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INDUCTIVE DEVICE

Filed March 16, 1932

FIG. 1

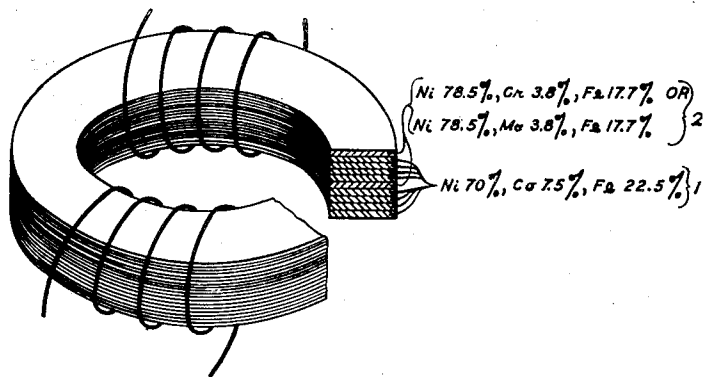
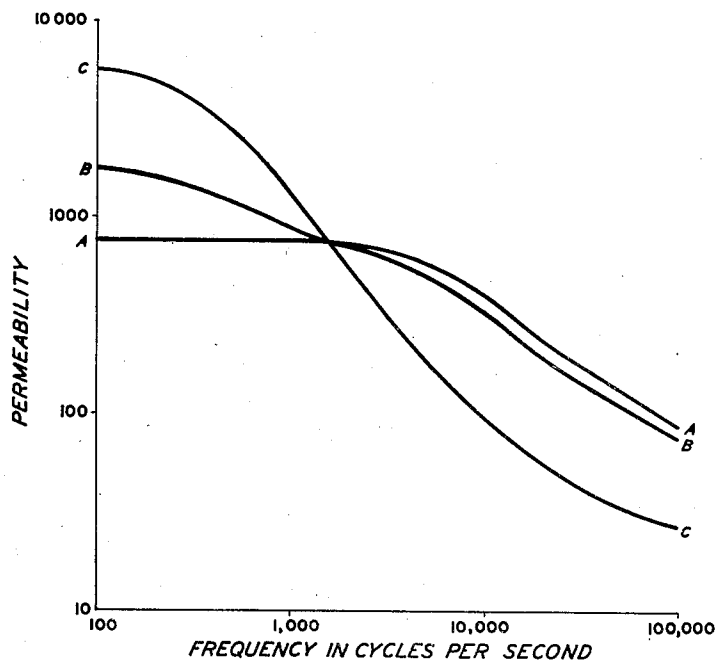


FIG. 2



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INDUCTIVE DEVICE

Application filed March 16, 1932. Serial No. 599,089.

This invention relates to electromagnetic devices and more particularly to transformers and repeating coils employed in telephone systems.

5 An object of this invention is to increase the frequency range over which an inductive device can effectively function.

10 A more particular object is to enable a transformer or repeating coil to pass both voice and carrier frequencies covering a wide range of frequencies, such as 100 to 50,000 cycles or higher, with high efficiency.

15 Another more particular object is to reduce the modulation effect in transformers and repeating coils to prevent undesirable cross-talk between adjacent communication channels.

20 In certain communication systems both voice and carrier currents are passed over the same line. A repeating coil employed for transmitting these currents must be capable of passing the low frequency currents as well as the high frequency carrier currents without objectionable modulation effect with consequential undesirable cross-talk. At present 25 two coils are required, one capable of passing the voice or low frequencies and another those of the carrier range. In addition two balanced line filters on the receiving side are necessary.

30 In accordance with this invention, the core of a repeating coil comprises two magnetic materials having characteristics which render it capable of transmitting efficiently both carrier and voice frequencies. One of these materials has a low modulation coefficient and a low permeability at low frequencies, while 35 the other exhibits a higher modulation coefficient and a higher permeability at low frequencies than the first material. Certain alloys of nickel-cobalt-iron when heat treated possess properties required of the first material, while other alloys of nickel-chromium- 40 iron have the characteristics of the second. A nickel-cobalt-iron alloy comprising approximately 69% to 70% nickel, 7% to 8% cobalt and the remainder chiefly iron when properly 45 heat treated has an extremely low modulation coefficient although its initial permeability at 100 cycles is approximately 780. A heat

treated nickel-chromium-iron alloy comprising about 77.5% to 79.5% nickel, 3.6% to 4% chromium and the remainder chiefly iron, on the other hand, has a higher modulation coefficient. The initial permeability at 100 cycles of laminations of this alloy, however, is 55 above 5,600. When laminations of these two alloys are arranged in parallel in the core of a repeating coil, the coil is capable of transmitting both voice and carrier frequencies in 60 a range of 100 to 50,000 cycles without undesirable modulation effects. As a result one coil instead of two is necessary in communication systems employing both frequencies. In addition the balanced line filters may be 65 eliminated and the more economical unbalanced filters substituted on the office side of the transformer. Other alloys of nickel-cobalt-iron and nickel-chromium-iron, the 70 quantity of the constituents of which substantially vary from those stated, may be employed with like results.

An embodiment of the present invention is illustrated in the accompanying drawing in 75 which:

Fig. 1 represents, in a diagrammatic manner, a repeating coil having primary and secondary windings, the core of the coil consisting of layers or laminations arranged in parallel of nickel-cobalt-iron alloys and nickel-chromium-iron alloys. 80

Fig. 2 is a graph indicating the effective alternating current permeability at various frequencies of the core shown in Fig. 1 together 85 with the same characteristic of its components.

In Fig. 1, the core consists of laminations 1, comprising approximately 80% of the total of those in the core, of a nickel-cobalt-iron alloy composed of 70% nickel, 7.5% cobalt and the remainder chiefly iron arranged in parallel with other laminations 2, comprising about 20% of the core, of a nickel-chromium-iron alloy having about 78½% nickel, 3.8% 90 chromium and the remainder chiefly iron. The laminations 2 may be a nickel-molybdenum-iron alloy comprising approximately 78½% nickel, 3.8% molybdenum and the remainder iron. The relative percentages of 95 the laminations of each alloy may be varied 100

from those employed in the above described core depending upon the frequency range and the modulation coefficient desired.

The laminations of the nickel-cobalt-iron alloy are heat treated by subjecting them to a temperature of $1000^{\circ}\text{C.} (\pm 20^{\circ}\text{C.})$ for a period of at least one hour in a container which insures their freedom from oxidation and contamination. They are then permitted to cool at a rate not in excess of 5°C. per minute.

The heat treatment of the laminations of nickel-chromium-iron alloy consists in placing them in a non-porous annealing box sealed to efficiently protect them from oxidation or contamination at any time. They are maintained at a temperature between 1050°C. to 1100°C. for a period of at least one hour. The rate of cooling is unimportant except between 525°C. and 325°C. Within this range the rate at no instance exceeds 1°C. per minute.

In Fig. 2, curve A represents on a double logarithmic scale the permeability characteristics of a nickel-cobalt-iron alloy in a range of frequency between 100 and 100,000 cycles; curve C, the permeability of the nickel-chromium-iron alloy; and curve B, the permeability curve of the core illustrated in Fig. 1. A representative core employed for the determination of the comparative permeability indicated in these curves together with the effective modulation consists of laminations of toroidal punched rings. The inside dimension of the core is $2\frac{3}{64}$ inches; outside 3 inches; and thickness $1\frac{1}{8}$ inches. The windings comprise twisted pair conductors of 280 turns. As shown in curve A at 5,000 cycles, the permeability of the nickel-cobalt-iron alloy is approximately 590. The permeability of the core of Fig. 1 is about 510 as indicated in curve B, although that of the nickel-chromium-iron alloy as shown in curve C at 5,000 cycles is 180.

Since the total effective permeability of the core of the two alloys over the carrier frequency range of 5,000 to 100,000 cycles is substantially controlled by the nickel-cobalt-iron alloy, the laminations of this alloy are responsible for the passage of the major portion of the effective flux. In addition to the modulation coefficients of these two alloys, the effective modulation is dependent upon the proportional flux conducted by the two materials at any given frequency. While the effective modulation of the composite core is somewhat greater at carrier frequencies than a core consisting entirely of laminations of the nickel-cobalt-iron alloy, it is appreciably less than that of a core composed entirely of nickel-chromium-iron or nickel-iron alloy. For example, it has been estimated that at a fundamental frequency of 6,000 cycles, the third harmonic current resulting from the coil containing the core of nickel-chromium-

iron alloy is approximately $1/60,000$ of the fundamental current; that of a core of nickel-cobalt-iron alloy approximately $1/1,000,000$ of the fundamental; and that of the above described composite core approximately $1/400,000$ of the fundamental.

The initial permeability of the composite core at 100 cycles is 1760 (curve B) while the nickel-cobalt-iron alloy has an initial permeability of less than 800 (curve A). As explained previously, while the addition of the chromium-nickel-iron alloy increases somewhat the effective modulation at carrier frequencies, by more than doubling the initial permeability of the core at 100 cycles, an appreciable improvement in transmission efficiency at this frequency results. Consequently, the use of the composite core markedly increases the service frequency range of repeating coils without any appreciable sacrifice in carrier frequency transmission.

The invention is not restricted in its application to repeating coils, but may be applied usefully to other transformers and other electromagnetic devices in which it is desired to increase the frequency range for which these devices are highly and uniformly effective.

What is claimed is:

1. An inductive device capable of passing both voice and carrier frequency currents covering a frequency range of 100 to 50,000 cycles, with high efficiency, comprising a core with windings thereon, said core comprising a plurality of materials differing in their electric and magnetic characteristics, one of said materials having a low modulation coefficient at carrier frequencies and relatively low permeability characteristics at low frequencies, and another of said materials having a higher modulation coefficient at carrier frequencies and a higher permeability at low frequencies than the said first stated material.
2. An inductive device in accordance with claim 1, in which the material having a low modulation coefficient at carrier frequencies and relatively low permeability at low frequencies is an alloy comprising the elements, nickel, cobalt and iron.
3. An inductive device in accordance with claim 1, in which the material having a higher modulation coefficient at carrier frequencies and a higher permeability at low frequencies than the said first stated material is an alloy comprising the elements, nickel, chromium and iron.
4. An inductive device in accordance with claim 1, in which the material having a higher modulation coefficient at carrier frequencies and a higher permeability at low frequencies than the said first stated material is an alloy comprising the elements, nickel, molybdenum and iron.
5. An inductive device capable of functioning efficiently in a frequency range of

100 to 50,000 cycles comprising a core and windings thereon, said core comprising laminations of a nickel-cobalt-iron alloy having a low modulation coefficient at carrier frequencies and low permeability at low frequencies arranged in parallel with other laminations of a nickel-chromium-iron alloy having a higher modulation coefficient at carrier frequencies and a higher permeability at low frequencies than the iron-nickel-cobalt alloy.

6. An inductive device in accordance with claim 5, in which the nickel-cobalt-iron alloy comprises 69% to 70% nickel 7% to 8% cobalt and the remainder chiefly iron.

7. An inductive device in accordance with claim 5, in which the nickel-chromium-iron alloy comprises 77.5% to 79.5% nickel, 3.6% to 4% chromium and the remainder chiefly iron.

8. An inductive device comprising a core with windings thereon, said core comprising laminations of an alloy having a low modulation coefficient at carrier frequencies, a low permeability at low frequencies, and a composition comprising 69% to 70% nickel, 7% to 8% cobalt and the remainder chiefly iron arranged in parallel with other laminations of an alloy having a higher modulation coefficient at carrier frequencies, a higher permeability at low frequencies than the said first stated alloy, and a composition comprising 77.5% to 79.5% nickel, 3.6% to 4% chromium and the remainder chiefly iron.

9. A repeating coil comprising a core with windings thereon, said core comprising laminations of nickel-cobalt-iron alloy comprising 69% to 71% nickel, 7% to 8% cobalt and the remainder chiefly iron, arranged in parallel with laminations of a nickel-chromium-iron alloy comprising 77.5% to 79.5% nickel, 3.6% to 4% chromium and the remainder chiefly iron.

In witness whereof, I hereunto subscribe my name this 14th day of March, 1932.

ARTHUR J. CHRISTOPHER.