June 13, 1950 S. WALD 2,511,230

HIGH-VOLTAGE INDUCTANCE COIL

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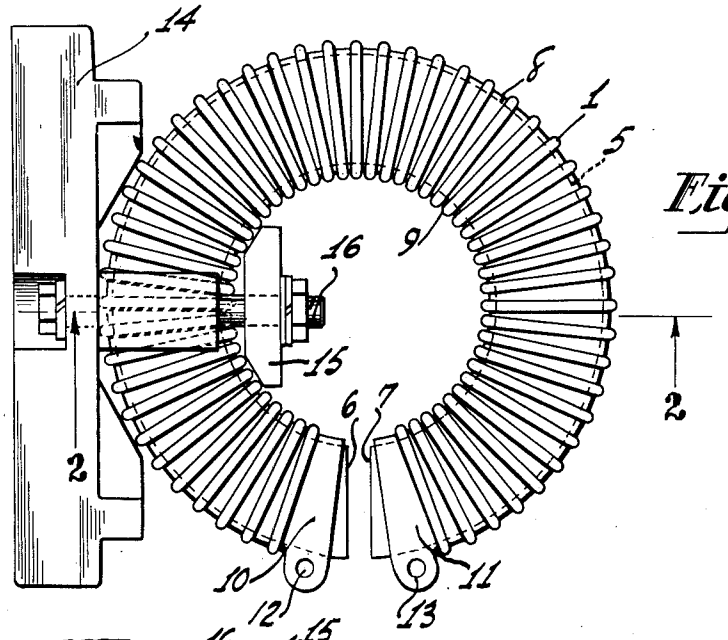


Fig. 1.

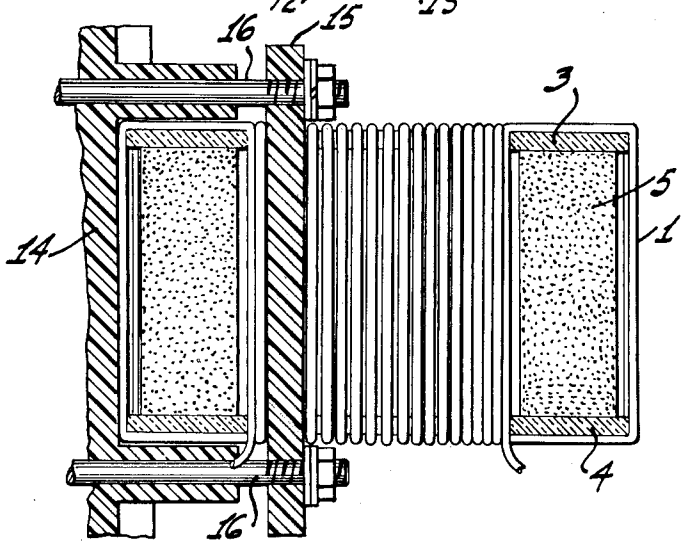


Fig. 2.

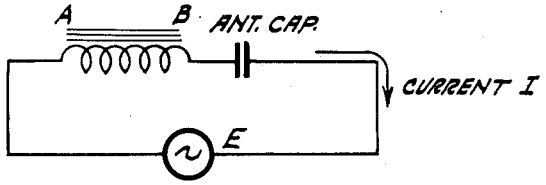


Fig. 3.

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Fig. 4.

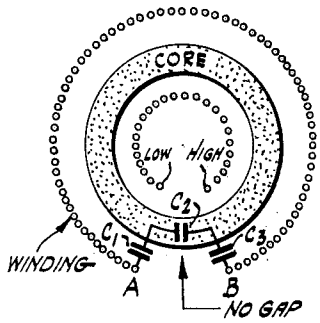


Fig. 4a.

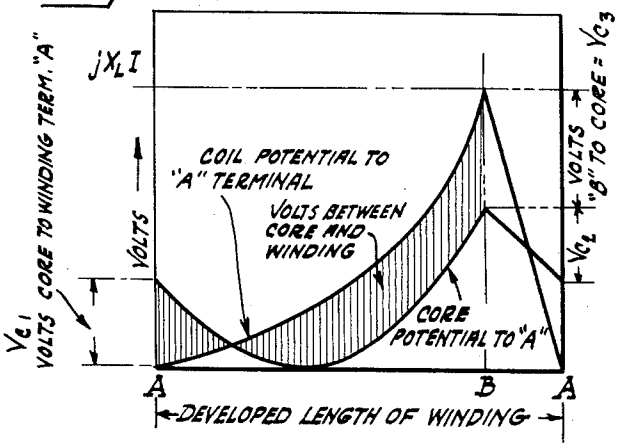


Fig. 5.

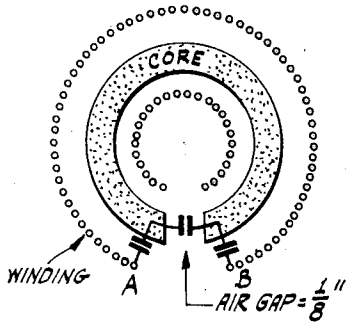


Fig. 5a.

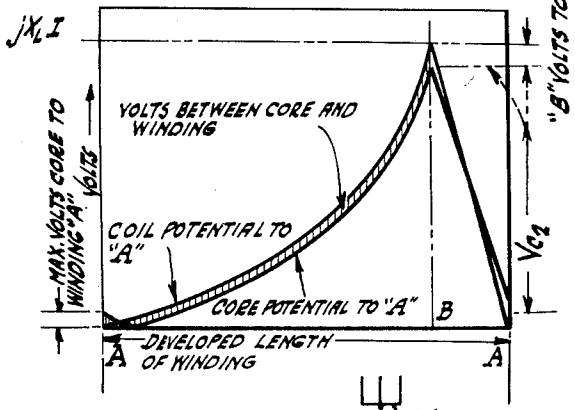
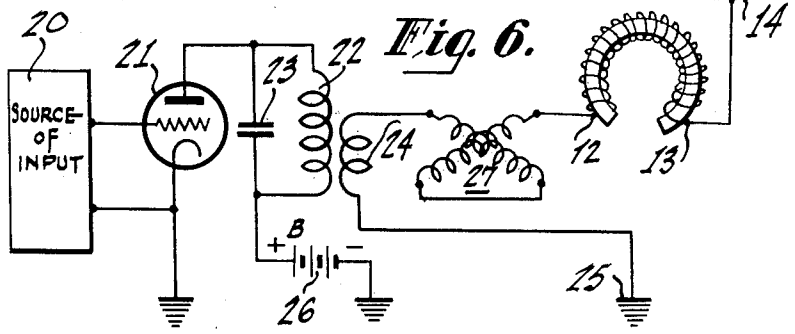


Fig. 6.



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HIGH-VOLTAGE INDUCTANCE COIL

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8 Claims. (Cl. 175—359)

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This invention relates to inductors and particularly pertains to a compact toroidal inductance coil for high frequency and high voltage transmitting circuits.

An object of this invention is to provide a novel compact inductance coil having high inductance, low frequency losses, and negligible external stray fields. The inductance coil of this invention is suitable for high voltage lines without danger of corona or breakdown.

Another object of this invention is to provide an improved antenna load coil for a radio transmitter operated at high radio frequency voltages.

These and other objects of this invention which will appear as the specification progresses are attained by an inductor having a powdered iron dust core which is cylindrical in shape and wound with a single layer spaced winding of bare copper wire, spaced a substantial distance from the core by means of two insulating spacing members. The core is provided with an air gap which is so located between the ends of the winding that all the electrical stress is transferred from the wire to the core, where it is then concentrated between the faces of the air gap. With this improved construction, the iron core will have a potential gradient therealong approximately the same as that of the winding, thus reducing the potential difference to a low value.

This invention will be more apparent from the following description of the drawings, in which:

Fig. 1 is a plan view of a coil according to this invention;

Fig. 2 is a cross-sectional view of the coil shown in Fig. 1, the section being taken on lines 2—2 of Fig. 1;

Fig. 3 is a schematic diagram useful in explaining the coil potential distribution;

Fig. 4 is a sectional view of a toroidal coil having a core with no air gap;

Fig. 4A is a curve showing the coil potential along the developed length of the winding for the arrangement shown in Fig. 4;

Fig. 5 is a sectional view of a toroidal inductor according to this invention;

Fig. 5A is a curve showing the coil potential along the developed length of the winding for the arrangement of Fig. 5; and

Fig. 6 is a circuit diagram showing a use of the coil of this invention.

Referring to the drawings now in detail, the high voltage winding 1 is space wound upon two thick spacers 3 and 4 of insulation material, preferably of high grade ceramic material. Interposed between spacers 3 and 4 is a member 5 of

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comminuted magnetic material, preferably that known as powdered iron, which forms the core of the coil. The core 5 is preferably of annular disc form and is provided with an air gap as shown between core faces 6 and 7. As will be explained later, the air gap is arranged to place the coil winding at approximately the same potential as the core at all times. The inner and outer edges of the spacers 3 and 4 are notched at 8 and 9 to retain the individual turns of the coil winding in spaced radial relationship from each other and from the core 5. The wire ends of the coil winding are terminated at 12 and 13 by any suitable means, such as having the ends of the coil soldered into holes in the ceramic spacer the walls of which are copperplated, or, if desired, by terminal screws (not shown). The coil winding is supported by means of an insulating base 14, a yoke 15 which is also of insulation material, and two bolts 16 which pass through the yoke at each end of the coil and are bolted into base 14.

Fig. 3 shows a schematic diagram which comprises a toroidal coil having terminals A and B. The coil is connected to an antenna capacity and a suitable current indicating meter E. This schematic diagram represents the circuit arrangement set up to explain how the electrical stress is transferred from the wire to the core to the face of the air gap of the core.

In Figs. 4, 4A, 5 and 5A of the drawings, C1 and C3 represent the air gap or spacing between the winding and the dust core. This spacing must be small in order to realize the high inductance and high Q of which a toroid is inherently capable. C2 represents the capacitance of the volume of iron core material included between terminals A and B. Thus, in the structure of Fig. 4 if the whole coil voltage at resonance is 7,000 volts, the latter is divided between C1, C2 and C3 in series. Of course, the longer path around the coil is likewise across this same voltage, but its capacitance is relatively small and may be ignored. Due to the high permittivity of powdered iron (about 30), the capacitance C2 is roughly seventeen times that of C1 or C3. Therefore, the voltage appearing across C1 is about 3,400, plus 3,400 for C3, plus 200 for C2 or 7,000 volts total.

The approximate distribution of potential around the ring is shown pictorially in Fig. 4 of the drawings. It will be seen that the core is far from the potential of the winding at any point. This condition which causes arcing and corona at high altitude is obviously undesirable. Fig. 4A

graphically shows the difference in potential between the core and the winding of the arrangement of Fig. 4.

Fig. 5 illustrates the result of this invention which includes a one-eighth inch air gap cut in the same toroidal core as shown in Fig. 4. This gap forms the capacitive coupling C2 which is located between the core terminals A and B. A novel feature of this invention is that the electrostatic potential between any two points is inversely proportional to the capacity between them. Electrically, C2 is now less than C1 or C3, using the same voltage as in the example of Fig. 4. There will be about 6,000 volts across the iron core gap and 500 volts each across C1 and C3. That is, the electrical capacity of C1 is about twelve times C2 which results in the voltage stress at the terminals being about twelve times less than the voltage stress at the opposed faces of the core air gap. This is the opposite effect from that which was obtained in the arrangement of Fig. 4. Graphically, the result is as shown in Fig. 5A, and the core potential stress is reduced so that it is now closely that of the winding all around the ring. There is always some slight residual potential between core and winding. However, it can always be made small enough to be harmless.

The inductance coil of this invention has been found particularly desirable for high frequency aircraft transmitter applications. In one antenna coil which was constructed and tested the core was approximately two inches outside diameter, one and one-quarter inches inside diameter, with an air gap of one-eighth of an inch wide, and one inch in height, and the winding consisted of about fifty turns of #18 B & S gage tin plated copper wire. On a heat run at high currents and voltages, it was found to efficiently operate at 2000 kilocycles with a current of approximately five amperes. The frequency range was from 200 to 3000 kilocycles. The temperature range was from 55° C. to +85° C. The distributed capacity with a one-eighth inch slot equaled 5 micromicrofarads. With such an iron core antenna coil, an inductance of 40 microhenries and a Q average above 400 was obtained. The peak modulated potential across the coil under these conditions was approximately 5400 volts.

Referring now in detail to Fig. 6 of the drawing which shows the use of the coil of this invention in a radio transmitter: The circuit comprises an input source 20; an electron discharge tube 21 having the usual anode, grid and cathode electrodes; and an output circuit connected to the anode of tube 21. The output circuit includes an inductance 22, a condenser 23, and a coupling coil 24. One end of the coupling coil 24 is connected through a variable inductance 27 to terminal 12 of the load coil of this invention. The terminal 13 connects to an antenna 14. The other end of coupling coil 24 is connected to ground 25. The lower end of coil 22 is connected to a source of positive plate potential 26. The antenna circuit is adjusted to maximum efficiency by means of the adjustable variable inductance 27. The inductance of 27 is of very small inductance value compared to the inductance of the fixed series high voltage load coil of this invention.

What is claimed is:

1. A high frequency high voltage inductance coil comprising an incomplete annular core of powdered iron having an air gap forming opposed faces, a space wound inductance coil surrounding a substantial portion of said core but not said gap, said coil being spaced from said core to form a capacitive coupling therewith, the width of said air gap being of such dimensions as to provide a smaller capacity between the opposed faces of the air gap than the capacity between the coil winding and the core whereby the difference in potential between said core and said coil winding at any point along said core is substantially zero.

2. A high frequency high voltage toroidal wound inductance coil comprising an incomplete annular core of powdered iron having an air gap forming opposed faces, a radial spaced wound inductance coil surrounding a substantial portion of said core with the coil ends located adjacent the edges of the air gap in said core, said coil being spaced from said core to form a capacitive coupling therewith, the width of said air gap being of such dimensions as to provide a smaller capacity between the opposed faces of the air gap than the capacity between the coil winding and the core, whereby the potential difference between the core and the coil winding at any point along said core is substantially zero.

3. A high frequency high voltage inductance coil comprising a core of powdered iron, having end faces and arranged in an incomplete geometrical configuration with said end faces in opposing relationship to form closed and open portions, a space wound inductance coil surrounding a substantial portion of the closed portion of said core, means spacing said coil from said core to form a capacitive coupling therebetween, the open portion of said core having dimensions at which a smaller capacity is provided between the end faces of said core than the capacity provided between the coil winding and the core, whereby the potential difference between the core and the coil at any point along said core is substantially zero.

4. An inductor comprising a core member of comminuted magnetic material arranged to define a hollow, substantially closed, geometrical figure having a discontinuity extending transversely through one side thereof to form an air gap between opposing core faces, and an elongated conductor wound in a toroidal configuration about said core member to form a winding, the individual turns of said winding being spaced from each other, from said air gap and from said core member, the spacing of said conductor from said core and the dimensions of said air gap having values at which the capacity across said air gap is less than the capacity between said conductor and said core whereby the difference in potential between said core and said coil winding at any point along said core is substantially zero.

5. An inductor comprising a substantially closed loop member of comminuted magnetic material having a discontinuity extending transversely therethrough and an elongated conductor space wound in toroidal configuration about a substantial part of said loop member to form a winding, the individual turns of said winding being spaced from said loop member, the spacing of said conductor from said loop and the dimensions at said discontinuity having values at which the capacity across said discontinuity is less than the capacity between said conductor and said loop whereby the difference in potential between said core and said coil winding at any point along said core is substantially zero.

6. An inductor comprising a core of comminuted magnetic material arranged in the form of a tubular member having a slot in one side thereof, annular insulation discs arranged on each end of said tubular member, a space wound coil surrounding a substantial portion of said discs and of said tubular member but not said slot, the transverse dimensions of discs being greater than the transverse dimensions of said tubular member whereby said coil is spaced therefrom, the capacity resulting from the spacing of said coil from said tubular member being greater than the capacity across said slot whereby the difference in potential between said core and said coil winding at any point along said core is substantially zero.

7. An inductor comprising a core of powdered iron arranged in the form of a hollow tubular member having a slot in one side thereof, annular ceramic discs arranged on each end of said tubular member, said discs having notches along at least one edge thereof, a coil space wound in said notches and surrounding a substantial portion of said discs and of said tubular member but not said slot, the transverse dimensions of discs being greater than the transverse dimensions of said tubular member whereby said coil is spaced therefrom, the capacity resulting from the spacing of said coil from said tubular member being greater than the capacity across said slot whereby the difference in potential between said core and said coil winding at any point along said core is substantially zero.

8. A high frequency high voltage toroidal wound inductance coil comprising an incomplete annular core of powdered iron having an air gap forming opposed faces, annular ceramic spacing members arranged one on each side of said core, a radial spaced wound inductance coil arranged on said spacers and surrounding a substantial portion of said core with the coil ends located adjacent the edges of the air gap in said core, said coil being spaced from said core by said spacers to form a capacitive coupling therewith, the width of said air gap having dimensions at which a smaller capacity is produced between the opposed faces of the air gap than the capacity produced between the coil winding and the core, whereby the difference in potential between said core and said coil winding at any point along said core is substantially zero.

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