device. The 295° temperature bakes the shellac with which the insulating paper is impregnated without interfering with the insulating value of the paper so that baked shellac adheres strongly to the layers of the winding. With the coil structure pressed into its desired form and allowed to cool while so held, the baked shellac hardens and bonds the coil structure together into rigid form. The coil may then be released from the press and will retain its form as seen in FIGURE 2. The heating operation must be carried on simultaneously with the press forming operation because in the absence of heating the coils would return to their original shape when released from the pressing device.

To carry out the heating, pressing, and cooling aspects of the method within the confines of an oven would be difficult and very time consuming because externally applied heat must be raised in temperature at a very slow rate in order to assure uniform temperature elevation throughout the body of the article being heated since the heat must penetrate into the article by penetration from the outside surfaces inward toward the center of the body. Additionally, of course, such a process also requires the use of an oven structure and a coil forming pressing device which may operate within the confines of the oven. The method according to the invention dispenses with the need for an oven of any sort because the coil to be formed is itself utilized as an electrical heating element. This is effected by short circuiting the low voltage windings and injecting an alternating current into the high voltage winding. A high circulating current will flow in the short circuited low voltage windings due to the transformer action, and this high circulating current together with the current flowing through the high voltage winding rapidly heats up the entire coil structure in a uniform manner. The "setting" temperature within the coil structure which it is desired to achieve may be monitored for example by placing a thermocouple inside the coil which will indicate the temperature condition therein.

A preferred method of monitoring the temperature without requiring access to the interior of the coil is by monitoring the current flowing in either winding, with the heating current being supplied to the coil structure from an essentially constant voltage source. The temperature change in the windings due to the high current flowing therethrough causes the winding resistance to increase with time and to therefore effectively throttle back the current flowing in the windings. By way of illustration, with a particular winding structure as for example of the type illustrated in the drawings, the current flow in the windings may drop to approximately 60 to 70 percent of the initial current for an increase from room temperature to 295° F. of the coil temperature. Thus, by monitoring the magnitude of the current flowing in the coil windings it may be readily determined that the desired temperature has been achieved when the current amplitude decreases to the predetermined value. At this time, the injected current may be turned off and the coil structure cooled to the point where coil rigidity occurs due to hardening of the shellac or other thermosetting bonding agent employed, after which the coil structure may be released from its pressing device.

Referring to FIGURES 5 and 6, there will be seen a fixed position press element 34 in the shape of a cross which is secured to any convenient flat underlying surface. Disposed within the angle formed by each adjacent pair of arms of the fixed press element 34 is a coil structure designated as 20*a*, 20*b*, 20*c* or 20*d*. Disposed within the respective coil windows is a rectangular forming block 35*a*, 35*b*, 35*c* or 35*d*. The outer side surfaces of the leg and yoke of each coil structure which is not engaged by an arm of the press element 34 presents toward the flat face of platens 36 and 37 respectively shiftable by means of the hydraulic cylinders 38 and 39, the platens and cylinders connected with each coil structure being identified with the same letter suffix. For example the platens and cylinders associated with the coil structure 20*a* are identified as platens 36*a* and 37*a*, their associated cylinders being designated as 38*a* and 39*a*, and similarly for the coil structures 35*b*, 35*c* and 35*d*.

Each of the coil structures is compressed into rectangular form by movement of the platens 36 and 37 at right angles toward one another against the confronting coil outer surfaces so that the coil legs are compressed between the arms of the fixed press element 34 and the rectangular forming block 35 and platens 36. The yokes are compressed in the orthogonal direction between the arms of the fixed press element 34 and the platens 37. As best seen in FIGURE 6, the leads 40 of the low voltage windings 21*d* and 22*d* are short circuited together by means of the clip 41, and the high voltage winding leads 42 are connectable to a constant voltage power source indicated by the arrows 50 in FIGURE 7.

As best seen in FIGURE 7, one of the high voltage leads 42 goes directly to the energizing source 50 while the other lead 42 connects to one end of the coil 43 of a solenoid 44, the opposite end of the coil 43 connecting to one terminal of a switch 45 which has its opposite terminal connected to the energizing voltage source 50. Connected across the terminals of the switch 45 are a contact 46 and pole 47 of the solenoid 44, which pole and contact are dis-engaged when the solenoid is de-energized. Also connected across the terminals of the switch 45 is an indicator lamp 48, while a second indicator lamp 49 is connected across the voltage source 50 through the switch 45.

As shown in FIGURE 7, the switch 45 is open, as are the pole and contact 46 and 47 of the relay 44. The impedance of the indicator light 48 is chosen to be very high compared to the impedance of the windings 23*d* and 43 so that substantially the entire voltage of the source 50 drops across the indicator 48 and thereby gives a visual indication that energizing current is not being supplied to the winding 23*d*. When now it is desired to energize the winding 23*d* to raise thte coil structure temperature to the desired level, the switch 45 may be momentarily closed to complete the circuit from the voltage source 50 through the solenoid coil 43 and winding 23*d* to thereby energize the solenoid 44 and close the pole 47 against the contact 46 to bypass the switch 45 and maintain the solenoid energized. The switch 45 may be released immediately since it is now bypassed. The bypassing of switch 45 by pole 47 and contact 46 also bypassing the indicator light 48 which is thereby extinguished, the indicator light 49 then being energized to give a visual indication that heating current is flowing through the winding 23*d* of the coil structure.

By setting the pull-in current of the relay 44 to be somewhat less than the initial current drawn by the winding 23*d*, and by setting the relay drop-out current to be at the desired value between 60 and 70 percent of the current initially drawn by the winding 23*d*, it will be seen that when a desired temperature rise within the coil structure 20*d* has occurred so that the energizing current will have dropped off to the aforedescribed value in the 60 to 70 percent range, the relay 44 will automatically drop out by disconnecting the pole 47 from the contact 46 and thereby open the energizing circuit from the voltage source 50. The indicator 49 will thereupon be extinguished and the indicator 48 will again give a visual indication of the circuit disconnect and thus signal that the heating cycle for this particular coil structure has been completed. The automatic disconnect circuit of FIGURE 7 could of course be replaced by more sophisticated control circuitry, or, if desired can be completely eliminated so that the heating cycle is constantly monitored by service personnel. In the latter case, an ammeter would be put in series with the winding 23*d* and the current reading would be monitored so that the energizing source could be disconnected when the current through the winding dropped to its pre-selected value.

The apparatus of FIGURE 5 is chosen to accommodate four coil structures so that coils may be continuously processed. The configuration results from the fact that about three times the length of time is required for cooling of each coil as is required for heating the coil to the desired temperature. Thus, when coil **20***a* has been installed in the press structure and heated for the necessary length of time, it is left to cool therein while coil **20***b* is installed in the press and connected to the energizing heating source. When coil **20***b* has been heated, the energizing source may be disconnected therefrom and transferred to coil **20***c*, and similarly then thereafter for coil **20***d*. At the termination of the heating time for the coil structure **20***d*, coil **20***a* will have been cooling for a time interval equal to the heating time for coil **20***b* plus coil **20***c* plus coil **20***d*, or a time equal to three heating intervals. It is therefore sufficiently cooled and may be released from the press and a new coil structure may be installed at that position. After the new coil in coil position **20***a* has been heated, coil **20***b* will be ready for removal and replacement with a new coil. Coil structures may thus be continuously processed with no loss of time.

Having now described our invention in connection with a particularly illustrated embodiment thereof it will be appreciated that variations and modifications of the same may now occur from time to time to those persons normally skilled in the art without departing from the essential scope or spirit of our invention, and accordingly it is intended to claim the same broadly as well as specifically as indicated by the appended claim.

What is claimed as new and useful is:

A rigid, unitary, multiple winding electrical coil structure having substantially straight and parallel side legs and a central window for use in inductive devices, comprising in combination, a plurality of concentric internested annular windings radially disposed directly one upon the other with no intervening void spaces, the innermost and outermost radially positioned ones of said plurality of windings each including radially disposed spirally wound unitary layers of electrically continuous foil conductor interleaved by layers of electrical insulating material and a hard setting bonding agent, said interleaved layers of conductor and insulating material being rigidly set in position and bonded together by said bonding agent, at least one of the windings disposed between the said innermost and outermost radially positioned windings including radially disposed layers of conductor wire separated only by intervening layers of electrical insulating material.

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