Dec. 11, 1962 C. H. OLIVER, JR., ET AL 3,068,435

ELECTROMAGNETIC COILS

Filed April 19, 1954 2 Sheets-Sheet 1

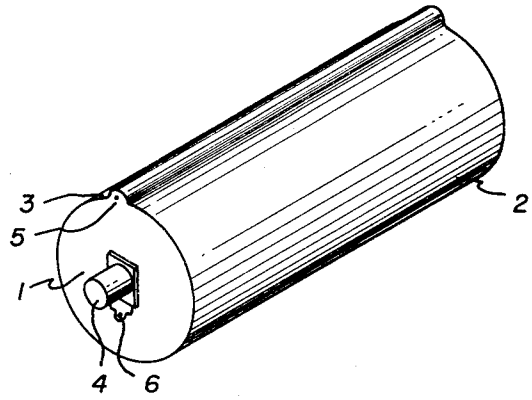

FIG. 1

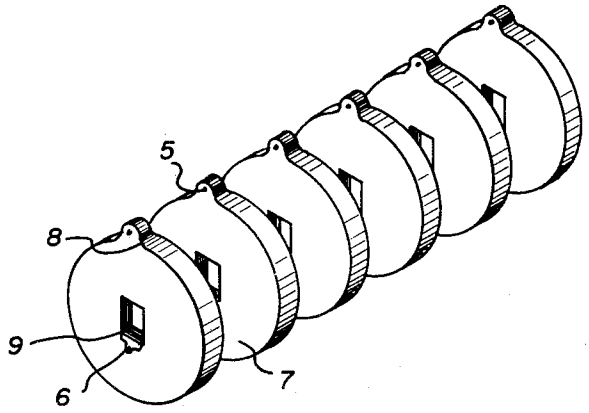

FIG. 2

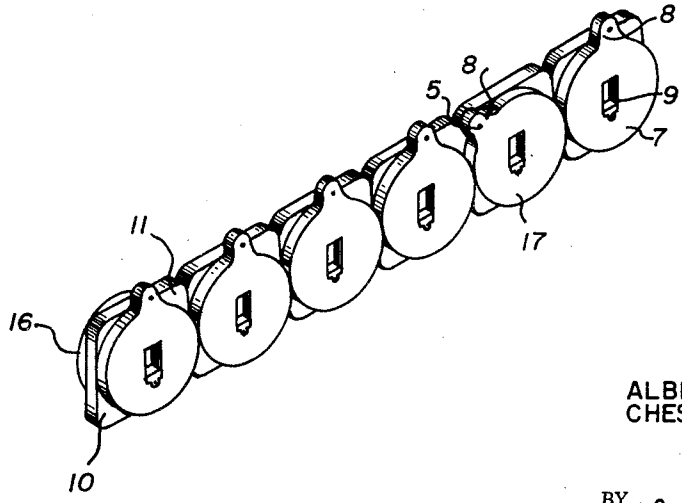

FIG. 3

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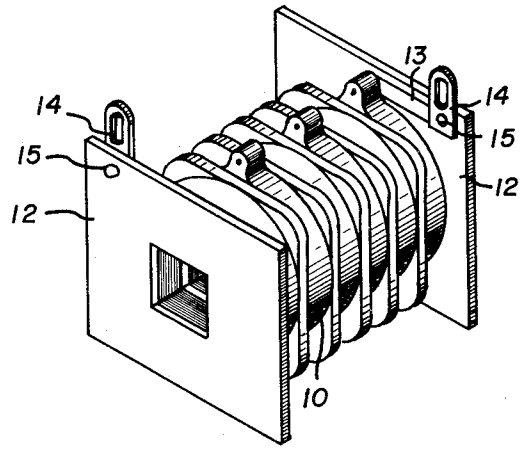

FIG. 4

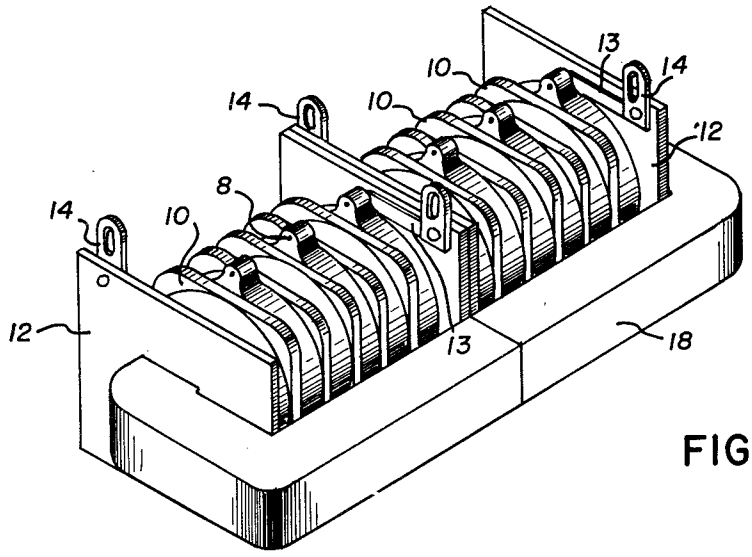

FIG. 5

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ELECTROMAGNETIC COILS

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Filed Apr. 19, 1954, Ser. No. 424,001
2 Claims. (Cl. 336—180)

This invention relates to electromagnetic coils, such as used in magnets, inductances, transformers and the like, and in particular to such coils in association with ferromagnetic cores.

Such coils have generally been made heretofore by winding wire around a form in successive longitudinal layers. The wire was round in cross-section with consequent poor space factor; the use of wire of rectangular cross-section was impractical because of twisting and the the like during the winding.

The present invention provides spiral coils, one turn wide, of metal strip or foil, insulated and stacked together, on a ferromagnetic core if desired. Such a device is better adapted to automatic manufacture than are the conventional types of present day electromagnetic devices.

The thinness of the strip or foil which can be used, and especially the thinness of the insulating layer between turn and between coils, improves the space factor so much over conventional coils that aluminum can often be used as the conducting material instead of copper, with no increase in resistance or geometrical size of the finished device.

Other features, objects and advantages of the invention will be apparent from the following specification in which:

FIG. 1 shows a sheet of metal and a sheet of insulating material rolled together on a core;

FIG. 2 shows coils sliced from the roll;

FIG. 3 shows the coils attached to an insulating strip;

FIG. 4 shows the coils stacked together with spacers;

FIG. 5 shows two such stacks of coils placed adjacent each other, with a closed iron core, extending through the centers of the stacks to form a transformer.

The roll **1** of foil **2** and paper **3**, or of foil covered with an insulating coating, is wound on the core **4**, which can be of insulating material, and which extends out of the roll **1**, for convenience in holding during the subsequent slicing. The core **4** can then be held in a chuck and rotated while a cutting blade is inserted into the roll to slice off thin spiral coils **7** from the wide spiral of the roll **1**, as in copending application Serial No. 401,333, filed December 30, 1953, by Albert Zack.

Before the slicing operation, the outside end of the foil **2** can be wrapped around a metal wire **5** which extends longitudinally along the roll **1** as shown in FIG. 1, for example. Before the winding operation, the inner end of the foil was wrapped similarly around a metal wire **6** on core **4**. After the slicing operation, the ends of the coils **7** thus present terminal areas **8, 9** suitable for soldering connections between the coils.

Before being sliced, the wound roll **1** can be impregnated or heat-sealed in wax, plastic, ceramic, glass, or other suitable insulating material, as shown, for example in the copending application to which reference has been made above, or can be set by drying of a solvent, as with lacquer or the like, or by the use of a catalyst, as with epoxy resins.

As in FIG. 3, the sliced coils **7** are attached to the insulating strip **10**, which may be of insulating paper or plastic, for example cellulose acetate, by an adhesive. The strip can then be cut laterally between the coils, for example along the line **11**, which can be scored before

the coils are attached, if desired. The coils can then be stacked together so that an insulating piece **10**, originally part of the insulating strip, is between each coil and the next, as shown in FIG. 4. A larger insulating piece **12** is set at the end of the stack of coils and connections **13** made to a tab **14**, riveted to the insulating piece **12**, by rivet **15** and connected to one of the terminals **8, 9** of the adjacent coil **7**, through the metallic connecting strip **13**.

The coils **7** are then connected in series by connections from one of the terminals **8, 9** of one coil to one of the terminals of the next. If the coils are all stacked with their windings in the same directions, then the inner terminal **9** of one coil **7** is connected to the outer terminal of the adjacent coil **7**. If the coils are stacked so that the windings of adjacent coils are in opposite directions, then the two inner terminals **9, 9** of the first two coils are connected together, then the two outer terminals of the second and third coils, and so forth.

The interconnection can be made by soldering or welding wires to the proper terminals **8, 9** taking care that the connecting wires are insulated from the turns of the coil. In some cases, as shown in FIGS. 4 and 5, it is desirable to put the outside terminal of one coil at the top of the winding, and the outside terminals of the next coil on the bottom, and so forth. In that case, to facilitate the making of the connections to the inside terminals **9**, two types of coil can be used, the coils **7** in which the terminals **8, 9** are on opposite sides of the core **4** and the coil **16**, shown at one end of strip **11** in FIG. 3, in which both terminals **8, 9** are on the same side of the core. Then when the terminal **8** is turned down from the position shown in the figure, the terminals **9** of coils **7** and **16** will line up and a connecting wire or strip can be run right through the strip **11**, through an opening in register with the terminals **8** on each side of the strip. In this case, for the voltages in the two coils **7, 16** to be in series-aiding relationship, their windings should be in opposite directions.

The strip **11** could then be made up with one set of coils **16** on its back portion and another set of coils **7** on its front portion, the front and back coils **7, 16**, being connected together as described above from terminal **9** of one to terminal **9** of the other. When the strip is cut along the line **11**, pairs of coils **7, 16** will result. The pairs can then be stacked as in FIGS. 4 and 5, with an insulating piece between each pair.

Instead of having the inside terminal **9** on opposite sides of the core in coil **16** than in coil **7**, it will generally be simpler to have the outer terminal **8** on the second set of coils **16** a few degrees different in circumferential position from that on coils **7**, as indicated in phantom on coil **17**, in FIG. 5. The inside terminals **8, 8** will then line up as before and can be connected through the strip **10**, and the outer terminals will be spaced apart a convenient angular distance, for example 15°, to facilitate connections to the next coil on each side of the pair when stacked.

The spacers **10** can be quite thin when the voltage between adjacent coils **7, 7** is low, an ordinary sheet of cellulose acetate one-mil thick often being sufficient. In that case the coils can be fastened to a cellulose acetate strip, connections made between coils and the sheet then folded up like an accordion to stack the coils. In other cases, by applying to the coils a thin insulating coating, for example of aluminum oxide or of a plastic such as epoxy resin, the spacers **10** can be eliminated.

FIGURE 5 shows two coils assemblies as in FIG. 4, mounted side by side on a closed iron core to form a transformer, one stack of coils being the primary winding of the transformer, the other the secondary. The core

18 is, of course, made up of iron laminations in the usual manner, although if desired it can be made of ferromagnetic powder held together by a binder such as the epoxy resin mentioned in copending application of Albert Zack and Theodore Wroblewski for Electromagnetic coils, Serial No. 423,370, filed on April 15, 1954.

Instead of having the primary and secondary windings in separate stacks, the primary and secondary coils can be interleaved, that is, the coils can be stacked and connected so that the first coil is a primary, the next a secondary, the next a primary, then another secondary, and so forth. Of course, if desired, one coil could be a primary, the next two coils secondaries, the next coil a primary, the next two secondaries, and so forth. Various such combinations can be made. When such interleaving of the primary and secondary coils is used, the coils can be assembled on a flexible prefabricated strip, for example cellulose acetate, and connections from the coil fixed to the strip and extending outsidewards from the strip, to facilitate connection of the coils.

Where the words, "top" and "bottom" are used in the foregoing, they refer merely to the top and bottom, respectively, of the device as oriented in the figures.

What we claim is:

1. An electromagnetic device comprising a ferromagnetic core, a series of one-turn wide, self-supporting spiral coils of conducting strip stacked on said core, insulating material between said coils and separate from the supporting structure of said coils, each said coil having an inner and an outer terminal, adjacent coils being wound in opposite directions, the outer terminal being in a portion of the coil projecting from the remainder of the coil,

the inner terminals being in register with each other and the outer terminals of adjacent coils being out of register with each other.

2. An electromagnetic device comprising a ferromagnetic core, a series of one-turn wide, self-supporting spiral coils of conducting strip stacked on said core, insulating material between said coils, each coil having an inner and an outer terminal, the inner terminals being in register with each other, the outer terminals of alternate coils being in register with each other but out of register with the outer terminals of the other coils to facilitate connections.

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