June 3, 1952 Q. A. KERNS 2,599,182

PULSE TYPE TRANSFORMER

Filed June 21, 1949 2 SHEETS—SHEET 1

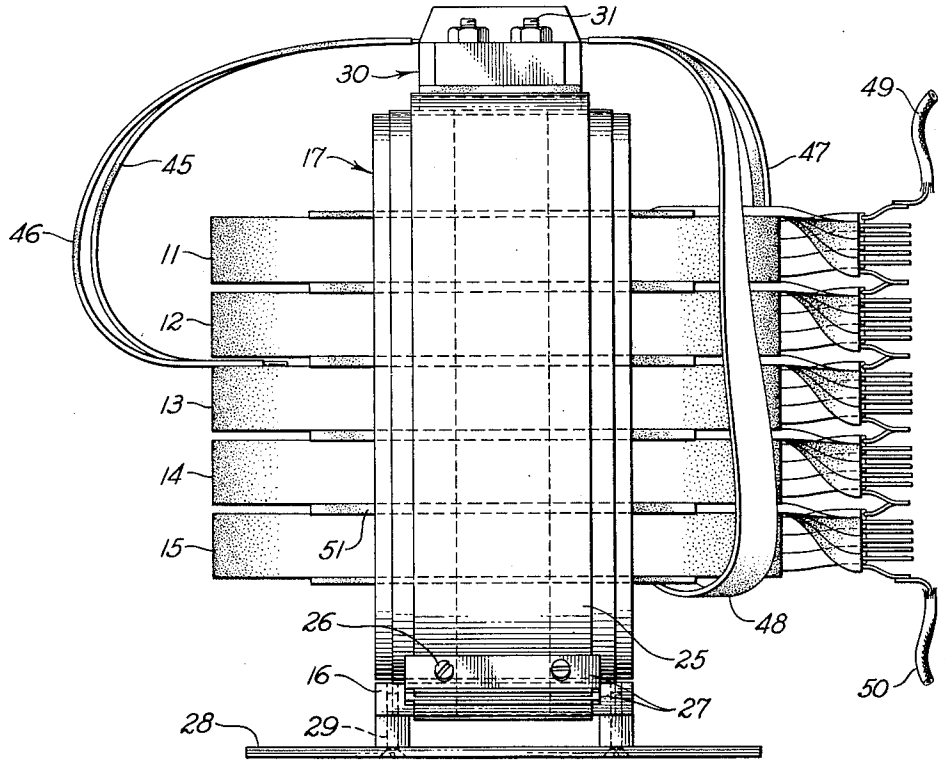


Fig. 1.

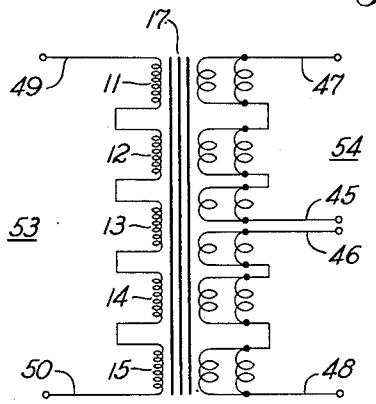


Fig. 5.

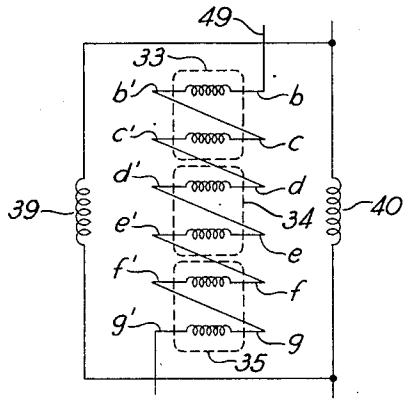


Fig. 4.

INVENTOR.
QUENTIN A. KERNS

BY

Roland A. Anderson

ATTORNEY.

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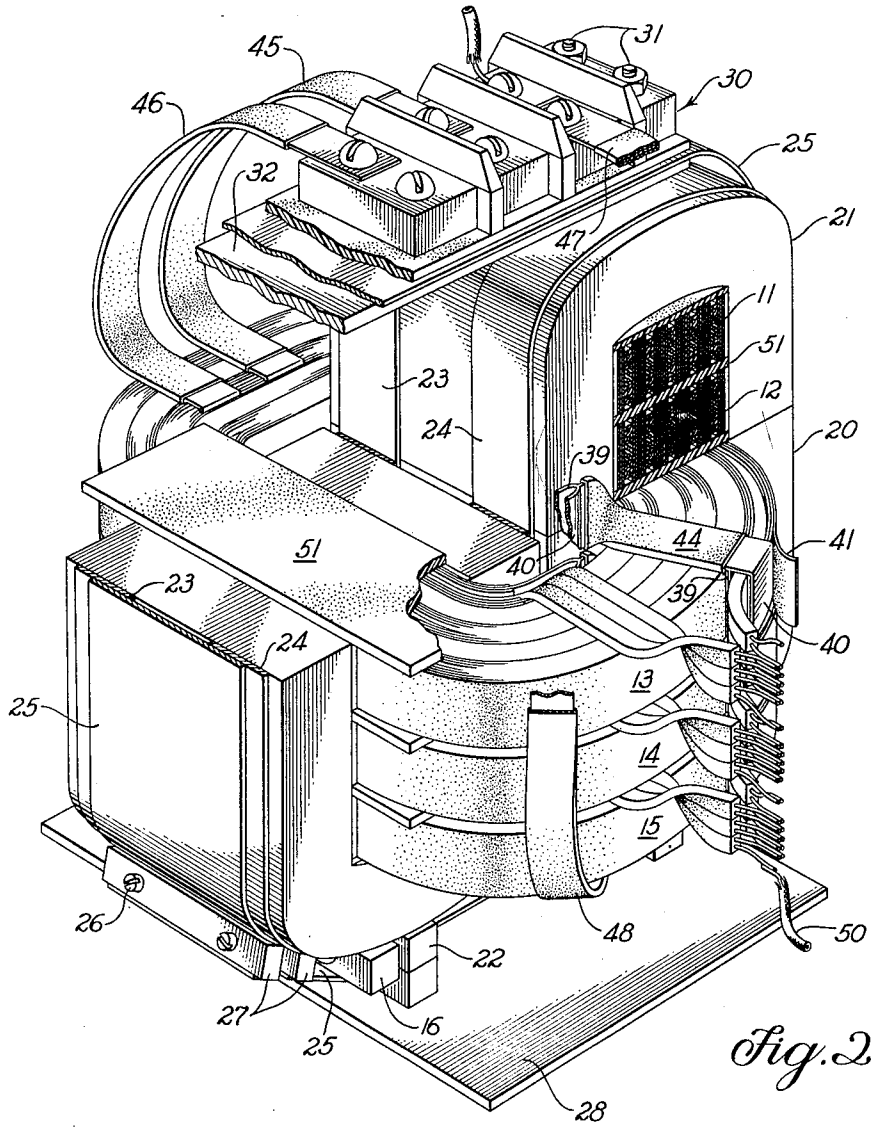


Fig. 2.

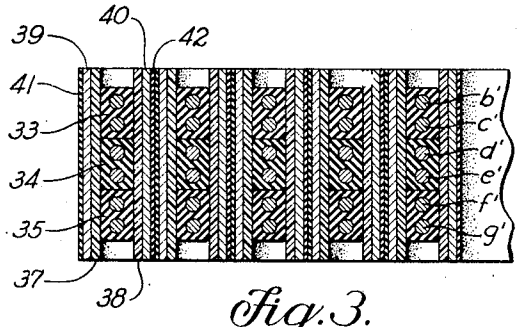


Fig. 3.

INVENTOR.
QUENTIN A. KERNS

BY

Roland A. Anderson

ATTORNEY.

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PULSE TYPE TRANSFORMER

Quentin A. Kerns, Oakland, Calif., assignor to the United States of America as represented by the United States Atomic Energy Commission

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6 Claims. (Cl. 175—356)

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This invention relates to transformers, and especially to low leakage reactance pulse transformers, having conjointly wound composite primary and secondary windings of low capacitance, and capable of providing any desired ratio of transformation. Further, the invention relates to a new and improved method for making such transformers.

Heretofore, the conventional transformers of the class described having conjointly wound primary and secondary windings also had large intrawinding and interwinding capacitances, a ratio of transformation of only unity, and consisted of only a single coil. Such transformer construction likewise had no voltage or current magnification, and the large capacitance of its windings distorted voltage pulses of short duration, such as a pulse of one microsecond. In addition, its impedance matching was also made somewhat difficult, since the conductors in the winding had to be relatively small if high impedances were desired. In contrast thereto, the present invention allows the simple and convenient construction of a low leakage reactance transformer with any desired ratio of transformation. Furthermore, it has been found that the utilization of a plurality of conjointly wound coils with an insulation having a low dielectric strength causes the transformer to inherently possess low capacitance windings and permits a wider latitude in the choice of impedances without resort to high resistance windings.

It is, therefore, an object of the present invention to provide a low leakage reactance pulse transformer of low capacitance having a composite primary and secondary winding.

A further object is to provide a low capacitance transformer capable of passing voltage pulses with little or no distortion.

Another object of the invention is to provide a transformer with a conjointly wound primary and secondary coil having any desired ratio of transformation.

A further object is to provide an improved method for winding a low leakage reactance pulse transformer having a compositely wound primary and secondary coil.

Still another object is to provide an improved low leakage reactance pulse transformer having a plurality of series connected, compositely wound coils.

Still a further object is to provide a low leakage reactance pulse transformer which is easily constructed and assembled.

Other objects and advantages of the invention

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will become more apparent when considered in conjunction with the following description and drawings, in which:

Figure 1 is an elevation view of a preferred embodiment of the invention;

Fig. 2 is a perspective view, partly in section, of the embodiment shown in Fig. 1;

Fig. 3 is an enlarged sectional view of one of the coils of Fig. 1 and disclosing the physical arrangement of the windings in accordance with the invention;

Fig. 4 is a schematic diagram disclosing the electrical connections of an individual coil; and

Fig. 5 is a schematic diagram disclosing the manner of connecting together the individual coils.

In the drawings, Figs. 1 and 2 disclose an assembled transformer structure having five parallel coils 11, 12, 13, 14, and 15 coaxially disposed in layers on a laminated ferromagnetic shell-type core indicated generally at 17 and comprising two core units, each of which is further divided into two mating sections, such as indicated at 20 and 21 on the right-handmost core unit in Fig. 2, for convenience of assembly, as will be more fully explained hereinafter. After assembly of the coils in each of the core units, the lower and upper portions of the units, such as the mating sections 20 and 21, are bound together with two steel inner straps such as indicated at 23 and 24. These straps pass around the upper and lower parts of their respective core units and securely clamp the upper and lower parts into a solid unit. The ends of the straps are clamped together in any conventional manner. For example, in the present embodiment the ends of the straps are attached to rectangular strap blocks such as indicated at 16 and 22 (shown in part in Fig. 2 for the leftmost core unit) and the blocks drawn together with bolts (not shown). After individual assembly of both core units of the transformer in this manner, another wider steel outer strap 25 preferably is used to bind together the two separate core units and to form the single rigid core indicated as 17. Strap 25 surrounds both cores and the ends thereof may be attached to a pair of somewhat smaller rectangular blocks 27 and may be tightened by means of a pair of screws 26. Thereafter the entire core assembly is attached to a base plate 28 by means of screws 29 between the base plate 28 and adjacent strap blocks, as for example, the strap block 22, shown in Fig. 2. Thereafter, a terminal block 30 is attached to the top of the assembled core by bolts 31 which pass through the wide outer strap 25

and fasten to a brass plate 32 previously positioned under strap 25.

Having now disclosed the structural relationship of the parts of my invention, the unique features of the transformer coils and connections will be considered. Each coil of the transformer is conjointly wound with the same electrically conductive materials as a composite spiral coil containing a primary winding 53 (Fig. 5) and a secondary winding 54. Fig. 3 shows an enlarged cross section of a preferred arrangement of the conductors in one of the coils. In such an embodiment the primary winding may consist of three flat insulated cables 33, 34, and 35. Each of such cables is of the adjacent parallel conductor type used in the transmission of microwave voltages and contains two circular cross-sectional conductors moldably imbedded in polyethylene insulation, for example. The three cables 33, 34, and 35 are arranged in superposition so that the conductors lie in a single plane. Two layers of insulation such as polystyrene 37 and 38 are then disposed one on each side of the superposed cables of the primary. Next, a secondary winding consisting of two layers of thin copper tape 39 and 40 at least as wide as the combined width of the three cables are disposed one on each side of the insulation 37, 38 so as to substantially surround the primary winding. Finally, two more layers of insulating material such as polystyrene 41 and 42 are disposed one on each side of the copper tape in the order shown in Fig. 3. Having thus provided the components of a single turn of composite winding, this unitary winding is then spirally wound into the desired shape of coil on a coil form which provides a central aperture in the coil just large enough to fit on the central portion of core 17. Due to the fact that the turns 39 and 40 of the secondary winding substantially surround the cables 33, 34 and 35 of the primary winding, practically all of the magnetic flux generated by current flowing through the primary winding links with the copper tapes of the secondary. This close linkage provides a high transformer efficiency and low leakage reactance.

Before assembly of the spirally wound coils on core 17, the inner ends of the copper tapes 39 and 40 of each coil are first connected together, the end of tape 40 being suitably bent to lie adjacent the end of tape 39 and the resultant single terminal thus formed is then connected in series with the similarly connected outer terminals of copper tapes 39 and 40 of an adjacent coil by insulated intercoil conductors of the type indicated by copper strip 44 which is surrounded by insulating material. The intercoil conductors, as for example, strip 44 serve not only to connect the inner terminals of copper tapes 39 and 40 of coil 12 with the outer terminals of the corresponding copper tapes of coil 13 but serve also to make electrical contact between the conjointly would tapes 39 and 40 of each coil, thus precluding the possibility of a voltage differential between the two parallel tapes. If desired, the coper tapes 39 and 40 of the middle coil 13 may be separated at their center and brought out to the terminal block 30 with a pair of mid-tap connecting strips 45 and 46. The secondary winding may, thereby, be divided into two halves to permit convenient doubling of the ratio of transformation, if such be desired. Doubling of the ratio of transformation is performed by connecting the two halves of the secondary winding in parallel instead of series, as will be readily understood.

Fig. 4 illustrates one suitable form of the connections of the primary winding of one of the coils which consists of the two-conductor cables 33, 34, and 35 connected in series. The method of making the cable conductor connections is indicated wherein *b*, *c*, *d*, *e*, *f*, and *g* are the outer ends of the conductors in the cables 33, 34, and 35, and *b'*, *c'*, *d'*, *e'*, *f'* and *g'* are the inner ends of the corresponding conductors in each of the cables. Thus, if we let Fig. 4 diagrammatically represent the upper coil 11, the first outer conductor terminal *b* (49) of cable 33 is connected to one of the primary connections on the terminal block 30. From the inside of coil 11, the inner conductor ends *b'*, *c'*, *d'*, *e'*, *f'*, and *g'* are bent up upwardly and are brought out over the top of coil 11 in side by side relation as shown in Fig. 2 and placed alongside the outer conductor ends of coil 11. The terminal connections are then made by soldering the inner terminals to the outer terminals as follows: *b'* to *c*, *c'* to *d*, *d'* to *e*, *e'* to *f*, *f'* to *g* and *g'* to the outer first or b conductor terminal of the adjacent coil 12. The successive electrical connections are made consecutively in the above manner for the remainder of the coils until the final inner g' conductor terminal 50 alone of bottom coil 15 remains unconnected. This latter *g'* terminal 50 is connected to the other primary connection on terminal block 30. The above connections of the primary conductors provide six primary turns for each secondary turn in each of the transformer coils. Hence, the ratio of transformation for each coil is six to one, i. e., the voltage measured on the secondary is one-sixth as large as that applied to the primary. If a greater number of primary conductors were used, the ratio of transformation would be larger, and hence any desired ratio of transformation desired is possible, limited only by the physical size of the coils.

Fig. 5 discloses the connections between the individual transformer coils 11, 12, 13, 14, and 15. The primary winding represented by 53 and the secondary winding represented by 54 are shown on opposite sides of core 17. It may be seen that the primary winding 53 is a group of single windings in series, whereas the secondary 54 is a group of double paralleled windings connected in series and discontinuous at the center. The middle secondary group, corresponding to the coil 13 (Figs. 1 and 2) is split in half, and the two mid-tap connections 45 and 46 are brought out of the winding for connection to the terminal block. When mid-tap connections 45 and 46 are connected together, the secondary winding 54 is, of course, effectively connected in series. The two halves of the secondary 54 may be connected in parallel by connecting lead 46 to lead 47 and lead 45 to lead 48; the effective number of secondary turns are thus halved and the ratio of transformation may thus be doubled. These latter secondary changes may conveniently be made at the terminal block 30. The primary terminal 49 corresponding to the outer terminal *b* of coil 11 and a primary terminal 50 corresponding to the inner terminal *g'* of coil 15 are connected to the terminal block 30 (Figs. 1 and 2) as previously indicated.

In the preferred method of assembling the several composite coils 11, 12, 13, 14, and 15 of the transformer, the coils are first correctly aligned and coaxially spaced on some rigid support such

as a bench. The terminals of the copper tapes **39** and **40** of the secondary portion of each coil are then connected in series and the mid-tap leads **45** and **46** brought out from between the composite coils **12** and **13**. Next, the inner terminals *b'*, *c'*, *d'*, *e'*, *f'*, and *g'* of the primary cables of each of the coils is brought out from the inside of the coils and electrically connected by soldering to their respective outer terminal connections as previously described above. The entire group of the five coils is then slipped over the central portion of the two lower sections of core **17**. Insulating strips such as indicated at **51** formed, for example, of cambric tape or other suitable dielectric material are slipped between the coils on each side of the core **17** to prevent the possibility of short circuits between coils. The upper portions of the core units are next rigidly clamped in place with two steel straps such as **23** and **24**. The brass plate **32** and the two upper core units are then clamped together with the wide steel strap **25**. Terminal block **30** is next bolted to the brass plate **32** at the top of the transformer and the base plate **28** is fastened by screws **29** to the strap blocks at the bottom of the transformer. Finally, the primary terminals **49** and **50**, the secondary terminals **47** and **48**, and the mid-tap leads **45** and **46** are attached to the terminal block **30**.

In a preferred embodiment of the invention as illustrated in Figs. 1 and 2, very satisfactory performance of the apparatus has been obtained when the core **17** is made up of two two-part adjacent ferromagnetic cores formed of strips of ferromagnetic material .002'' thick. The secondary **54** consists of two sets of parallel, ½'' wide, .010'' thick copper tapes wound conjointly with three sets of flat, two-conductor, polyethylene insulated, 75 ohm, high-frequency transmission cable as the primary winding **53**. Between the primary and secondary windings and between adjacent turns thereof are ½'' wide strips of polystyrene insulation. Since the conductors of the three primary cables of each coil are effectively connected in series, whereas the copper strips of the secondary are connected in parallel, the ratio of transformation of voltage in each coil is six to one referred from the primary to the secondary. Connecting the primaries of all the coils in series and the secondaries of all of the coils in series does not affect the ratio of transformation of the transformer, but does change the transformer impedance. The interwinding capacitance of the above transformer embodiment is only about .005 microfarads, and the transmission of square wave pulses of one to 100 microseconds duration is possible with little distortion. Application to the primary winding **53** of electrical pulses of 4 amperes and 5 kilovolts yields a correspondingly pulsed output at the terminals **47** and **48** of secondary winding **54** of about 24 amperes at 800 volts. The leakage inductance due to magnetic flux of the primary winding which does not link with the secondary winding is about 55 microhenries for the primary and about 1.5 microhenries for the secondary. This is a reduction of leakage inductance by a factor of approximately 10 as compared with a conventionally wound transformer having the same ratio of transformation. Such efficient flux linkage is due to the proximity and consequent efficient flux linkage of the secondary tapes **39** and **40** with the primary cables **33**, **34**, and **35**.

It will be apparent to one skilled in the art that modifications in the arrangement of parts may be made within the spirit of my invention, and I do not wish to be limited otherwise than by the scope of the appended claims.

I claim as my invention:

1. A low leakage inductance pulse transformer comprising a magnetic core, a plurality of coils mounted on said core, each of said coils having a primary and a secondary winding, said primary winding having a plurality of continuous mutually insulated conductors aligned transversely to the direction of continuity thereof in stacked array, extended as a spiral of equal radius of curvature for each of said conductors, and continued for a predetermined number of spaced turns about a portion of said core, said secondary winding having a pair of insulated parallel-connected, strap conductors also extended as a spiral and interleaved, one on each side of said stacked primary conductors, between said spaced turns with the width of said straps parallel to said primary conductors, the ends of said primary conductors of each coil being interconnected to form a single primary winding, the primary winding of each coil being connected in series with the primary winding of each adjacent coil, and the secondary winding of each coil being connected in series with the secondary winding of each adjacent coil.

2. In a low leakage inductance pulse transformer having a magnetic core, a plurality of coils mounted on said core, each of said coils containing a primary and a secondary winding, said primary winding having a plurality of continuous mutually insulated conductors aligned transversely to the direction of continuity thereof in stacked array, extended as a spiral of equal radius of curvature for each of said conductors, and continued for a predetermined number of spaced turns about a portion of said core, said secondary winding having a pair of parallel-connected strap conductors also extended as a spiral and interleaved, one on each side of said stacked primary conductors, between said spaced turns with the width of said straps parallel to said primary conductors, a low dielectric strength insulation disposed between said primary conductors and said strap conductors and between adjacent portions of said strap conductors, the ends of said primary conductors of each coil being interconnected to form a single primary winding, the primary winding of each coil being connected in series with the primary winding of each adjacent coil, and the secondary winding of each coil being connected in series with the secondary winding of each adjacent coil.

3. In a low leakage inductance pulse transformer, the combination comprising a primary winding having a plurality of continuous mutually insulated conductors aligned transversely to the direction of continuity thereof in stacked array, extended as a spiral of equal radius of curvature for each of said conductors, and continued for a predetermined number of spaced turns about a central opening, a secondary winding having a pair of insulated, parallel-connected, strap conductors also extended as a spiral and interleaved, one on each side of said stacked primary conductors, between said spaced turns with the width of said straps parallel to said primary conductors, the ends of said primary conductors being interconnected to form a single electrical path, and a magnetic core having a portion thereof extended through said central

opening and surrounding a portion of said primary and secondary windings.

4. In a low leakage inductance pulse transformer, the combination comprising a primary winding having a plurality of parallel disposed conductors in stacked array, said stacked conductors being separated by an insulating material, extended as a spiral with a similar radius of curvature for each of said stacked conductors, and continued for a predetermined number of spaced turns about a central opening, a secondary winding having a pair of parallel-connected strap conductors also extended as a spiral and interleaved, one on each side of said stacked conductors, between said spaced turns with the width of said strap conductors parallel to said stacked conductors, said strap conductors being separated from said stacked conductors and from each other by an insulating material having a low dielectric constant, the ends of said primary conductors being interconnected to form a single electrical path, and a magnetic core having a portion thereof extended through said central opening and surrounding a portion of said primary and secondary windings.

5. In a lower leakage inductance pulse transformer, the combination comprising a plurality of coils each having a primary and a secondary winding, said primary winding having a plurality of continuous mutually insulated conductors aligned transversely to the direction of continuity thereof in stacked array, extended as a spiral of equal radius of curvature for each of said conductors, and continued for a predetermined number of spaced turns about a central opening, a secondary winding having a pair of insulated, parallel-connected, strap conductors with a width dimension substantially equal to the height of said stacked primary conductors also extended as a spiral and interleaved, one on each side of said stacked primary conductors, between said spaced turns with said width dimension parallel to said primary conductors, the ends of said primary conductors being interconnected to form a single primary winding, the primary winding of each coil being connected in series with the primary winding of each adjacent coil, the secondary winding of each coil being connected in series with the secondary winding of each adjacent coil, and a magnetic core having a portion thereof extended through the central openings of said coils.

6. In a low leakage inductance pulse transformer, the combination comprising a plurality of coils each having a primary and a secondary winding, said primary winding having a plurality of parallel disposed conductors in stacked array, said stacked conductors being separated by an insulating material, extended as a spiral with a similar radius of curvature for each of said stacked conductors, and continued for a predetermined number of spaced turns about a central opening, said secondary winding having a pair of insulated, parallel-connected, strap conductors also extended as a spiral and interleaved, one on each side of said stacked conductors, between said spaced turns with the width of said strap conductors parallel to said stacked conductors, the ends of said primary conductors being interconnected to form a single electrical path, a magnetic core having two sections each comprising two opposing C-shaped structures, and means for clamping said core structures about diametrically opposite portions of said coils with a portion of each extended through said central openings.

QUENTIN A. KERNS.

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