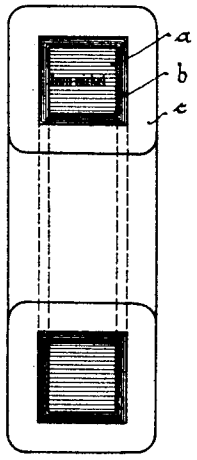
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E. SCHÜRER

SELF INDUCTION COIL

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INVENTOR:
Eugen Schürer
By Wm Wallace White
ATTY.

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EUGEN SCHÜRER, OF COLOGNE-MULHEIM, GERMANY, ASSIGNOR TO FELTEN AND GUILLEAUME CARLSWERK ACTIEN-GESELLSCHAFT, OF COLOGNE-MÜLHEIM, GERMANY.

SELF-INDUCTION COIL.

Application filed April 28, 1921. Serial No. 465,251.

To all whom it may concern:

Be it known that I, EUGEN SCHÜRER, a citizen of Germany, residing at Cologne-Mulheim, Prinz-Wilhelmstrasse Nr. 41, Germany, have invented new and useful Improvements in Self-Induction Coils, of which the following is a specification.

If, R, C and A represent the resistance, capacity and leakage per unit of length of a telephone line loaded with self induction coils for the purpose of lessening its attenuation, and if W and L represent the effective resistance and inductance of one of the coils inserted a distance s from one another, then, as is well known, the attenuation of the telephone line will be:—

$$\beta = \frac{R + \frac{W}{s}}{2} \cdot \sqrt{\frac{C \cdot s}{L}} + \frac{A}{2} \cdot \sqrt{\frac{L}{C \cdot s}}$$

The attempted diminution of β by increasing L is adversely affected, not only by the second expression in the formula, but also by the fact, that an increase in the inductance by the value $\frac{L}{s}$ per unit of length is accompanied by an increase in the resistance R by the value $\frac{W}{s}$ per unit of length of the effective resistance of the coils. The effective resistance of the coils must therefore be as low as possible. However, with the kinds of iron hitherto employed in the manufacture of coils, the reduction of W causes the weight of the coils, and therefore the cost of loading, to increase out of all proportion. Hence it has been found advisable to construct the coils, as far as possible, in such a way that, according to the value of R, the value $\frac{W}{s}$ does not exceed 10 to about 50% of R, the upper limit which is really too high—was used for telephone cable conductors having a diameter of 3 millimetres because smaller values of W could be attained only by increasing the weight of the coil to an excessive degree. Consequently, the possibility of being able to make the effective resistance of the coil per unit of inductance less than that hitherto possible, while retaining or even reducing the weight of the coil is therefore of high technical importance, especially in the case of low-resistance telephone lines. The present invention enables this to be done.

The effective resistance of the coils is made up of the ohmic resistance Wg^1 of the coil winding, and of an increment Δ. If P_s represents the specific watt loss due to hysteresis and eddy currents in the iron core having a volume V, and if i is the effective strength of the alternating current,

$$\Delta = \frac{P_s \cdot V}{i^2}$$

It is comparatively easy to reduce the ohmic resistance of the coil winding to any desired low value by employing wire of suitable sectional area for winding the coils although the size and the weight of the coil is thereby increased. It is, however, more difficult to reduce the resistance Δ since, for this purpose it is necessary to discover a suitable kind of iron with sufficiently small loss constants.

The specific watt loss in iron due to hysteresis and eddy currents, with induction B and periodicity is, according to the known formula:

$$P_s = v \cdot \eta \cdot B^x + v^2 \gamma B^2$$

η and x meaning constants for the hysteresis losses and γ for the eddy current losses.

Within the limits of B that are practicable for constructing the coils this formula may, with a close approximation be replaced by:

$$P_s = \alpha v B^m$$

in which αv and m are constants holding good for a particular periodicity v and for a particular degree of lamination.

Since:

$$B = i \sqrt{\frac{L \cdot \mu \cdot 8 \cdot \pi \cdot 10^7}{v}}$$

μ being the permeability of the iron, it follows that for current strength i and periodicity

$$\Delta = \alpha v \cdot i^{(m-2)} \cdot \frac{(8 \cdot \pi \cdot 10^7)^{\frac{m}{2}} \cdot (L \cdot \mu)^{\frac{m}{2}}}{V\left(\frac{m}{2} - 1\right)} = \text{Ohm}$$

The value of m is always only about

10–15% greater than 2. In order to obtain a considerable diminution of $\triangle$ by increasing the volume V, this latter must therefore assume proportions that are far beyond practicable limits. On this account it is desirable to obtain a diminution of $\triangle$ by selecting a kind of iron having a coefficient of loss αv that is sufficiently low.

The formula also shows that the value of $\triangle$ can also be diminished, by reducing the permeability μ of the iron, but in that case, in order to prevent any change in the inductance of the coil, it is necessary to increase either the number of turns in the winding (and therefore the resistance $W\varrho^1$) or, if these be kept constant, the weight of the coil. There exists, therefore, a favourable value for the permeability at which for a given time constant

$$Z = \frac{L}{W}$$

the weight of the coil is at a minimum. Exhaustive investigations have shown that this favourable value of permeability is not very decided for small time constants (up to about 0.025 second), but, as the time constant increases, lies between progressively narrowing limits, which, for the values of inductance occurring in actual coil construction, (namely from about 0, 10 to 0, 25 henry) lie between about 80 and 150 for time constants up to about 0.04 sec., and between about 50 and 110 for higher time constant values. As the magnetic field in the coil cores is very weak the so-called initial permeability of the material only is in question.

I have therefore made experiments in order to obtain a material having a considerably smaller loss coefficient αv in comparison with previous materials, while at the same time having an initial permeability within the aforesaid limits. As the result of the experiments a material was discovered which consists of an alloy of iron and nickel, the iron being as free as possible from carbon and other impurities.

Iron-nickel alloys containing a suitable amount of carbon are well known in the art as nickel steels. They exhibit very considerable hysteresis losses. My experiments, have shown that if the carbon content is reduced to about 0.09 to 0.06%, the addition of nickel effects a considerable reduction in the hysteresis losses of the iron, without at the same time increasing the initial permeability—as occurs to example with the known iron-silicon alloys used for transformer and dynamo plates. Moreover the initial permeability can be reduced to any desired extent by increasing the proportion of nickel and can therefore be varied within the aforesaid limits. Since the added nickle also considerably lowers the conductivity of the iron, the eddy-current losses are also reduced.

For example, I have made a nickel-iron alloy consisting of practically pure iron with about 8% of nickel. The coefficient of loss αv of this alloy is less than one third that of pure iron. The initial permeability is about 135. Self-induction coils made of this alloy having an inductance of 0.15 henry and a time constant of 0.04 seconds with a current of 0.5 milliampere at 800 periods weigh only about 3.5 kilograms, whereas the self-induction coils at the same electrical constants hitherto used in the art weigh 10.5 kilograms.

The drawing accompanying and forming part of this specification illustrates in sectional elevation a coil embodying the present invention. In the drawing, *a* indicates the core formed in any well-known manner from a nickel-iron bar, *b* designates the insulating jacket extending around the core, and *c* designates the wire coil.

It is immaterial as regards the invention, how the material is subdivided for constructing the magnetization core, i. e., whether it is used in the form of discs, strips, wire or powder. The advantage of using this material for loading coils can likewise be obtained when it is used for all magnetization cores in which it is desirable to combine the smallest possible weight with the highest possible time constants or with the smallest possible losses.

What I claim is:—

An improved self-induction coil comprising a magnetization core composed of an iron nickel alloy having 8 to 20 per cent nickel content and a carbon content of .06 to .09 per cent, in combination with an insulating jacket and a surrounding wire coil.

In testimony whereof I have signed my name to this specification.

EUGEN SCHÜRER.