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R. GURTLE

1,876,451

IRON CORED INDUCTANCE (CHOKE COIL, TRANSFORMER) FOR DIRECT CURRENT LOADS

Filed July 11, 1931

2 Sheets-Sheet 1

Fig. 1

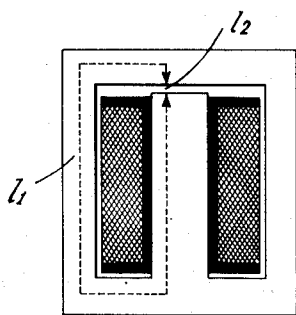


Fig. 2

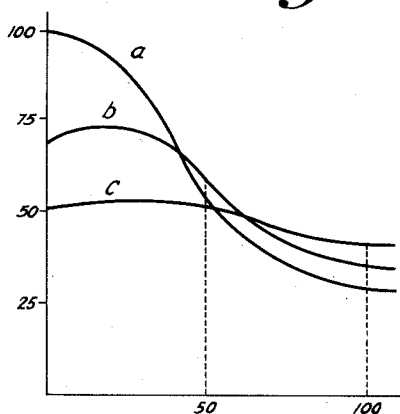


Fig. 3

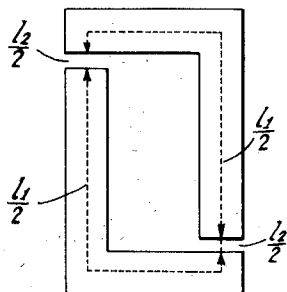


Fig. 4

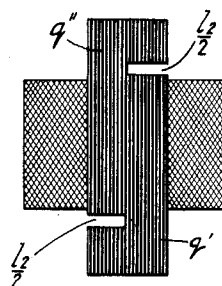
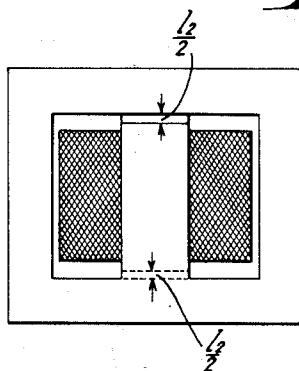
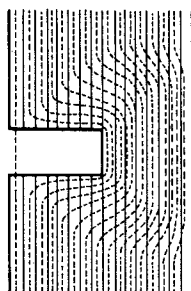


Fig. 5



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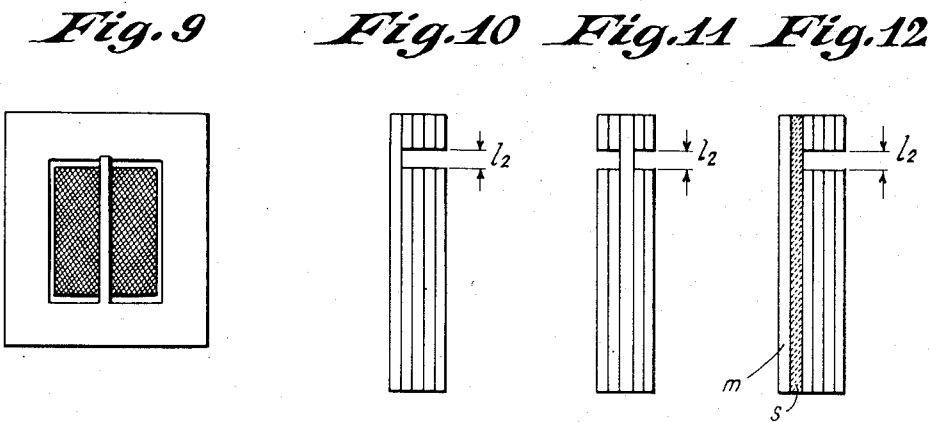
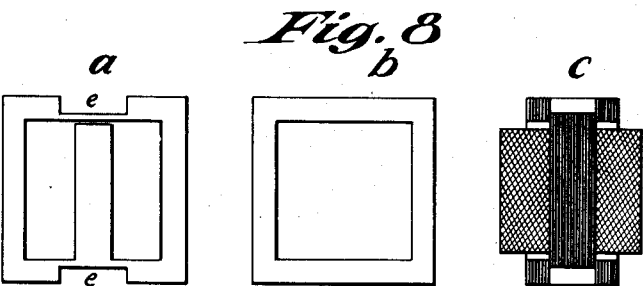
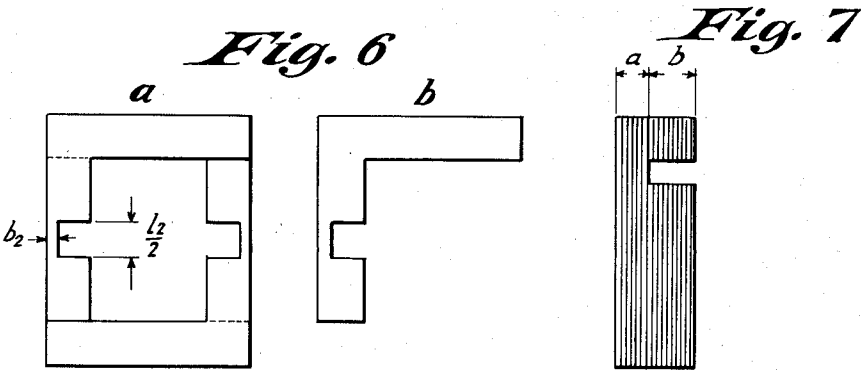
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2 Sheets-Sheet 2



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IRON-CORED INDUCTANCE (CHOKE COIL, TRANSFORMER) FOR DIRECT CURRENT LOADS

Application filed July 11, 1931, Serial No. 550,118, and in Germany August 14, 1930.

This invention relates to electric inductance apparatus and the like and more particularly to novel methods of controlling the magnetic reluctance of cores used in electrical work.

The objects of the invention will be apparent from the following specification when read in connection with the appended drawings, wherein,

Fig. 1 shows a core of the shell type with a winding;

Fig. 2 illustrates curves utilized in describing the invention;

Fig. 3 shows diagrammatically another form of core construction;

Fig. 4 illustrates a core in which two air gaps are provided;

Fig. 5 is a diagrammatic showing of conditions existing in a core wherein an air gap is provided partly through the core;

Figs. 6 and 7 illustrate cores wherein the cross-section has been reduced;

Fig. 8 illustrates a shell type core with the cross-section along certain portions of the core reduced;

Fig. 9 illustrates diagrammatically another type of core; and,

Figs. 10, 11 and 12 illustrate in a diagrammatic manner various constructions of cores contemplated by the invention.

It is known that the inductance of an iron-cored coil (choke-coil or transformer) decreases to a small value in the presence of D. C. loads. But if an air-gap is provided in the iron-core as illustrated, for instance, in Figs. 1 and 3, it is possible to increase the inductance for D. C. loads. Fig. 2 roughly illustrates the dependence of the self-inductance of a given choke-coil upon the D. C. Graph *a* refers to a choke-coil comprising a closed iron-core (stratified or superposed sheets or laminations), *b* to a choke-coil with $l_2=0.5$ mm. air-gap, *c* to $l_2=1.5$ mm. It will be seen from the curves that in the presence of a D. C. of 50 milliamps., and an air-gap of $\frac{1}{2}$ mm., shows maximum inductance, while for a D. C. of 100 milliamps., the gap must be 1.5 mm. in order that maximum inductance and thus optimum utilization may be insured. This size of air-gap therefore shall be called the "optimum gap".

The mathematical representation of this fact briefly is as follows:

The inductance of an iron-cored choke-coil with an air-gap is

$$L = 0.4\pi n^2 \frac{1}{R_1 + R_2} \times 10^{-8} \text{ henry}$$

if n =number of turns

R_1 =reluctance of iron path (for A. C.)

R_2 =reluctance of air-gap.

There is furthermore:

$$R_1 = \frac{1}{\mu} \frac{l_1}{q_1}$$

where l_1 =mean iron-path

q_1 =iron cross-section

μ =permeability for A. C. flux, in the presence of a given D. C. ats load of the iron.

This A. C. flux permeability μ (also known as incremental permeability) is a marked function of the D. C. ats. When the latter increase μ decreases, as borne out by graph *a*, Fig. 2, since the inductance is proportional to μ with a closed iron-core or path, the purpose of the reluctance R_2 (air-gap), as will now be seen, is to absorb a large part of the aggregate D. C. ats, and as a result the iron will have far less ats per centimeter and exhibit a far higher incremental permeability μ . As a result the magnetic reluctance of the iron path decreases so markedly that in spite of the added air-gap reluctance R_2 the total reluctance $R_1 + R_2$ is then considerably lower than R_1 alone previously. (Cf, for instance, *L* of graphs *a* and *c*, Fig. 2, for 100 milliamps). But if R_2 becomes too large, a decrease of R_1 will do no good any more, for the total reluctance $R_1 + R_2$ will grow. Hence, there is a certain air-gap width, i. e., the optimum width for which $R_1 + R_2$ is of a minimum value and thus *L* a maximum.

If this fact were left out of consideration, then, in order to obtain a certain required inductance, there would result several times more material, weight, labor and cost.

For this reason it is extremely important to choose the optimum air-gap for the core. Where relatively large-sized types of choke-

coils and transformers are concerned, it is generally speaking not difficult to provide the optimum air-gap width being found either by calculation or empirically.

5 The same problem becomes often difficult and expensive, occasionally even impracticable, where smaller types of choke-coils and transformers are dealt with, most particularly those furnished with cores consisting of
10 high-permeability material. For in these instances there result such small values for the air-gap that they can often not be made at all, for instance, the frequently employed shell-type Fig. 1. In the case of the
15 core-type, Fig. 3, the provision of a small air-gap if obtainable at all (for instance, by interposing a very thin piece of mica or the like) is attended with such great difficulties that the discrepancies in inductance between different coils are mostly unduly great.

Now, according to the present invention the above problem is solved in a cheap and simple manner by that the iron-core has no break in the form of a continuous air-gap
25 (l_2 , Figs. 1 and 3), but that the iron-core cross-section is reduced at one or more points. An embodiment of this idea is illustrated in Fig. 4, where the core is cross-sectionally reduced at two points, this end being
30 here attained by suitable superposition or assembly of sheet laminations with an air-gap. Fig. 5 shows the approximate shape or path of the induction lines about the reduced section. But what should be borne in mind is
35 that the major part of the induction lines passes the (admittedly) very short spaces between the laminations. The regulating reluctance R_2 , as it could be called which in the standard form of construction consists
40 of a longitudinal air-gap (in the direction of the mean path through the iron), consists in the disclosure essentially of a transversal air-gap (at right angles to the iron path),
45 and of a portion having a diminished iron cross-section. At this place, of course, the iron permeability is lower than in the rest of the core.

By means of such an arrangement it is possible to insure the desired value in the regulating reluctance R_2 , a value that can not be exactly attained with small-size choke-coils having the usual air-gap or which would have to be exceeded several times.

55 A choke-coil corresponding to Fig. 4 comprised 30,000 turns and a core comprising 45 laminations of ordinary transformer sheet material. This coil showed an inductance of 290 henry when provided with a solid core,
60 at a D. C. of 1 millamp. When furnished with a core as shown in Fig. 1 having a 0.3-mm. air-gap the inductance is found to be 315 henry. Calculation shows that this choke-coil, in the presence of a current of
65 1 millamp., exhibits a maximum inductance

for an air-gap of 0.07 mm. However even an air-gap of 0.1 mm. cannot be made by punching; and even if it were practicable one would have to calculate with too large tolerance
70 limits. Hence, the choke-coil was furnished with a core as shown in Fig. 4, laminations of 0.3-mm. being used, 22 thereof being shifted in the coil body or bobbin in one direction,
75 and 23 in the opposite sense. For such a core the inductance, at 1 millamp. D. C. amounted to 400 henry. Hence, by utilizing the basic idea of this invention an improvement of the coil of about 30% was possible.

The usefulness of the invention can be demonstrated still more clearly by the following example: With a core of the same size as in the previous instance a plate choke-coil for 1 millamp. D. C. and not less than 500
80 henry was to be made. When completely wound with practically still permissible thin wire, there were 36,000 turns on the bobbin to be used. For the smallest air-gap that is still permissible in practice of 0.3 mm., there results an inductance of only ca 440 henry
85 (for a D. C. of 1 millamp.). Hence, ordinarily a larger core would have to be used, and this would mean higher cost, expenditure of more material, greater weight, and more space. But if a core as shown in Fig. 4
90 is taken comprising two reductions in cross-sectional area then an inductance of 550 henry was obtained, for 1 millamp.

This design of the core offers this further merit that a high manufacturing tolerance is permissible. In actual manufacture there
100 suffices the rule that approximately one-half of the sheets to build up a core should be placed in one direction, and the balance in the opposite direction. In case it should then happen that in one direction only 12 instead
105 of 22 are piled up, and in the opposite direction 33 instead of 23, the inductance was found to be at most only 2% lower. Such great tolerance as regards the optimum inductance may be explained from the circumstance that one of the cross-sections (q') is
110 somewhat reduced, and the other one (q'') is increased.

Under certain circumstances it may be desirable to constitute the regulating reluctance
115 R_2 merely by one iron reluctance, in other words, to reduce the core cross-section at one place by that the lamellæ are made narrower at one place. An embodiment is shown in Fig. 6, where a is the core, and b a lamination. The notches or cut-outs can be used in the mounting work.

In what follows a number of other embodiments shall be described to further illustrate the basic idea of the invention.

Fig. 7 shows a longitudinal cross-section at right angles to the lamination surface laid through a core, laminations with air-gap and laminations without air-gap being used for building up the core. The height a is formed
125

by sheets without air-gap which are laid in the usual way staggered (i. e., "solid on joint"), while the height b is formed by laminations with air-gap.

5 Fig. 8 represents a choke-coil with normal and "frame" laminations. The normal laminations, Fig. 8a, present in this embodiment two grooves $e-e$, while the frame laminations, Fig. 8b, differ from the standard form in that the tongue is missing. Fig. 8c is a longitudinal cross-section of the choke-coil. In addition of a core consisting of a laminations, it has two frames built up of b laminations connected with the core. By means of this design for a given space, a high induc-

15 tance is attainable without unduly many turns being required, for a greater number of turns would mean an unduly high drop of D. C. potential.

20 Another instance of a choke-coil comprising one local cross-sectional reduction is shown in Fig. 9. The laminations have a very narrow tongue and are laid staggered-fashion so that the choke-coil neither has a longitudinal nor a transversal air-gap. R2 is constituted by the tongue of reduced cross-section.

Generally speaking, the reduction in cross-sectional area can be effected at any number of points and in various ways, for instance, by the use of different shapes of laminations. Also the sequence in piling up the strata may be different, as shall be explained in what follows by a simple example.

35 Fig. 10 is a longitudinal section through the core of a choke-coil which consists of a lamination without air-gap and a number of laminations with air-gap l_2 . The solid or unreduced lamination is placed marginally, though if desired, it could be placed also between the air-gap laminations, as in Fig. 11.

The manufacture of choke-coils with larger air-gaps could be also simplified by that laminations with a comparatively large air-gap l_2 are employed, while bridging the same by a sheet shifted in inversely (as, for instance, in Fig. 10). If, then, the reluctance R2 should turn out too low, the bridging lamination m (Fig. 12) is provided with a sufficiently heavy coat of insulation s , with the result that the transverse air-gap and thus also R2 are augmented.

I claim:

1. In the manufacture of electrical induction apparatus comprising a magnetic core and at least one winding on said core, said core being constructed of laminations of core material, the method of fixing the magnetic reluctance of the apparatus which comprises forming air gaps in enough of said laminations to increase the magnetic reluctance of the apparatus to a value slightly less than the desired value and then further increasing the value of the magnetic reluctance to the desired value by inserting a layer of in-

sulation material between, at least two adjacent laminations.

2. A core for transformers, choke coils and the like comprising a plurality of laminations some of which are provided with air gaps, and strips of insulation material between certain adjacent laminations.

3. Electric induction apparatus comprising a magnetic core adapted to have a winding supported thereon, said core being formed of laminations of core material some of which are provided with air gaps and insulation material between said laminations of varying insulating qualities for determining the magnetic reluctance of the apparatus.

4. In the manufacture of electrical induction apparatus comprising a magnetic core and at least one winding supported on said core, said core being constructed of laminations of core material, the steps in the method of fixing the magnetic reluctance of the apparatus which comprise forming air gaps in enough of said laminations to increase the magnetic reluctance of the apparatus to a value which is less than that of the desired value and further increasing the value of the magnetic reluctance thereof to more nearly the exact desired value by inserting a layer of insulation material between two adjacent laminations, at least one of which is not provided with an air gap.

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