Oct. 6, 1953 A. S. KHOURI 2,654,861

INDUCTANCE UNIT

Filed June 4, 1948

FIG. 1.

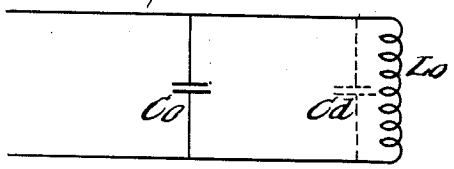
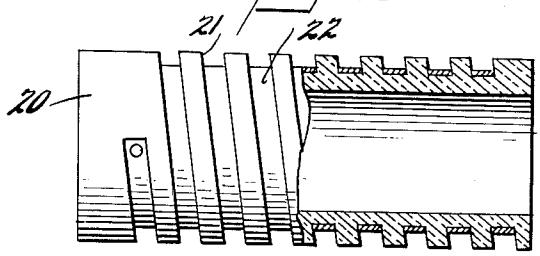
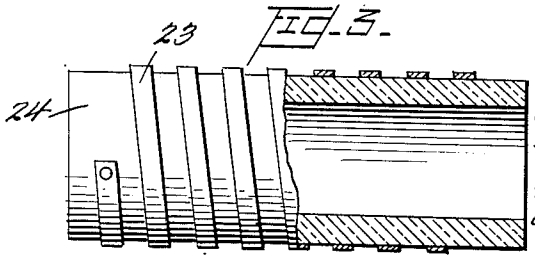


FIG. 2.



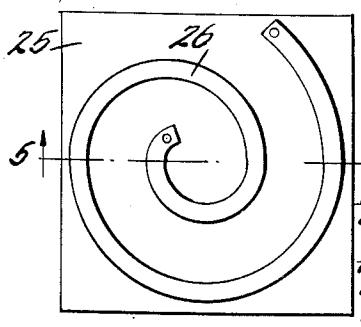
Coil form of ceramic material having a negative temperature coefficient of dielectric constant.

FIG. 3.



Coil form of ceramic material having a negative temperature coefficient of dielectric constant

FIG. 4.

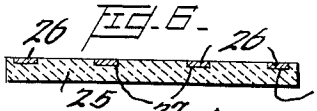


Flat coil form of ceramic material having a negative temperature coefficient of dielectric constant

FIG. 5.



FIG. 6.



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INDUCTANCE UNIT

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15 Claims. (Cl. 323—76)

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This invention is an inductance unit having substantially fixed resonant frequency characteristics and a method of making the same.

The inductance unit of the present invention is rendered substantially self-compensating in respect to ambient temperature changes by so correlating the temperature coefficient of dielectric constant of the material of which the coil form is made to the temperature coefficient of expansion thereof, that the increase of inductance with increasing temperature is substantially compensated for by the decrease in interturn capacity.

One object of the invention is to provide an inductance unit of the character described which will have substantially fixed resonant frequency characteristics and accurate re-trace characteristics.

Another object of the invention is to provide an inductance unit of the character described comprising a coil form made from ceramic material having a negative temperature coefficient of dielectric constant such as rutile, various ceramic titanate combinations including magnesium, calcium, and strontium titanates, and the like.

Another object of the invention is to provide an inductance unit having a coil form of ceramic material with a negative temperature coefficient of dielectric constant, which form is provided with a spiral conductor receiving groove so that a continuous conductor may be deposited within the groove to insure that substantially all of the interturn capacity of the coil is through the material of the coil form.

Another object of the invention is to bond the coil of an inductance unit of the character described to the ceramic coil form so that the coil and the coil form move together during expansion and contraction due to temperature changes.

These and other objects of the invention will become apparent from the following specification read in connection with the accompanying drawings wherein preferred forms of the invention have been illustrated.

In the accompanying drawings:

Fig. 1 is a diagrammatic view of a circuit showing the inductance unit of the present invention incorporated therein,

Fig. 2 is a view partly in section showing a preferred form of the invention, and

Fig. 3 is a similar view showing a modified form of the invention,

Fig. 4 is a top plan view of a flat type spiral coil form of inductance unit made in accordance with the present invention,

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Fig. 5 is a sectional view taken on the line 5—5 of Fig. 4, and

Fig. 6 is a sectional view similar to that of Fig. 5 but of a modified form of flat coil form having a groove in which the conductor is deposited.

In describing the present invention, it is convenient to refer to a resonant circuit such as shown in Fig. 1 which includes an inductance L_0 having distributed capacity C_d, and a capacity C_0. For a circuit such as represented in Fig. 1 and in which the total inductance may be represented by L_T, and the total capacity by C_T, the resonant frequency may be expressed as follows:

$$F=\frac{1}{2\pi}\cdot\frac{1}{\sqrt{L_TC_T}}=\frac{1}{2\pi}L_T^{-\frac{1}{2}}C_T^{-\frac{1}{2}} \tag{1}$$

The total differential of F is

$$dF=\frac{\partial F}{\partial L_T}dL_T+\frac{\partial F}{\partial C_T}dC_T$$

$$=-\frac{1}{4\pi\sqrt{L_TC_T}}\cdot\frac{dL_T}{L_T}=\frac{1}{4\pi\sqrt{L_TC_T}}\cdot\frac{dC_T}{C_T} \tag{2}$$

$$dF=-\frac{F}{2}\cdot\frac{dL_T}{L_T}-\frac{F}{2}\frac{dC_T}{C_T} \tag{3}$$

In general, both C_T and L_T will be functions of temperature, that is they are subject to change due to changes in ambient temperature, and hence the rate of change of the resonant frequency F with respect to temperature may be derived from (3) thus:

$$\frac{dF}{dt}=-\frac{F}{2}\cdot\frac{dL_T/L_T}{dt}-\frac{F}{2}\frac{dC_T/C_T}{dt} \tag{4}$$

For the resonant frequency F to be independent of temperature, it follows that

$$\frac{dF}{dt}=0 \tag{5}$$

Hence, substituting in (4) there results

$$\frac{dL_T}{L_T/dt}=-\frac{dC_T}{C_T/dt} \tag{6}$$

Assuming that substantially all the inductance of the circuit is localized in the coil, a consideration of the last given formula shows that

$$\frac{dL_T}{L_T/dt}$$

is the temperature coefficient of inductance of the coil and

$$\frac{dC_T}{C_T/dt}$$

is the temperature coefficient of capacitance of

the total capacity of C_T of the resonant circuit shown in Fig. 1. It therefore follows that in order for the resonant circuit of Fig. 1 to be independent of ambient temperature, the temperature coefficient of capacitance must be equal to the negative of the temperature coefficient of inductance.

It can be shown that for a certain class of ceramic materials such as rutile, and various combinations of titanates such as magnesium, strontium, and calcium titanates, and the like, there is a simple relationship between the temperature coefficient of inductance of a coil wound on a coil form of such ceramic material and the coefficient of linear expansion of the coil form. It has been established that the inductance of a single layer solenoid having N turns wound on a coil form, the diameter of which is D and the length of which is l is:

$$L=fN^2D \tag{7}$$

where f is a function of the ratio

$$\frac{D}{l}$$

Since both the diameter and the length of the coil change with temperature in accordance with their coefficients of linear expansion, f is seemingly a function of temperature. Thus

$$f=f_t\left(\frac{D}{l}\right) \tag{8}$$

Ceramic materials such as titanates, rutile, and the like, have temperature coefficients of expansion which are linear over a wide range of temperatures falling generally within the range of −60° C. to +85° C. Thus, over this range of linearity, f may be expressed as

$$f=f\left[\frac{D_0(l+at)}{l_0(l+at)}\right]=f\left[\frac{D_0}{l}\right] \tag{9}$$

where D_0 and l_0 are the diameter and length of the coil measured at the same temperature and a is the temperature coefficient of expansion; t is the change in temperature measured from the temperature at which D_0 and l_0 are measured.

It is seen from (9) that f is a parameter independent of temperature and hence the inductance L in (7) of a coil having a given length and a given number of turns is a function of its diameter only. From (7) and (9) it follows that

$$L=fN^2D \tag{7}$$

$$\frac{dL}{dt}=fN^2\frac{dD}{dt}$$

$$\frac{dL/dt}{L}=\frac{dD/dt}{D}$$

or

$$\frac{dL}{L/dt}=\frac{dD}{D/dt}=a \tag{10}$$

That is, the temperature coefficient of inductance of a single layer solenoid coil on a coil form of the ceramic materials described, is equal to the temperature coefficient of expansion of its diameter. As assumed in (9) this is true only when the diameter and length of the coil have the same temperature coefficient of expansion a.

From (6) and (10) is follows that

$$a=-\frac{dC_T}{C_T/dt}$$

$$a=-TC \text{ of } C_T \tag{11}$$

Thus, in order for the resonant frequency of the

circuit of Fig. 1, to be independent of temperature change the temperature coefficient of linear expansion of the coil form must be equal to the negative of the coefficient of capacitance of the total capacity (C_T) associated with the total inductance (L_T) in said circuit.

At this point, due consideration must be given to the fact that in the previous derivations, the value C_T is composed of C_0 and C_d. Since

$$C_T=C_0+C_d \tag{12}$$

it follows that

$$\frac{dC_T}{dt}=\frac{dC_0}{dt}+\frac{dC_d}{dt}$$

$$\frac{dC_T}{dt/C_TC_0C_d}=\frac{dC_0}{dt/C_TC_0C_d}+\frac{dC_d}{dt/C_TC_0C_d}$$

$$\frac{dC_T/C_T}{dt}\cdot\frac{l}{C_0C_d}=\frac{dC_0/C_0}{dt}\cdot\frac{l}{C_dC_T}+\frac{dC_d/C_d}{dt}\cdot\frac{l}{C_TC_0}$$

$$TC_T\cdot\frac{l}{C_0C_d}=TC_0\cdot\frac{l}{C_dC_T}+TC_d\frac{l}{C_TC_0}$$

and

$$TC_T=TC_0\left(\frac{C_0}{C_T}\right)+TC_d\left(\frac{C_d}{C_T}\right) \tag{13}$$

From this it is seen that the temperature coefficients of capacitances of both the external capacitor C_0 and the distributed capacitance C_d of the coil are additive in the proportions that C_0 and C_d are to the total capacity, C_T.

From (11) and (13) a convenient design formula may be obtained such as

$$a=-\left[TC_0\left(\frac{C_0}{C_T}\right)+TC_d\left(\frac{C_d}{C_T}\right)\right] \tag{14}$$

If the inductance coil or unit L_0 of Fig. 1 is used by itself without the external capacitor C_0, then the Formula 14 becomes

$$a=-TC_d \tag{15}$$

For practically all materials suitable for coil forms, except ceramic materials of the class hereinbefore referred to, namely rutile and various combinations of titanates, both a and TC_d would be positive values and the conditions represented by (15) cannot be satisfied, when materials are employed which give positive values for these two factors. Ceramic materials of the class herein mentioned are characterized by temperature coefficients of dielectric constant of negative values and these values can be varied over a wide range by varying the composition of the cramic mixture. At the same time, the temperature coefficient of expansion of these materials is positive and substantially constant over a wide range of temperatures falling generally between −60° C. and +85° C. The temperature coefficient of capacitance is likewise constant over a wide temperature range which for the most part overlaps the temperature range of constant temperature coefficient of expansion. Hence it is evident that if a coil or inductance unit is made having a coil form of ceramic material chosen from the group of ceramic materials herein noted, of which the temperature coefficient of capacitance is equal to but opposite in sign to the temperature coefficient of expansion and the conductor of the unit of the coil is associated with the form in a manner such that the conductor is made to follow substantially the expansion and contraction movements of the coil form and also to have substantially all of its interturn capacity occur through the material of the form, the condition represented by the Formula 15 can be satisfied. In order to make

the electric conductor follow the coil form in expansion and contraction movements thereof and in order to confine the interturn capacity of the unit to the material of the coil form, the coil form is preferably formed with a spiral groove in its surface and the conductor is deposited in the groove preferably on the bottom wall thereof, and is bonded to the coil form so as to of necessity follow the coil form in its expansion and contraction movements.

Referring to Fig. 2 of the drawings, there is shown a coil form **20** made of ceramic material such as rutile, or various combinations of titanates, and the like, the coil form being substantially cylindrical in form and hollow. The exterior cylindrical surface of the form is provided with a spiral groove or thread **21**, on the bottom wall of which is deposited a continuous coating of conductor **22** such as silver, copper, or the like. The coating is preferably bonded or mechanically locked to the surface of the form **20**, on the bottom wall of the groove **21** in order to insure that the conductor **22** will follow the form in movement due to expansion and contraction. The spiral groove or thread **21** is preferably dimensioned in respect to depth so that the conductor **22** is confined substantially to the groove and has no substantial part thereof projecting above the external surface of the form whereby to insure that substantially all of the interturn capacity between adjacent convolutions of the conductor is through the material of the form. The metal conductor **22** may be deposited on and bonded to the bottom wall of the spiral groove **21** by any suitable means or method such as electroplating, a Schoop's gun, or the like.

Although the form of the invention shown in Fig. 2 is preferred because of the enhanced temperature compensation realized by confining the metal coating or conductor within the spiral groove as shown, it is also possible to deposit the conductor film in the form of a spiral ribbon **23** directly upon the cylindrical outer surface of a coil form **24** as shown in Fig. 3. In this form of the invention, it is also preferable to mechanically bond or otherwise secure the spiral ribbon **23** to the outer surface of the form **24** in order that the conductor **23** will follow substantially the expansion and contraction movements of the coil form **24**. Due to the fact that some of the interturn capacity of adjacent convolutions of the ribbon **23** in that form of the invention shown in Fig. 3 is through the air, or other surrounding medium, the compensating effect due to variations of temperature will not be as complete in this form of the invention as in the form of the invention shown in Fig. 1. However, the compensation will be substantial and in many instances fully adequate to meet specifications.

From the foregoing it is apparent that the inductance unit L_0 can be made self-compensating when used by itself in a circuit without an external capacitor such as C_0 of Fig. 1. If, however, the coil is to be used in a circuit with an external capacitor as C_0 and wherein the temperature coefficient of capacitance of the external capacitor is zero, then (14) becomes

$$a=-TC_d\left(\frac{C_d}{C_T}\right) \qquad (16)$$

This requirement can be satisfied by providing a coil form made of ceramic material within the teaching of the present invention and constructed in the manner hereinafter referred to.

However, it should be noted that under these circumstances the temperature coefficient of dielectric constant of the coil form must needs be greater in the ratio

$$\frac{C_T}{C_d}$$

to compensate for the added capacity C_0 even though the latter has a zero temperature coefficient dielectric constant TC.

If the inductance L_0 is used in a circuit including an external capacitor such as C_0 which has a temperature coefficient of dielectric constant greater than or less than zero, the value of the temperature coefficient of dielectric constant of the coil form required may be calculated from (14). For this purpose (14) may be written thus:

$$TC_d=-\left[a+TC_0\left(\frac{C_0}{C_T}\right)\right]\frac{C_T}{C_d} \qquad (17)$$

which gives rise to three possible conditions:

(1) $\left(a>-TC_0\frac{C_0}{C_T}\right)$ in which TC_d of (17) will be negative and realizable by using a coil form within the teaching of the present invention,

(2) If $a=-TC_0\left(\frac{C_0}{C_T}\right)$ than TC_d of (17) will have to be zero, and as taught in Ehlers Patent 2,398,088 of April 9, 1946, ceramic material mixtures may be readily formed which have zero temperature coefficients of dielectric constant.

(3) If $a<-TC_0\left(\frac{C_0}{C_T}\right)$, TC_d of (17) will have to be positive and a ceramic coil form of the type described herein will serve no purpose.

The foregoing derivation of formulae proceeding from Formula 7 pertain to an inductance unit of cylindrical form and including a single layer helical or solenoid form of coil. However, the same advantages emphasized in respect to the cylindrical form of inductance may be realized with a flat coil form having a spiral coil mounted thereon as shown in Figs. 4, 5, and 6. Thus, as shown in Fig. 4, the unit may comprise a substantially flat, co-planar base **25** of ceramic material having a negative temperature coefficient of dielectric constant as previously referred to herein, which base may be round, square, or any other desired contour, and on which is deposited a flat spiral coil **26** in the form of a thin metallic ribbon. The ribbon coil **26** is bonded to the surface of the base **25** by electro-deposition, Schoop's gun, or the like, to insure that the ribbon follows the base in its movement of expansion and contraction, due to changes in ambient temperature. Preferably the upper surface of the base 25 is provided with a spiral groove 27 in which the ribbon **26** is deposited and bonded to the bottom wall thereof, the groove **26** being of a depth sufficient to completely house the ribbon as shown in Fig. 6. If desired, the groove **26** may be substantially deeper than the thickness of the ribbon, so that the upper surface of the ribbon lies below the upper surface of the form similar to the manner shown in connection with the cylindrical form of coil, in Fig. 2.

It can be shown that flat spiral inductors made by bonding a metallic conductor, in the same manner and to the same class of ceramic bodies as hereinbefore described, onto the surface of

a ceramic plate will behave in identically the same manner as the helical type described before. Furthermore, it can be shown that the same formulae developed for the helical coil will also apply to the spiral.

Thus from the text "Inductance Calculations," Frederick W. Grover, D. Van Nostrand Co., Inc. (page 167) we have the following formula for the inductance of a flat spiral:

$$L=.001N^2aP-.004\times Na(G_1+H_1) \qquad (1a)$$

where

N=no. of turns
a=mean diameter
B=the thickness of the conducting layer
C=the width of one convolution
p=the distance between centers of adjacent convolutions

$$P=f\left(\frac{C}{2a}\right)$$

$$G_1=f\left(\frac{B+C}{p}\right)$$

$$H_1=f\left(N,\frac{B}{p},\frac{C}{p}\right)$$

Formula 1a can be written as

$$l=N^2a\left[.001P-\frac{.004x}{N}(G_1+H_1)\right] \qquad (2a)$$

When the expression within the brackets of (2a) is examined it is observed that, with the exception of N which is a constant for a given coil, P, G_1, and H_1 are functions of the ratios of the sum of one or more linear dimensions of the spiral.

The method of constructing a spiral of the type being described, produces a thin conductor such that the B dimension is usually in the order of 1/20 the C dimension. Consequently, in the expressions for G_1 and H_1, namely

$$G_1=f\left(\frac{B+C}{p}\right) \qquad (3a)$$

$$H_1=f\left(N,\frac{B}{p},\frac{C}{p}\right) \qquad (4a)$$

it can be seen, that since $C=or>20B$, the parameter B is small enough to neglect, and G_1 and H_1 can be rewritten as:

$$G_1=f\left(\frac{C}{p}\right) \qquad (5a)$$

$$H_1=f\left(N,\frac{C}{p}\right) \qquad (6a)$$

Now, due to the coefficient of linear expansion of the ceramic plate, a, onto which the inductor is bonded, the spiral will change dimensions with change in ambient temperature. In general, any dimension, l, on the plate will behave according to the following well known law for materials having a linear coefficient of expansion, a:

$$l_t=l_0\ (l+at) \qquad (7a)$$

where l_0 is the dimension at reference temperature, and l_t is the dimension after a change in temperature, t.

All the parameters in the brackets of (2a) which are functions of temperature may be rewritten as follows:

$$P=f\left(\frac{C}{2a}\right)=f_t\frac{C_0(l+at)}{2a_0(l+at)}=f\left(\frac{C_0}{2a_0}\right)$$

$$G_1=f\left(\frac{C}{p}\right)=f_t\frac{C_0(l+at)}{P_0(l+at)}=f\left(\frac{C_0}{P_0}\right)$$

$$H_1=f\left(N,\frac{C}{p}\right)=f_tN,\ \frac{C_0(l+at)}{P_0(l+at)}=f\left(N,\frac{C_0}{P_0}\right)$$

from which it appears that the variable, t, drops out of the parameters P, G_1, and H_1.

Consequently (2a) may be written as

$$L=f_1N^2a \qquad (8a)$$

where f_1 is not a function of temperature, t.

Thus it will be observed that (8a) is identically the same in form as (7). Consequently, the formulae and conclusions developed for the helix will also apply to the spiral.

The following examples are given to illustrate the manner in which the value of the negative temperature coefficient of dielectric constant of coil forms made in accordance with the present invention may be varied within wide limits.

I. *Titanium dioxide and titanate combination*

	Per cent
Titanium dioxide	28¾
Magnesium titanate	51¼
Calcium titanate	5
Strontium titanate	5
Ball clay	10

Properties of coil form composed as above: K=19; TC=−30 parts per million per degree centigrade. Temperature coefficient of expansion=7.8×10^{-6} per °C.

II. *Titanate combination*

	Per cent
Magnesium titanate	90
Strontium titanate	10

K=17; TC=−43. Temperature coefficient of expansion=8.7×10^{-6} per °C.

III. *Oxide combination*

	Per cent
Titanium dioxide	40.5
Rare earth oxides	56.0
Clay	3.5

K=36; TC=−14. Temperature coefficient of expansion=9.0×10^{-6} per °C.

IV. *Titanium dioxide combination*

	Per cent
Titanium dioxide	30
Clay	10
Talc	50
Barium carbonate	10

K=12; TC=−15. Temperature coefficient of expansion=6.2×10^{-6} per °C.

Rutile, hereinbefore referred to, is the well known mineral consisting of titanium dioxide.

It is apparent from the foregoing that a temperature-compensated inductance unit may be provided by utilizing a coil form made from ceramic material having a negative temperature coefficient of dielectric constant and equal to but opposite in sign to the temperature coefficient of expansion of the coil form when the conductor forming the coil is deposited thereon in a manner to constrain the conductor to follow expansion and contraction movements of the coil form and to confine the interturn capacity of adjacent convolutions of the coil substantially to the material of the coil form. It is further apparent from the present invention that an inductance unit made in accordance with the present invention may be made self-compensating per se or may be designed so that when used in circuit with an external capacitor of known but unspecified

temperature variation, will provide a circuit of substantially fixed resonant frequency in the face of ambient temperature changes.

I claim:

1. A self-compensating inductance coil comprising a substantially cylindrical coil form of ceramic material having a negative temperature coefficient of dielectric constant substantially equal in value to but of opposite sign to its temperature coefficient of expansion and a conductor disposed spirally about said coil form and anchored to the coil form to cause the conductor and coil form to move together during movements of expansion and contraction due to temperature changes.

2. A self-compensating inductance coil comprising a substantially cylindrical coil form of ceramic material having a negative temperature coefficient of dielectric constant substantially equal in value to but of opposite sign to its temperature coefficient of expansion, a spiral groove formed in the surface of said coil form, a continuous conductor deposited within said groove with all portions thereof disposed within the confines of said groove whereby substantially all of the interturn capacity of adjacent convolutions of the conductor is through the material of the coil form and means for anchoring the conductor to the coil form to cause the coil and coil form to move together during movements of expansion and contraction in response to temperature changes.

3. A self-compensating inductance coil comprising a coil form of ceramic material having a negative temperature coefficient of dielectric constant substantially equal in value to, but of opposite sign to, its temperature coefficient of expansion and a conductor disposed spirally upon said coil form and fixed thereto to cause the conductor and coil form to move together during expansion and contraction due to temperature changes.

4. A self-compensating inductance coil comprising a coil form of ceramic material having a negative temperature coefficient of dielectric constant substantially equal in value to but of opposite sign to its temperature coefficient of expansion, a spiral groove formed in the surface of said coil form, a continuous conductor deposited within said groove and fixed to the coil form to cause the conductor and the coil form to move together during expansion and contraction due to temperature changes all portions of said conductor being disposed within the confines of said groove whereby substantially all of the interturn capacity of adjacent convolutions of the conductor is through the material of the coil form.

5. A self-compensating inductance coil comprising a flat, co-planar coil form of ceramic material having a negative temperature coefficient of dielectric constant substantially equal in value to but of opposite sign to its temperature coefficient of expansion, a spiral groove formed in one flat surface of said coil form, a continuous conductor deposited within said groove and fixed to the coil form to cause the conductor and coil form to move together during expansion and contraction due to temperature changes, all portions of said conductor being disposed within the confines of said groove whereby substantially all of the interturn capacity of adjacent convolutions of the conductor is through the material of the coil form.

6. A self-compensating inductance coil comprising a substantially flat-co-planar coil form of ceramic material having a negative temperature co-efficient of dielectric constant substantially equal in value to but of opposite sign to its temperature coefficient of expansion and a conductor disposed spirally upon one flat surface of said form and anchored thereto to cause the conductor and coil form to move together during expansion and contraction due to temperature changes.

7. The method of forming an inductance unit which is self-compensating in respect to temperature changes which comprises selecting and proportioning the ingredients of a ceramic mix including at least one compound having a negative coefficient of dielectric constant chosen from the group consisting of magnesium titanate, calcium titanate, and strontium titanate, and titanium dioxide, which mix will provide in a coil form made therefrom a negative temperature coefficient of dielectric constant and a positive temperature coefficient of expansion that are numerically equal but of opposite sign, mixing the chosen ingredients, forming a ceramic coil form from said ceramic mix, depositing on the coil form an electrical coil the interturn capacity of which is restricted to the material of the coil form, and bonding said electrical coil to the coil form substantially throughout the length of said coil so that the coil and coil form move together as the result of expansion and contraction due to ambient temperature changes.

8. The method of forming an inductance unit which is self-compensating in respect to temperature changes which comprises forming a ceramic mix including at least one compound having a negative temperature coefficient of dielectric constant chosen from the group consisting of magnesium titanate, calcium titanate, and strontium titanate, and titanium dioxide, said compound being present in an amount to provide in a coil form made from said mix a negative coefficient of dielectric constant substantially equal to but of opposite sign to its temperature coefficient of expansion, making a ceramic coil form having said characteristics from said mix, depositing on said coil form a continuous conductor in the form of a coil, confining the interturn capacity of adjacent convolutions of said coil substantially to the material of the coil form, and constraining the conductor coil, substantially throughout its length, and the coil form to move together in their movements of expansion and contraction under ambient temperature changes.

9. The method of forming an inductance unit which is self-compensating with respect to temperature changes which comprises forming a ceramic mix including at least one compound having a negative temperature coefficient of dielectric constant chosen from the group consisting of magnesium titanate, calcium titanate, and strontium titanate, and titanium dioxide, said compound being present in an amount to provide in a coil form made from said mix a negative temperature coefficient of dielectric constant substantially equal to but of opposite sign to its temperature coefficient of expansion, making a generally flat, spirally grooved ceramic coil form having said characteristics from said mix, depositing on said coil form within said groove a continuous conductive layer in the form of a coil, confining said coil substantially within said groove, so that substantially all of the interturn capacity of adjacent convolutions of said coil will be through the material of the coil

form, and bonding the coil substantially throughout its length to the coil form so they move together in their movements of expansion and contraction due to ambient temperature changes.

10. The method of forming an inductance unit which is self-compensating with respect to temperature changes which comprises forming a ceramic mix including at least one compound having a negative temperature coefficient of dielectric constant chosen from the group consisting of magnesium titanate, calcium titanate, and strontium titanate, and titanium dioxide, said compound being present in an amount to provide in a coil form made from said mix a negative temperature coefficient of dielectric constant substantially equal to but of opposite sign to its temperature coefficient of expansion, making a cylindrical, helically grooved ceramic coil form having said characteristics from said mix, winding on said coil form within said groove a continuous conductive layer in the form of a coil, confining said coil substantially within said groove, so that substantially all of the interturn capacity of adjacent convolutions of said coil will be through the material of the coil form, and bonding the coil substantially throughout its length to the coil form so they move together in their movements of expansion and contraction due to ambient temperature changes.

11. A self-compensating inductance unit of the character described in claim 2 wherein the conductor is bonded to the bottom surface of the spiral groove whereby to follow the movements of the coil form in its expansion and contraction due to temperature variations.

12. A self-compensating inductance coil such as described in claim 1 wherein the conductor is bonded substantially throughout its length to the coil form whereby the conductor is constrained to move with the coil form as the latter expands and contracts due to temperature variations.

13. In combination with a capacitor of predetermined value, a temperature compensated inductance unit operatively connected thereto and comprising a coil form of ceramic material having a conductor coil mounted thereon and fixed thereto so as to move therewith substantially throughout its length during movements of expansion and contraction due to temperature changes, the adjacent turns of said coil providing inherent distributed capacity in said unit, the coil form having a negative temperature coefficient of dielectric constant and a positive temperature coefficient of expansion, the temperature coefficient of expansion being substantially equal in value but of opposite sign to the combined temperature coefficient of dielectric constant of said unit and the temperature coefficient of dielectric constant of said capacitor.

14. A self-compensating inductance coil such as described in claim 3 wherein the conductor is bonded substantially throughout its length to the coil form as the latter expands and contracts due to temperature variations.

15. A self-compensating inductance unit of the character described in claim 4 wherein the conductor is bonded to the bottom surface of the spiral groove whereby to follow the movements of the coil form in expansion and contraction due to temperature variations.

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