Dec. 20, 1932. P. F. SCOFIELD 1,891,481

INDUCTANCE COIL

Filed Feb. 24, 1931

Fig. 1.

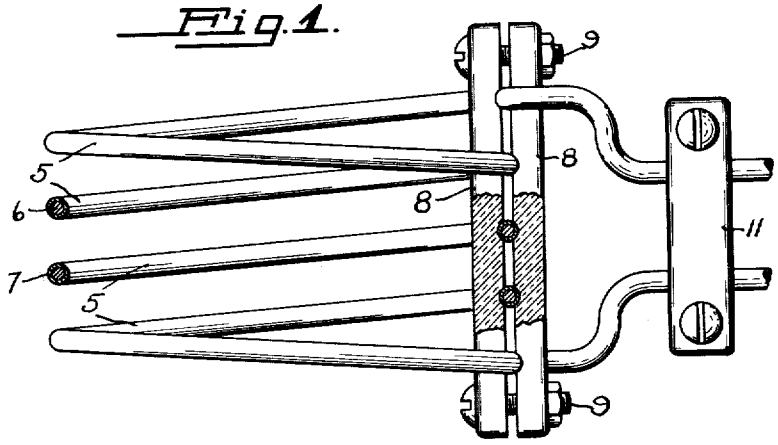


Fig. 2.

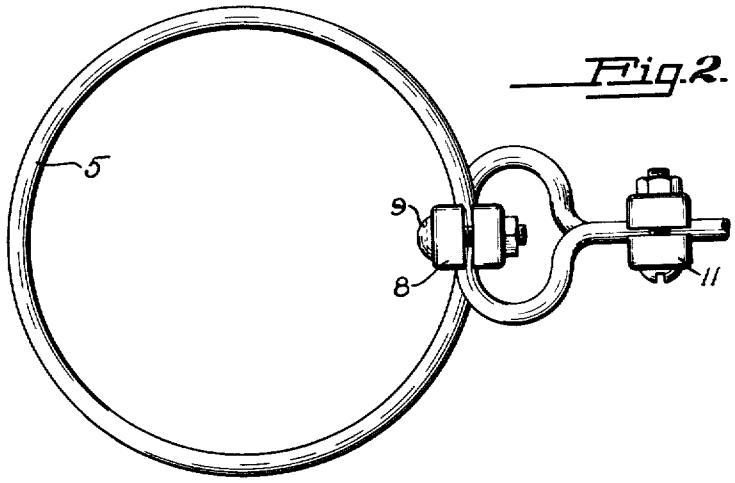
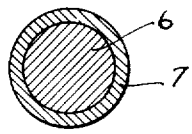


Fig. 3.



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Patented Dec. 20, 1932 1,891,481

UNITED STATES PATENT OFFICE

PHILIP F. SCOFIELD, OF PALO ALTO, CALIFORNIA, ASSIGNOR TO HEINTZ & KAUFMAN, LTD., OF SAN FRANCISCO, CALIFORNIA, A CORPORATION OF NEVADA

INDUCTANCE COIL

Application filed February 24, 1931. Serial No. 517,851.

My invention relates to inductance coils, and particularly to such coils as are adapted for use in the oscillating circuits of wave meters, standard frequency oscillators, and other services wherein it is desirable or essential that the constants of the circuit remain fixed regardless of variation in temperature or other working conditions.

Among the objects of my invention are: First, to provide an inductance whose variation with temperature is practically nil; second, to provide a coil having a relatively low resistance at radio frequencies; third, to provide a coil which may be cheaply and easily constructed from readily obtainable materials; and fourth, to provide a coil which is rigid and self-supporting.

Other objects of my invention will be apparent or will be specifically pointed out in the description forming a part of this specification, but I do not limit myself to the embodiment of my invention herein described, as various forms may be adopted within the scope of the claims.

Referring to the drawing:

Figure 1 is an elevation and Figure 2 is a plan view of an inductance coil made in accordance with my invention, portions of Figure 1 being cut away in the drawing to show the construction.

Figure 3 is a cross-section of the conductor used in the coil.

The inductance of any conductor depends both upon the length of the conductor, upon its cross-section, and particularly upon its disposition relative to other conductors with which it is magnetically linked. The usefulness of an inductor in an oscillating circuit also demands that it have low resistance. It is further desirable that it be compact, not only for purely mechanical reasons, but also to reduce accidental linkages with other circuits. For these reasons it is customary to form inductors as helices or spirals, so that each element of the conductor may be linked magnetically with as many other elements as possible, thus reducing the length and therefore the resistance of conductor required to give a given inductance.

All of the materials having high conductivity have also relatively large coefficients of thermal expansion. A rise in temperature of the coil therefore increases its inductance, not merely in direct proportion to its increase in length, but also by increasing the flux linkages with the other turns of the coil.

Where the inductor is made a portion of an oscillating circuit which must be operated as nearly as possible at a standard frequency, or one which is used to measure frequency, as in a wave meter, it is necessary that such coils as those described be operated under carefully predetermined thermal conditions, in order that errors due to temperature variations shall not be introduced. In cases where temperature control boxes will not give the required results, i. e., in inductances for radio transmitters of such power that a material amount of heat is generated in the coils themselves, such devices as water-cooling have been introduced to maintain the temperature substantially constant.

Broadly considered, this invention comprises an inductance coil wherein the conductor is formed of a core which has a substantially zero coefficient of linear expansion, surrounded by a shell or jacket of high conductive material such as copper, which material may also have a relatively high coefficient of thermal expansion. Such a conductor, when used in a radio frequency circuit, carries substantially all of the current in its highly conducting shell, and its resistance is therefore not measurably different from that of a solid conductor. Moreover, the conductor has two coefficients of expansion; a linear coefficient of expansion which is but slightly greater than that of the core, and a diametral coefficient of expansion which is markedly greater. Since the inductance of the conductor decreases with increase in diameter, these two coefficients of expansion serve to neutralize each other, so that the thermal coefficient of inductance of the completed coil may be made substantially zero.

The particular form of inductor shown in the drawing is a self-supporting coil of a type applicable to transmitting circuits. It will be understood that the same principle may be applied to coils of fine wire wound

on forms, such as are frequently used in wave meters and other low power circuits, the difference merely being one of dimension and not of principle.

Describing in detail the coil shown in the drawing, it comprises a plurality of turns 5 of wire or rod comprising a core 6 (see Figure 3) which is preferably of the nickel steel alloy which is known commercially as "invar", and which is composed of approximately 36% of nickel and 64% of iron. Such an alloy may be obtained having a coefficient of thermal expansion which is about $.8\times10^{-6}$ per degree C., and which may even be negative over a limited temperature range in selected samples.

Surrounding this core and welded or brazed thereto is a shell 7 which is preferably of copper or other highly conductive material. This shell or jacket has a relatively high coefficient of expansion, but since the core has a much greater mechanical strength than the shell, and since the shell is fixed rigidly to the core, the resulting conductor has a linear coefficient which is extremely small, the highly expansive copper being constrained by the more rigid steel core.

The volumetric coefficient of expansion of the copper remains, however, unchanged, and the composite conductor retains an appreciable diametral coefficient of expansion, which is greater than the linear expansion of that portion of the conductor which is formed of copper would be were the copper unstressed.

The coil is held by a pair of clamps 8, preferably of fused quartz, which is also a material having a negligible coefficient of expansion. The quartz clamps may be retained in position by bolts 9. A similar pair of clamps 11 is shown as positioning the terminals of the coil.

In practice, the extremely slight linear coefficient of expansion, which tends to increase the inductance of the coil, is offset by the diametral coefficient which decreases the inductance. Moreover, although the core material is of high resistance and is magnetic, its net effect at high frequencies is sensibly zero, and experience has shown that these inductance coils operate over wide temperature ranges even more accurately than water-cooled coils, and practically as accurately as light duty coils operated under thermal control.

I am aware that composite wires of the type described have been used as lead-ins in electric lamps and elsewhere, as a substitute for platinum. In these cases, however, the effort has been to give the compound wire a diametral coefficient of expansion equal to glass, and the difference between the diametral and longitudinal coefficients of expansion has been ignored.

In the present invention it is the negligible linear coefficient of expansion which is the dominant factor, the diametral coefficient serving merely to give a second order correction.

A modified form of my invention which is particularly useful in circuits operating at very high frequencies, utilizes a core 6 formed by a fused quartz rod, formed into a helix, and having a conductive shell plated thereon. In appearance this form of coil may be identical with that already described, the difference residing in the materials and dimensions only. The shell 7 may be of copper, but for this service I prefer to use silver, depositing the initial coat by one of the well known processes which are used for forming mirrors.

Thus, the quartz helix may be introduced into a warm solution of silver nitrate and ammonia, and a reducing agent such as Rochelle salt, tartaric acid, or glucose added. This forms a firmly adherent coat of silver, upon which as thick a layer of silver or copper as is desired may be electroplated.

Since the skin effect at high frequencies is very great, a relatively thin shell is ample to supply the greatest possible conductance, and owing to the great rigidity of the quartz as compared to the metal coating the longitudinal expansion of the conductor is practically that of the fused quartz; i. e., about $.26\times10^{-6}$ per degree C., as compared to about 17×10^{-6} for copper or silver. A relatively thin shell of metal will give the diametral expansion to compensate for this.

Other low expansion cores, such as "Pyrex" or "Nonex" glass may be used where the conditions are less rigorous.

I claim:

1. An inductor comprising a conductor disposed in a coil of at least one turn, said conductor having a core of material having a low coefficient of thermal expansion fixed to a shell of conducting material having a high electrical conductivity and a relatively high coefficient of expansion.

2. An inductance coil comprising a conductor having a core of nickel steel of negligible coefficient of expansion and a copper shell fixed to said core.

3. An inductor comprising a conductor disposed in a coil of at least one turn and having a plurality of layers, said conductor having a combined diametral coefficient of thermal expansion which is relatively great as compared to the combined longitudinal coefficient of thermal expansion thereof.

4. In an inductance coil, a conductor having a relatively low longitudinal coefficient of expansion and a relatively high diametral coefficient of expansion, and means for maintaining said coil in its predetermined form, said means comprising a material whose dimensions are substantially unaffected by temperature.

5. An inductor comprising a conductor dis-

posed in a coil of at least one turn, said conductor having a core of relatively low coefficient of expansion and high rigidity, and a conducting shell fixed to said core and constrained thereby against expansion in the direction of the length of the core.

6. An inductor comprising a conductor disposed in a coil of at least one turn, said conductor having a core of nonconducting material having a low coefficient of thermal expansion fixed to a shell of conducting material having a high electrical conductivity and a relatively high coefficient of thermal expansion.

7. An inductance coil characterized by having a substantially constant inductance under varying temperatures, comprising at least one turn of a quartz rod plated with metal of high conductivity and having a high coefficient of thermal expansion.

8. The method of maintaining the inductance of a coiled conductor having a shell of material of a high coefficient of thermal expansion constant under varying temperatures, which comprises restricting the longitudinal expansion of said shell without interfering with the diametrical expansion of said shell.

In testimony whereof, I have hereunto set my hand.

PHILIP F. SCOFIELD.

DISCLAIMER

1,891,481.—*Philip F. Scofield*, Palo Alto, Calif. INDUCTANCE COIL. Patent dated December 20, 1932. Disclaimer filed December 2, 1935, by the patentee.

Hereby enters this disclaimer to claims 1, 5, and 6 of said Letters Patent which are in the following words, to wit:

"1. An inductor comprising a conductor disposed in a coil of at least one turn, said conductor having a core of material having a low coefficient of thermal expansion fixed to a shell of conducting material having a high electrical conductivity and a relatively high coefficient of expansion."

"5. An inductor comprising a conductor disposed in a coil of at least one turn, said conductor having a core of relatively low coefficient of expansion and high rigidity, and a conducting shell fixed to said core and constrained thereby against expansion in the direction of the length of the core.

"6. An inductor comprising a conductor disposed in a coil of at least one turn, said conductor having a core of nonconducting material having a low coefficient of thermal expansion fixed to a shell of conducting material having a high electrical conductivity and a relatively high coefficient of thermal expansion."

[*Official Gazette January 14, 1936.*]

posed in a coil of at least one turn, said conductor having a core of relatively low coefficient of expansion and high rigidity, and a conducting shell fixed to said core and constrained thereby against expansion in the direction of the length of the core.

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"6. An inductor comprising a conductor disposed in a coil of at least one turn, said conductor having a core of nonconducting material having a low coefficient of thermal expansion fixed to a shell of conducting material having a high electrical conductivity and a relatively high coefficient of thermal expansion."

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