May 5, 1931. H. F. PORTER 1,803,868

MAGNETIC DEVICE

Filed Sept. 28, 1928 2 Sheets-Sheet 1

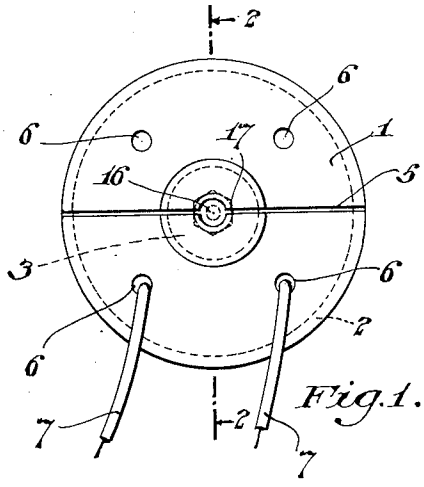


Fig. 1.

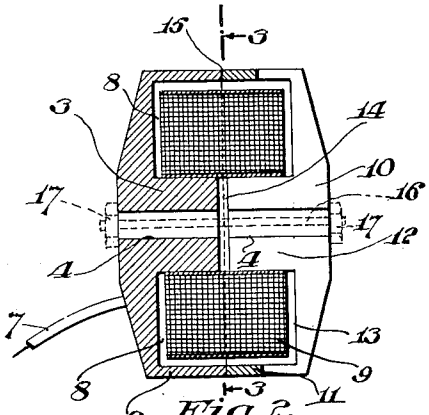


Fig. 2.

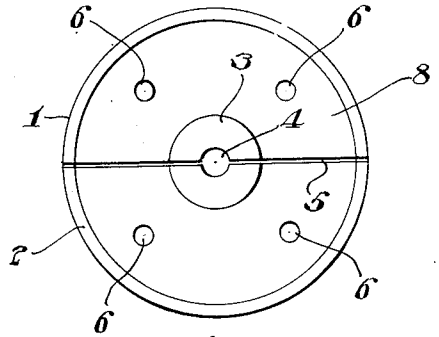


Fig. 3.

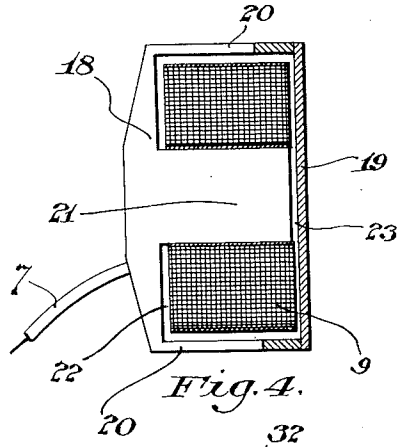


Fig. 4.

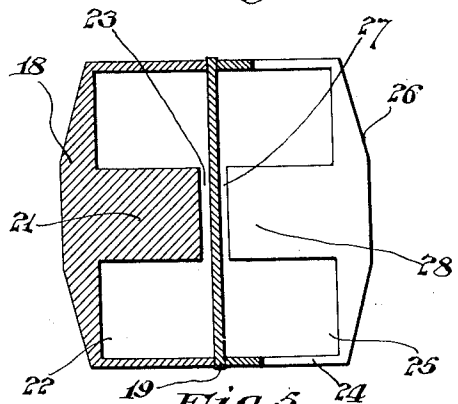


Fig. 5.

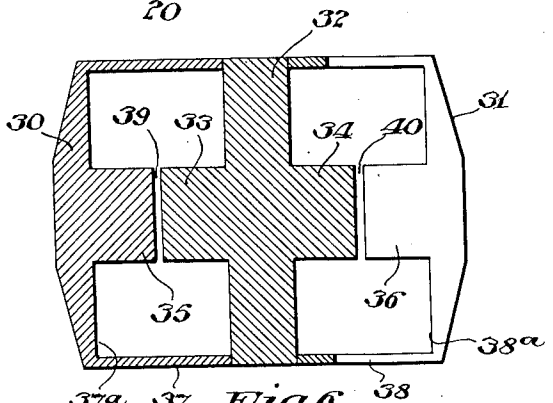


Fig. 6.

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MAGNETIC DEVICE

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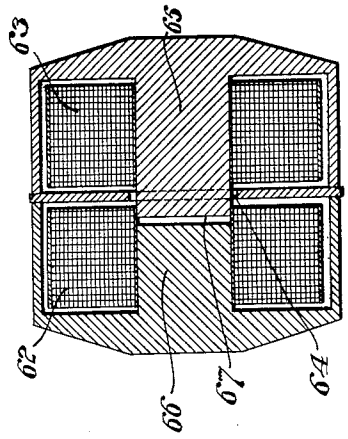


Fig. 8

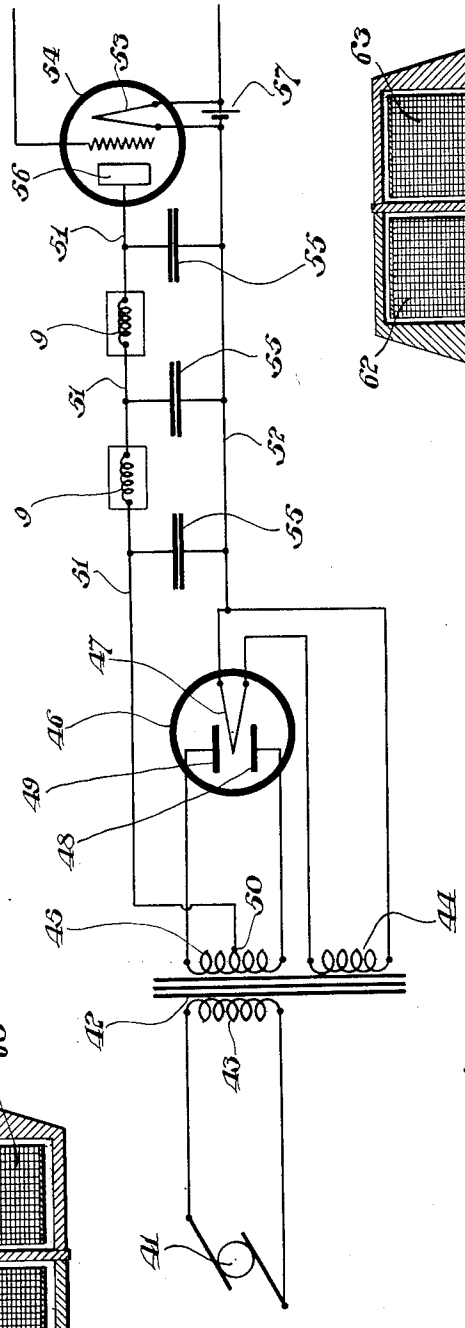


Fig. 7.

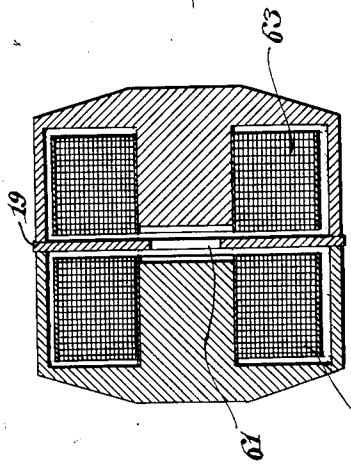


Fig. 9.

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UNITED STATES PATENT OFFICE

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MAGNETIC DEVICE

Application filed September 28, 1928. Serial No. 309,086.

My invention relates to magnetic devices, and more particularly to reactor structure.

My invention resides in a reactor for substantially eliminating pulsations or variations in amplitude of a direct current, wherein a coil traversed by said current is substantially enclosed by structure of magnetic material.

My invention further resides in a reactor of the above character wherein the coil is disposed within an annular recess of a member of magnetic material which co-operates with another member of magnetic material to complete a magnetic circuit; furthermore the material comprising said magnetizable structure preferably has a comparatively high initial permeability and high electrical resistivity.

My invention further resides in a reactor of the above character wherein the members of magnetizable material substantially enclosing said coil are spaced to form an air gap centrally of the coil; furthermore, at least one of said members is a casting or forging.

My invention resides in structure of the character hereinafter described and claimed.

The development of the alternating current receiving or transmitting set in radio apparatus and telephone amplifying equipment has directed particular attention to the proper design of smoothing reactors for eliminating the fluctuations or ripples generally existing in the rectified current. In a smoothing reactor, the core or magnetizable element is polarized by a fairly heavy direct current and a comparatively small fluctuating field is produced by the aforesaid current ripples, which of necessity must be eliminated by the smoothing reactors and associated apparatus in order that objectionable "hum" may not appear in the tone reproductions.

Heretofore smoothing reactors used in combination with condensers in the usual manner have only partially eliminated the "hum," due to the fact that a small stray or leakage field generally exists outside of the reactors, thereby preventing a perfect smoothing effect. My invention comprehends apparatus for substantially eliminating the ripples in the direct current, and in preventing stray or leakage field of the reactors from existing outside of their core members.

For a better understanding of my invention, reference is to be had to the accompanying drawings in which:

Fig. 1 is a top plan view of a smoothing reactor constructed in accordance with my invention.

Fig. 2 is a sectional side view taken along the line 2—2 of Fig. 1.

Fig. 3 is a view taken along line 3—3 of Fig. 2 with the coil element removed.

Fig. 4 is a sectional view of a modified form of my invention.

Fig. 5 is a view partly in section of another modification of my invention.

Fig. 6 is a view partly in section of another modification.

Fig. 7 is a view in section of another modification.

Fig. 8 is a view in section of another modification.

Fig. 9 is a diagrammatic illustration of a system for rectifying alternating current having included therein smoothing reactors and condensers.

Referring to Figs. 1 and 2, a cast or forged member 1 being cup-shaped in form comprises an outer annular flange 2 and a centrally disposed hub or boss 3 which has a bore 4 extending centrally therethrough. Casting 1 is of magnetic material of the character hereinafter described and has a slot 5 extending diametrically across the entire top section, through the central boss 3, and partly through the outer flange 2. Slot 5 may be cut in casting 1 by a circular cutter, which would enable the slot to extend entirely through boss 3 without entirely separating the castings in halves. It will be understood that in the above structure, and that hereinafter referred to, a plurality of slots may be used if desired and may extend either parallel with each other or radially with respect to the casting. Member 1 has holes 6 bored therethrough for permit-

ting conductors 7 to extend to the inner side of member 1.

The outer flange 2 together with the top portion of casting 1 and central boss 3, form an annular recess 8 in which a coil 9 is adapted to be seated. Coil 9 may be of any suitable design, depending on the inductance required and is so shaped that its central portion fits easily over boss 3.

A second casting or equivalent, of magnetic material 10, is adapted to co-operate with member 1 so as to substantially enclose coil 9 and to complete the magnetic circuit around the same. Member 10 may be of exactly the same design and construction as member 1, in that it also has a side flange and central boss 12 forming an annular recess 13 for also enclosing a portion of coil 19.

Referring to Fig. 2 the diametrically extending slot of member 10 is illustrated as extending vertically. Non-magnetic securing means, as a brass bolt 16 having threaded ends on which nuts 17 are mounted, extend through the central bores 4 of bosses 3 and 12 to clamp members 1 and 10 firmly together at the edges of their outer flanges. Bosses 3 and 12, however, are ground down, or otherwise reduced in height, so that an air gap 14 is formed between adjacent portions thereof when members 1 and 10 are clamped together about coil 9 to form a unitary structure. The width of air gap 14 may obviously vary in accordance with the particular design requirements of the smoothing reactor. The terminals of coil 9 are electrically connected to conductors 7 which are led through casting 1 in the manner previously described.

Fig. 4 illustrates a modification of my invention in which a cup-shaped member 18, of substantially the same design as member 1, has a plate-like or equivalent member 19 of magnetic material cooperating therewith, instead of another cup-shaped member. Member 18, as shown, has a slot extending vertically therethrough, and comprises an outer flange 20 and a central inner boss 21 forming with the side portion of member 18 an annular recess 22 within which is seated coil 9. Recess 22 is substantially deeper than recess 8 shown in Fig. 2, so that coil 9 is entirely within the said recess. The plate 19 of magnetic material is snugly clamped to the edge of outer flange 20 in any suitable manner, and is spaced by an air gap 23 from boss 21. The air gap 23 between members 19 and 21 may be accurately formed by grinding off a predetermined amount of boss 21, or by forming a depression in member 19.

In the modification illustrated in Fig. 5, substantially the same structure as shown in Fig. 4 is utilized with the exception that a second coil may be used in connection therewith by providing a second coil enclosing member for co-operating with plate 19. One coil may be disposed within recess 22 of member 18, and the other coil within recess 25 of member 26. The edges of flange 24 abut against and are secured to plate 19, as well as to member 18 by any suitable means, so that the magnetic element 19 serves as a common path for flux produced by both coils. The width of plate 19 may obviously vary in accordance with flux density requirements, and the air gap 27 formed between boss 28 and member 19 may be the same as, or differ from air gap 23.

Figs. 7 and 8 each disclose modifications of the structure shown in Fig. 5 whereby there will be a predetermined amount of mutual inductance between the two coils. It is sometimes advantageous, for reasons hereinafter explained, that there be a certain degree of mutual inductance between the coils in rectifier circuits.

Referring to Fig. 7, which is identical in structure to Fig. 5, except for the construction of plate 19, an aperture 61 is provided in said plate for permitting a certain amount of flux of one coil to traverse the magnetic circuit of the opposite coil. The construction of the two magnetic circuits being symmetrical, it will be apparent that there will be mutual inductance between coils 62 and 63 to an equal degree. The size of aperture 61 may be varied to change the degree of mutual inductance, this change being proportional to the change in size of the aperture. When the aperture exceeds a certain size it will be apparent that the two coils will act as a single choke, provided of course that they are connected in such way that their magnetic fields are not in opposition to each other.

Referring to the construction shown in Fig. 8, plate 19 is shown having a single aperture 64 of slightly larger dimensions than the cross-section of boss 65. In this modification, the construction of the magnetic circuits is not symmetrical with respect to their respective coils. Boss 65 extends through aperture 64 for a short distance beyond plate 19 and is spaced from boss 66 by an air gap 67 of predetermined width. The normal magnetic circuit of coil 62 will therefore have greater reluctance than the normal magnetic circuit of coil 63, since it will comprise air gap 67 in addition to the air gap formed by the space between boss 65 and plate 19. The normal magnetic circuits of coil 63 includes but one air gap, which is simply the space between boss 65 and plate 19, and the amount of flux traversing the magnetic circuit of coil 62 through air gap 67 will depend on the ratio of the dimensions of the two air gaps. In other words, if boss 65 was in fairly snug engagement with plate 19 there would obvi-

ously be a very small amount of leakage flux through air gap 67 to the magnetic circuit of coil 62. On the other hand, flux produced by coil 62 would traverse air gap 67 and then flow in parallel through both plate 19 and boss 65 through the magnetic circuit of coil 63. In such an event there would be a decided difference between the inductive effects of coils 62 and 63 on each other, coil 62 of course having far greater inductive effect upon coil 63.

It will be apparent therefore that by varying the size of aperture 64, and thereupon varying the dimensions of the air gap between plate 19 and boss 65, the ratio of mutual inductance, as well as the degree thereof between coils 62 and 63, may be controlled. To effect this adjustment, any suitable means for varying the size of aperture 64 may be utilized. For example, plate 19 may be separated through its diameter into halves and suitable adjusting means may be provided to move the halves with respect to each other and therefore vary the size of aperture 64.

In the modification illustrated in Fig. 6, there is shown structure for substantially completely shielding one coil from the field of another. Two cup-shaped members 30 and 31 of the character previously described have interposed between them a member 32 of magnetic material having bosses 33 and 34 extending centrally thereof. Members 30 and 31 have bosses 35 and 36, which are approximately only about one-half as high as the corresponding outer flanges 37 and 38. Bosses 35 and 33 are designed to form an air gap 39 of predetermined width, and bosses 34 and 36 are also designed to form an air gap 40 of predetermined width when the edges of flanges 37 and 38 of members 30 and 31 are clamped or secured to member 32. In the construction illustrated, air gaps 39 and 40 are remotely positioned with respect to each other, and there is small danger of stray or leakage flux penetrating to the opposite coil. Moreover, member 32 is of such thickness that the coils are magnetically shielded from each other to a complete extent.

Fig. 9 diagrammatically illustrates a system for utilizing rectified alternating current in connection with radio circuits. A source of alternating current 41, which may be the usual 110 volt house supply, is connected to a transformer 42 having a primary 43 and individual secondary coils 44 and 45. A rectifying tube 46 has its filament 47 heated directly through secondary 44. The opposite terminals of secondary 45 are connected individually to the anodes 48 and 49 of the rectifying tube which cooperates with the filament or cathode 47 for effecting double wave rectification of the alternating current. Secondary 45 has a central tap 50, to which is connected conductor 51 having in series therewith individual smoothing reactor coils 9. Reactors 9, in the present application thereof, may sometimes be mutually inductive to a certain degree for obtaining desired filtering effects for a given frequency. This is a well known characteristic of rectifier circuits.

Cathode 47 has connected thereto conductor 52 which connects to filment 53 of a vacuum tube 54. Condensers 55 of suitable capacity are connected between conductors 51 and 52, there being a condenser connected on each side of each of the reactor coils 9. The plate 56 of vacuum tube 54 is connected by conductor 51 to one of the reactor coils, the resultant direct current potential being impressed across plate 56 and filament 53. For the sake of convenience filament 53 is shown as heated by a cell 57, although in alternating current sets the filaments are generally heated directly by the alternating current.

By insertion of smoothing reactors of the character herein described in the system shown in Fig. 9, the fluctuating direct current potential between plate 56 and filament 53, which in the past has not been entirey eliminated, may be corrected. These fluctuations in the D. C. potential are of course of audio frequency, and if not eliminated will produce the objectionable "hum" which detracts greatly from the quality of the tone reproduction.

Although in the present instance the cup-shaped member of magnetic material has been particularly described as a casting, it will be understood that the said member may take other forms, such as a forging or structure comprising built-up laminations, for example, if so desired. There are, however, several important practical advantages in using castings or forgings instead of a laminated structure, and for that reason they are preferred.

Since the alternating component of the flux in the core of a smoothing reactor is very small as compared with the main direct current flux, the hysteresis and eddy current losses are rarely the limiting factor of design. For this reason the use of laminated structure is not only unnecessary but more expensive and therefore solid sections, as castings, are entirely practical. Furthermore from a viewpoint of manufacture and assembly the advantages of castings and forgings are apparent.

Referring to Fig. 2, for exmple, there is shown but a single securing element for holding the two castings together and making the same a complete unitary structure. The castings themselves moreover serve both as container and mounting for the coil, and effect perfect magnetic shielding of the unit.

Since a casting is obviously more compact than laminated structure for a given cross-sectional magnetic area, it follows that considerably less space is required for mounting the reactors, and due to the perfect magnetic shielding previously referred to, close spacing of the reactor with respect to other parts of the circuit is therefore permitted.

The location of the air gap in a smoothing reactor is of particular importance since elimination of leakage flux is an essential requirement, and since the air gap when the parts are assembled should be of predetermined width in the case of accurate reactor design. By locating the air gap in the center of the unit as illustrated in Fig. 2, leakage field is obviously eliminated since all the flux traversing air gap 14 must necessarily return by way of outer flanges 2 and 11 of castings 3 and 10. From a standpoint of accurate design, it is clear that by grinding boss 3 a predetermined distance below the plane of the edge of flange 2, and by grinding boss 12 in the same manner an air gap 14 of predetermined width is formed which will be constant as long as castings 3 and 10 are firmly clamped together at their outer edges by bolts 16.

It will be seen therefore that the air gap is not only accurately formed, but is maintained constant at all times. This is not entirely true of reactors which are so assembled that mechanical shock may vary the width of the air gap to a slight degree, and so materially vary the reluctance of the magnetic circuit.

The dimensions, etc. of the air gap and coil are designed to meet the requirements of the particular circuit in which the smoothing reactor is to be used in accordance with well known rules and laws.

The structure shown in Fig. 4 from a magnetic standpoint is entirely suitable for use as a smoothing reactor, in that there is perfect magnetic shielding of the coil and no leakage field due to air gap 23 exists outside of the unit. Applicant has found that a soft iron sub-panel, such as 19, not less than one-sixteenth of an inch thick, is sufficient for magnetic purposes, although a thicker plate from a mechanical standpoint would be desirable so that the plate may have sufficient strength and rigidity to resist shock which would tend to warp plate 19 and so vary the width of air gap 23. I have found that 4% silicon steel is the best material obtainable at present for plate 19.

When two reactors of the type shown in Fig. 4 are clamped end to end by non-magnetic fastening means, with but .008″ non-magnetic spacing between the end plates 19, no measurable coupling or interaction can be detected. This establishes the fact that there is no external magnetic field of either unit.

In the structure shown in Fig. 5 panel 19 is entirely protected by castings 18 and 26, and I have found that by using a soft iron panel only one-sixteenth of an inch thick, there is but slight mutual inductance between the coils seated in recess 22 and 25 respectively.

The structure illustrated in Fig. 6 removes all possibility of any interaction between the coils due to the opposite air gaps, and coils located in recesses 37*a* and 38*a* respectively are as perfectly shielded from each other as if they were enclosed in individual units of the type shown in Fig. 2.

The material of which the castings are made may vary in accordance with the different requirements for the reactor. I have found that 4% silicon steel castings, with carbon 1/100th of 1% or under, is best from a practical standpoint when the total ampere turns of direct current exceeds 100. In other words 4% silicon steel castings are preferred for most rectifier circuits since in such cases the number of ampere turns generally exceeds 100. However, where the number of ampere turns is less than 100, I have found that a special alloy of nickle, copper and iron, bearing the trade name "A-metal", is more economical and gives better results. The field of the latter application is in audio frequency impedances where impedance coupling is used.

The preferred magnetic material for the castings or forgings has such characteristics that the product of the initial permeability and the electrical resistivity is a maximum. As this product approaches a maximum the inductance per turn of the coils will increase and the limits of frequency at which the smoothing of these reactors is effective will be lower. If it is desired to smooth relatively high frequency pulsations most effectively, an alloy of lower electrical resistivity may be employed, or a short-circuited turn, as a copper annular ring may be incorporated within the cup-like container for the coil or coils.

For example, a choke designed to operate most efficiently at 60 cycles would not necessarily be equally as efficient at 540 cycles. In the latter case, a fairly heavy short-circuited copper turn or annular ring will reduce the effective inductance of the choke for 60 cycles but will give better smoothing characteristics at 540 cycles. Similarly an alloy of somewhat lower resistivity may be used to advantage at the higher frequencies.

The use of "A-metal" is particularly advantageous where the alternating flux density is reduced to very small values, the D. C. magnetizing force being substantially constant, since "A-metal" prossesses a characteristic known as high initial A. C. perme-

ability. It is a well known fact that for a given value of alternating flux density, the value of A. C. permeability decreases with increases of D. C. flux density. This is a property common to all ferro-magnetic materials. The A. C. permeability has no direct dependence on dB/dH, or the mathematical slope of the D. C. magnetization curve. If the value of the A. C. flux density is reduced to very small values, the D. C. flux being constant, the A. C. permeability of iron and its alloys approaches a definite limiting value. This limiting value of A. C. permeability is usually called initial A. C. permeability.

By utilizing metal of comparatively high A. C. initial permeability characteristics, as "A-metal", the reactor may obviously be more efficient within the range of small changes in A. C. flux density.

I claim:

1. Reactor structure comprising a pair of cup-like members of magnetizable material, a coil disposed in each of said members, and a plate of magnetizable material interposed between said members and forming a partition between said coils whereby mutual inductance of said coils is controlled.

2. Reactor structure comprising a pair of cup-like members of magnetizable material each having a centrally extending boss, a coil seated axially upon a boss in each of said members, and a plate of magnetizable material interposed between said members, whereby a magnetic circuit for each coil is completed through its respective boss and cup-like container, said plate and an air gap between said plate and said boss.

3. Reactor structure comprising a pair of cup-like members of magnetizable material, each having a centrally extending boss forming an annular recess within said member, a coil seated within each of said recesses, and a plate of magnetizable material interposed between said coils forming a partition between said members, said plate having an opening therein for permitting mutual inductance of said coils to a predetermined degree.

4. A reactor comprising a member of magnetizable material having comparatively high permeability at low alternating flux densities, said member having an annular recess formed therein, and a longitudinally slotted core member, a coil traversed by current whose direct current component is large relative to its audio frequency alternating current component disposed within said recess and about said slotted core, and a second member of similar magnetic characteristics completing with said first member and slotted core a magnetic circuit traversed by flux produced by current in said coil.

5. A reactor comprising a solid member of magnetizable material having high permeability at low alternating flux densities, said member having a base portion, a flange normal thereto, and a core member slotted longitudinally, a coil traversed by current whose direct current component is large relative to its audio frequency component disposed in part in an annular recess of said member formed by said slotted core and said flange, and second similar member oppositely disposed with respect to said first member with the slots of said cores in staggered relation.

6. A reactor comprising a pair of solid magnetizable members each having a base portion, a flange normal thereto, and a central core member, coil structure enclosed by said members, and a non-magnetic member extending axially of said core members for holding said pair of members against each other.

7. A reactor comprising a solid magnetizable member having a base portion, a flange normal thereto, and a core member forming with said flange an annular recess, said member having a slot extending across said base portion and longitudinally of said core member, a coil traversed by current whose direct current component is large compared to its audio frequency component disposed within said recess about said core, and a second magnetic member completing the magnetic circuit between said flange and said slotted core member.

8. A reactor comprising a pair of magnetizable members, each having an annular recess, coil structure disposed in said recesses, and a single member of non-magnetic material extending through said members axially of said coil for securing said members together, thereby enclosing said coil and forming a magnetic circuit for the flux thereof.

9. A reactor comprising a pair of magnetizable members each having a base portion, a flange normal thereto, and a core member with a slot extending across the base portion, and longitudinally of said flange and core member, and coil structure disposed within an annular chamber formed by the flanges and cores of said members.

10. A reactor comprising a cup-shaped member of magnetizable material having high initial permeability at low alternating flux densities, a coil traversed by current whose direct current component is large compared to its audio frequency alternating current component, and a second member of magnetizable material engaging the periphery of said first member completely to enclose said coil and spaced from the central portion thereof to form an air gap internally of said coil, said member having a continuous periphery and slotted to divide said member into portions united only at said periphery.

11. A reactor comprising a coil traversed by current whose direct current component is large compared to its audio-frequency alternating current component, and cup-shaped members of magnetizable material having high initial permeability at low alternating flux densities enclosing said coil, each of said members having a continuous periphery engaging the periphery of the other member and each slotted to divide it into portions united only at the periphery, the slots of one member being staggered with respect to the slots of the other member.

12. A reactor comprising a coil traversed by current whose direct current component is large compared to its audio-frequency alternating current component, a cup-shaped member of solid cross-section and of a magnetic copper-nickel-iron alloy, and a second member of magnetizable material engaging the periphery of said first member to enclose said coil, said first member being slotted to divide it into portions united only at said periphery.

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