

Oct. 22, 1940.

A. D. WHIPPLE

2,218,669

CORE OF COMMINUTED MAGNETIC MATERIAL

Filed April 25, 1938

3 Sheets-Sheet 1

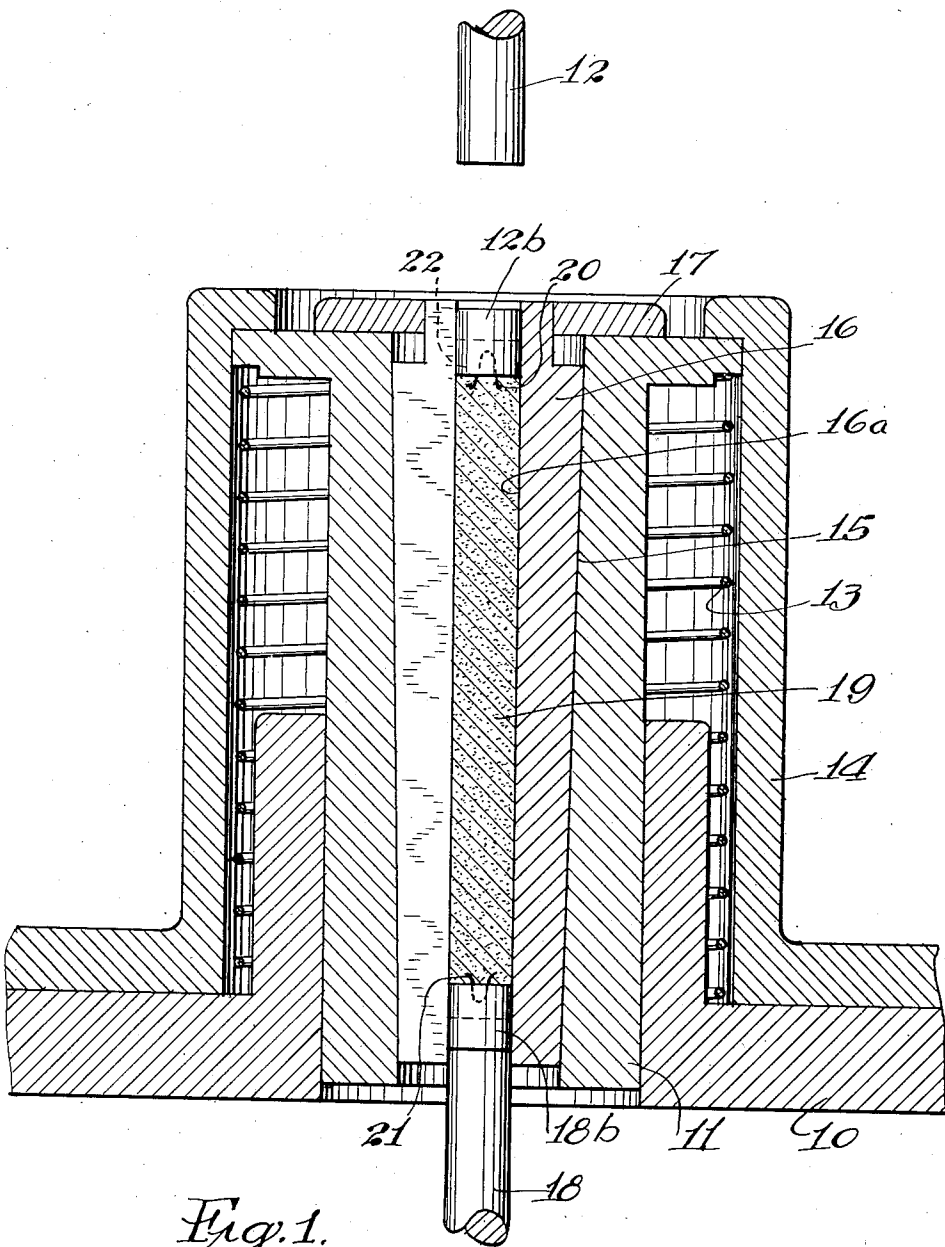


Fig. 1.

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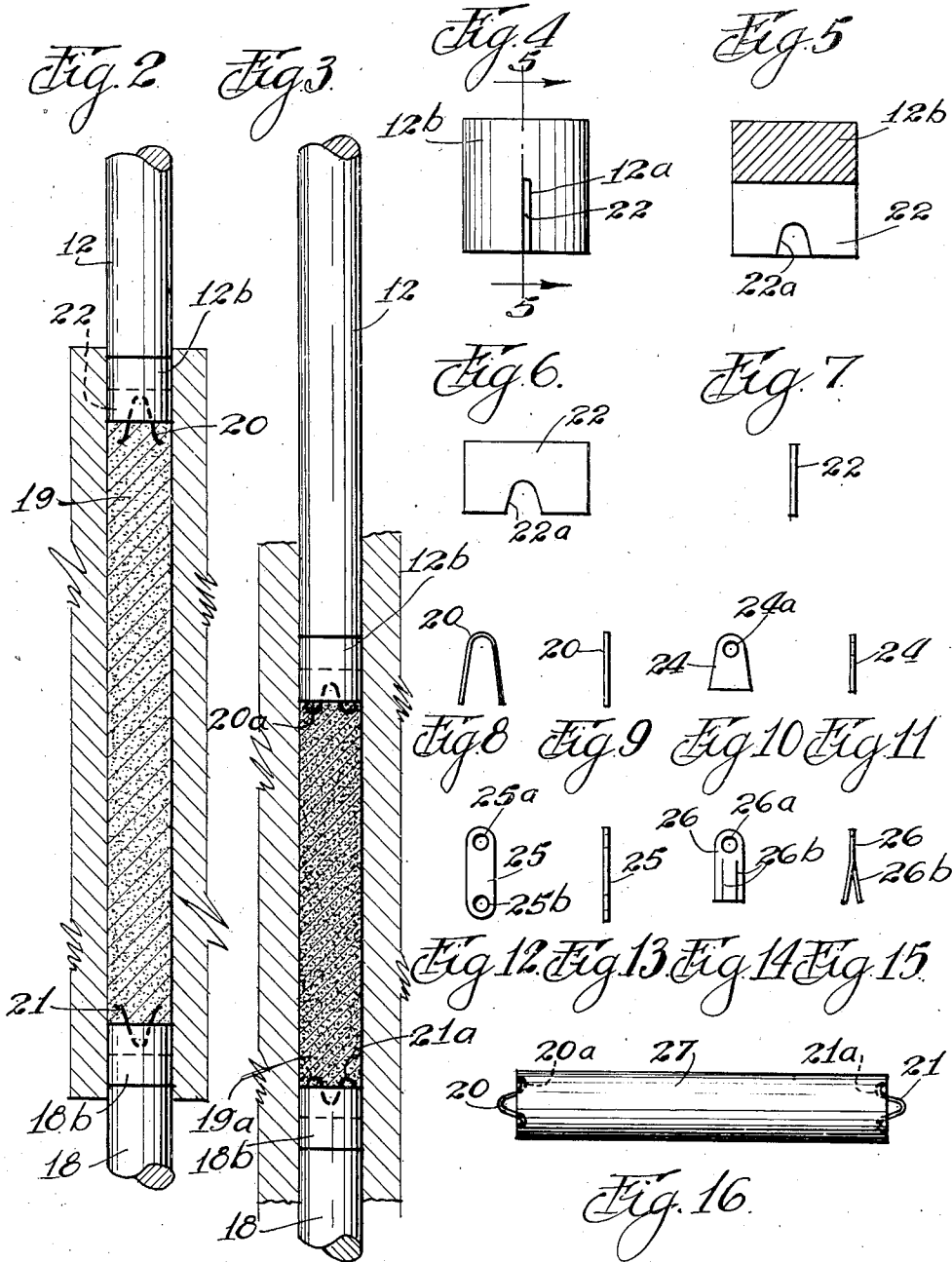
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CORE OF COMMUNUTED MAGNETIC MATERIAL

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3 Sheets-Sheet 2



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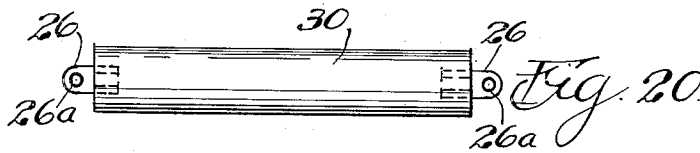
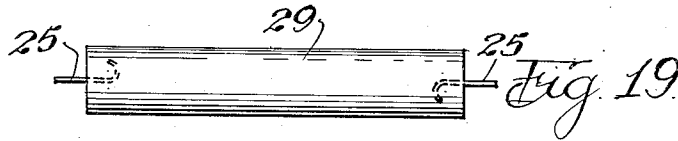
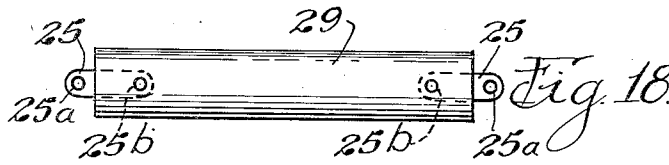
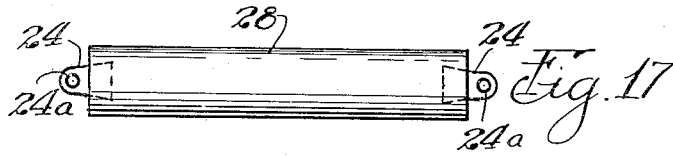
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CORE OF COMMUNUTED MAGNETIC MATERIAL

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3 Sheets-Sheet 3



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2,218,669

CORE OF COMMINUTED MAGNETIC MATERIAL

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Application April 25, 1938, Serial No. 204,245

3 Claims. (Cl. 175—21)

My invention relates to an improved form of core consisting of compressed comminuted magnetic material by which the core is provided with connection members adapted to facilitate the movement of the core longitudinally by flexible operating means, such for example as flexible cables. Cores of the kind described are adapted for use in connection with inductance coils respectively associated with the cores, so that the effective permeability of the magnetic paths of the coils may be changed as desired by movement of the cores to correspondingly change the inductance of the coils for tuning and other purposes.

Commercial developments in the art of radio communication have demonstrated the advantages of incorporating cores of the class referred to, in radio transmitting and receiving apparatus, for example, in variable inductance units forming parts of high frequency resonant circuits for tuning purposes. The relatively low inductance of the material of the cores, greatly increases the effective permeability of the magnetic paths of the inductance coils with which the cores are used, with a corresponding increase in the inductance of said coils for any condition for which the cores constitute effective parts of the magnetic paths of the coils; the effective resistances of the circuits with which the cores are used, are not correspondingly increased, due to the magnetic particles of the cores being of minute size and being electrically insulated from each other notwithstanding the many tons of pressure exerted upon said particles to compress them into stable solidified magnetic cores; in such inductance tuned resonant circuits, the capacitors required to selectively tune the circuits over a desired range of frequencies, are of fixed capacitance and are of small size, besides being relatively stable in use; as a result, such variable inductance tuning units may be compact and of much smaller bulk than corresponding variable capacitance tuning units on account of the relatively large bulk of the variable capacitors required, regardless of other disadvantages of variable capacitance tuning units, and again, with such variable inductance tuning units, increased gain may be had, and any desired selectivity and coupling may readily be secured.

Although units tuned as described by variable inductance, possess the advantages referred to, the mechanical characteristics of the cores under consideration have required, heretofore, forms of operating mechanism so exact, expensive and

even complicated in some cases, for example, where gang operation of a plurality of the cores has been required, as to substantially offset said advantages from the economical standpoint. Cores of the kind referred to, although they have substantially the same appearance as cores of solid soft iron, are in fact weak under mechanical strain, so brittle that they cannot be bent or deformed to any appreciable degree without rupture, and so easily injured by tooling operations on account of the soft nature of the particles of the cores and the burnishing effects of the tools on the cores, that turning the cores or otherwise machining them, is apt to produce continuous and electrically conductive metal paths on the machined surfaces, which for the higher frequencies of operation for which the cores are intended, serve to impede the magnetic operation of the cores, and to a degree offset some of the advantages they would otherwise have. As a result, it is practically necessary that the cores be completely finished when they leave the molds in which they are compressed, and furthermore in making the compressed cores, it is of the greatest importance to avoid undue burnishing effects between the compressed cores and the molds in ejecting them from the molds, to make certain that electrically conductive paths of metal are not produced around the cores.

From the nature of the cores above referred to, it develops that attempts to operate them in variable inductance tuning units, by means of rigid mechanical operating structures, either require a prohibitive degree of skill and workmanship if the operating mechanism is to be satisfactory, or, where the operating mechanism is inaccurately made, which is apt to be the case with low cost apparatus, that such attempts usually result in imparting dangerous mechanical strains to the cores, and particularly dangerous transverse or lateral strains that the cores are not adapted to withstand.

The difficulties referred to, incident to producing successful low cost variable inductance units tuned by the movement of cores of compressed comminuted magnetic material, are obviated by a recently proposed type of variable inductance tuning unit, in which the cores of compressed comminuted magnetic material are operated by flexible cables connected with the ends of the cores and extending to suitable operating devices by which the cores may be accurately operated without developing appreciable transverse strains in them, and by which they may be simply and

successfully arranged for gang operation if desired. The cores constituting the subject matter of my present invention, which may have any form of cross-section and any proportions desired, are particularly adapted for use in variable inductance tuning devices of the kind last referred to, and particularly where it is desired to use such cores having great length relatively to their diameter. On account of the difficulty of ejecting long slender cores of compressed comminuted magnetic material from the molds, it has heretofore been difficult if not impossible to produce such cores satisfactorily, excepting by means of the improved devices disclosed in my co-pending application Serial No. 196,653, which I find very satisfactory in producing such cores with lengths of from eight to ten times the diameter of the core and without appreciable burnishing, and with no harmful results of any kind from the ejection of the cores from the molds in which they are compressed, the cores being true, and not deformed in any way when they are ejected from the molds.

By my present invention, I am able to provide long slender cores of comminuted magnetic material with end connection members which, even when made of metallic material, have no appreciable detrimental effect on the cores electrically, magnetically or mechanically, and which serve effectively for connection with the flexible cables employed in operating the cores. This I accomplish by embedding the connection members in the end portions of the cores during the compressing of the cores, so that no subsequent machining operation of any kind is required to secure the connection members to the cores, or to adapt the connection members for use in the variable inductance units. Where the connection members are metallic, it is of great importance that the amount of metallic material involved shall be no more than required to reliably withstand the operating forces which may be exerted on the cores by the flexible cables when the cores are in use; this results in a form or forms of connection members which are readily deformable under the great pressures involved in compressing the comminuted magnetic material to form the cores, unless special provisions are employed to prevent such deformation. It is one of the objects of my invention to provide improved apparatus for supporting the connection members during the compression of the cores, so that such deformation of the external parts of the connection member will not occur during the compression of the cores, and in addition, my present invention includes the improved process of making the cores of the kind referred to, with connection members of kinds susceptible to ready deformation during compression but so manipulated during the making of the cores that deformation of the external parts of the connection members does not occur.

My invention will be best understood by reference to the accompanying drawings illustrating a preferred embodiment thereof, in which

Fig. 1 illustrates in vertical, central, sectional view, and somewhat schematically, a form of machine in accordance with my said co-pending application and adapted to produce long slender cores in accordance with my present invention.

Fig. 2 shows in a view similar to Fig. 1, the mold portion of the machine, with the compressing plunger in its position assumed at the beginning of a compressing operation.

Fig. 3 shows in a view similar to Fig. 2, the

compressing plunger at the end of a compressing operation.

Fig. 4 shows in side elevation and to an enlarged scale, the lower end of the compressing plunger.

Fig. 5 is a vertical, sectional view through the compressing plunger, taken along the line 5-5 in Fig. 4.

Fig. 6 shows in front elevation, a thin insert plate used in the end of the compressing plunger shown in Figs. 4 and 5.

Fig. 7 is an end view of the plate shown in Fig. 6.

Figs. 8, 10, 12 and 14, show respectively different forms of connection members that may be employed in connection with my present invention.

Figs. 9, 11, 13 and 15 are side views of the connection members respectively illustrated in Figs. 8, 10, 12 and 14.

Figs. 16, 17, 18 and 20 are respectively plan views of completed cores equipped respectively with connection members of the kinds illustrated in Figs. 8, 10, 12 and 14.

Fig. 19 is a front elevation illustrating the core shown in Fig. 17, as well as the core shown in Fig. 18, since said front elevation is the same for either of the said cores, and

Fig. 21 shows in front elevation the core illustrated in Fig. 20.

Similar numerals refer to similar parts throughout the several views.

The core machine illustrated in Fig. 1 includes a base 10 having a tubular bore in which a tubular and floating cell 11 is disposed for axial movement, the cell 11 being held in its position nearest the compressing plunger 12 by a spring 13 which has sufficient strength to support the floating cell but insufficient strength to in any way interfere with free movement of the cell during a compressing operation. Movement of the cell 11 under the action of the spring 13 is limited by a tubular housing 14 surrounding the spring 13 and supported by the base 10. The cell 11 contains a bore 15 which is tapered slightly with its larger end towards the compressing plunger 12, and the mold 16 of the machine is correspondingly externally tapered and fits the bore 15. The mold 16 is provided with a bore 16a of the size of the cores to be made by the machine, and said mold is divided into a plurality of sections longitudinally of the mold, so that raising the mold relatively to the cell 11 permits a slight radial expansion of the mold sections, which frees the compressed core for ready ejection without appreciable burnishing of the core and without distorting the core in any way from the form imparted to it by the mold 16. The small movement of the mold 16 towards the compressing plunger 12, to free a compressed core, is limited by a plate 17 carried by the cell 11. As a result of the construction described, after a core is compressed in the mold 16 and the compressing plunger 12 is withdrawn, movement of the ejecting plunger 13 into the mold, easily removes the compressed core because of the housing 14 limiting movement of the cell 11, and also because of the plate 17 limiting movement of the mold 16, the adhesive forces between the mold and the compressed core being practically eliminated by the expansion of the mold 16. The plungers 12 and 13 may be operated by any known means, not shown.

By means of this machine, I am able to produce accurate cores of compressed comminuted

magnetic material without burnishing due to ejection and without damaging them in any way, which are from eight to ten times as long as their diameters, or longer.

5 In using the machine described in making the improved cores of my present invention, in the first place, the body portion of the plunger 12, which includes a body portion and a bushing 12b for butting engagement with said body portion but not mechanically connected therewith, is raised sufficiently to permit a charge 19 of comminuted magnetic material to be placed in the mold 16, the bushing 18b of the ejecting plunger 18 being in the lower end of the mold, in which position it is held positively by the body portion of the plunger 18 during the compressing operation. The bushings 12b and 18b, which are similar, carry in the manner described below, connection members 20 and 21 respectively, which have projecting end portions extending towards the cavity in the mold 16. After a charge 19 has been placed in the mold, the bushing 12b and the connection member 20 carried thereby are placed in the mold and the compressing plunger 12 is forced into the mold by any suitable means not shown until the charge 19 is compressed from a condition illustrated in Fig. 2 to the compressed condition illustrated at 19a in Fig. 3. During this operation, the projecting portions of the connection members 20 and 21 are forced into the comminuted material before it is appreciably compressed and are subjected to the compressive forces developed in said material by the plunger 12, the result being that the projecting end portions of the connection members are deformed from the shape illustrated in Fig. 2 to the shape illustrated at 20a and 21a in Fig. 3, thereby effecting a clinching engagement of the connection members with the material of the compressed core.

During the compressing operation, the spring 13 permits the cell 11 to move more or less with the compressing plunger 12, depending upon how the intermediate adhesions develop between the material being compressed in the mold and the surface of the mold, which effects a substantially homogeneous distribution of the compressive pressures throughout the material in the mold. The pressure forcing the mold 16 into the cell 11, is at all times substantially equal to the force of the spring 13 upon the cell 11, which results in later requiring correspondingly small pressure during ejection, to release the mold for expansion. After the compression of the charge is ended, the body portion of the plunger 12 is raised by suitable means not shown and the ejecting plunger 18 is moved into the mold, and by its initial movement due to the large adhesions or friction then existing between the compressed charge and the mold, the mold 16 is moved a small distance with the plunger 18, in the cell 11, assuming that the cell is at the time in engagement with the housing 14, and if it is not in such engagement, the movement of the mold 16 relatively to the cell 11 just described, is effected immediately after the movement of the plunger 18 has engaged the cell 11 with the housing 14. This slight movement of the mold 16 relatively to the cell 11 permits the mold to expand sufficiently to release the surface friction or adhesion on the compressed charge 19a, which now is a compressed and solidified core of comminuted magnetic material, and continuing movement of the ejecting plunger 18 by suitable means not shown, moves the solidified core 19a and the adhering

bushings 12b and 18b from the mold, and the machine is ready for the making of the next core, after the ejecting plunger 18 has been retracted and the mold 16 has been firmly seated in the cell 11.

To support the connection members during the compressing operation, the bushings 12b and 18b are constructed as illustrated for the bushing 12b in Figs. 4 and 5. It will be understood that to stand the large compression pressures exerted upon the charge of comminuted magnetic material to compress it into a solidified core, which pressures frequently amount to many tons, the bushings must be constructed of a metal which is highly resistant to deformation, for example, hardened steel or steel alloy of one kind or another, and that as a result it is difficult to tool the compressing faces of the bushings to provide proper seats in them for the connection members, particularly where, as in the present case, the connection members are made of thin material to reduce to a minimum the amount of material inserted in the cores, and particularly when the connection members are made of metallic material. To overcome this difficulty, I provide each of the bushings as illustrated for the bushing 12b in Figs. 4 and 5, with a slot 12a opening through the compressing face of the bushing and of substantially the thickness of the connection member employed, the slot extending transversely across the bushing and longitudinally thereof. In the slot so formed, I place a thin plate 22 of suitable material, for example, hardened steel or steel alloy, in which, as more clearly shown in Figs. 6 and 7, a seat 22a has been formed extending through the plate, said seat having a conformation to fit the edges of the portion of the connection member which is to project from the core when the core is completed, the form of the seat 22a being such that the large pressures on the connection member resulting from adhesion of the end portions of the connection member with the comminuted magnetic material during a compression operation, will all be exerted outwardly against the seat, so that the connection member will not buckle or be deformed as to its portion contained in the bushing, by the compressing operation. The plate 22 formed as described, is a snug fit in the slot 12a and is secured therein in any convenient manner, for example by welding at its end portions. With some kinds of comminuted material and particularly where heat is used in compressing the cores, the compressed cores adhere to the compressing faces so strongly that they cannot be safely removed from said compressing faces until they have cooled and hardened. Where the bushings carry connection members as described, the adhesion between the ends of the bushings and the ends of the compressed core, is large, particularly where heat is used in compressing the core, and the plunger bushings described, provide a means for cooling and hardening the compressed cores so the bushings may then be removed from the cores without injuring them. This desirable result is effected without interfering with the continuous operation of the compressing machine, since a sufficient number of duplicate bushings may be employed to amply cool the cores before removing the bushings and at the same time keep the machine operating at the maximum speed of which it is capable.

As shown in Figs. 8-15 inclusive, the connection members may have a variety of forms, the connection member 20 illustrated in Figs. 8 and 9

being in the form of a staple, made by suitably bending a rod or wire to the shape indicated. The connection member 24 illustrated in Figs. 10 and 11 is of sheet material provided with an aperture 24a in the portion that projects from the finished core, the remaining portion of the connection member being continuous and imperforate and preferably having edges diverging from each other away from the aperture 24a.

The connection member 25 illustrated in Figs. 12 and 13 is of sheet material having an aperture 25a in its projecting portion and a second aperture 25b in its portion to be embedded in the material of the core, so that said material may at least to some extent, enter the aperture 25b and interlock with the connection member. The connection member 26 illustrated in Figs. 14 and 15 is of sheet material provided with an aperture 26a in its projecting portion relatively to the finished core, its other end portion being provided with slits 26b so that the resulting tongues of sheet material may be slightly bent in opposite directions, as illustrated in Fig. 15, to facilitate effective interlocking with the material of the core during a compressing operation.

In Fig. 16, I illustrate a finished core 27 in the end portions of which the adjacent end portions of connection members of the staple type illustrated in Figs. 8 and 9, have been embedded during the compressing operation. As illustrated in this figure, the end portions 20a and 21a of the connection members 20 and 21, are shown as substantially bent from their original form, by the adhesion or friction of the end portions with the material of the compressed core during the compressing operation, so that the connection members have clinching engagement with the core. At the same time, by supporting the connection members in the seats 22a above described, during the compression operation, an aperture remains between each connection member and the adjacent end of the core body, for facilitating attachment to the connection member of the flexible operating cable desired to be employed with the core.

In Figs. 17 and 18, I illustrate finished cores 28 and 29 respectively provided with end connection members 24 and 25 of the type illustrated in Figs. 10, 11 and 12, 13. The connection members 24 are in part embedded in the end portions of the core 28 to leave apertures 24a in the projecting portions of the connection members to receive the flexible operating cables to be employed. The connection members 25 are in part embedded in the end portions of the core 29 so that the material of the core will interlock with the apertures 25b in said connection members and leave the apertures 25a in the projecting portions of the connection members for attachment to the flexible operating cables to be employed.

In Fig. 19, I illustrate the core 29 in front elevation to show the deformation that may occur in the embedded portions of the connection members by the compressing operation, and by which to a greater or lesser degree, clinching engagement between the connection member and the core results. The illustration in Fig. 19 also illustrates in front elevation either of the completed cores shown in Figs. 16 and 17.

In Fig. 20, I illustrate a completed core 30 provided with connection members 26 having their split ends embedded in the core material and with their apertures 26a extending through the projecting portions of the connection members

for attachment with the flexible operating cables to be employed.

In Fig. 21, I illustrate the core 30 in front elevation to show the deformation of the split end portions of the connection members 26 by the compressing operation to effect clinching engagement between the connection members and the core.

It will be understood that whatever may be the form of the connection members, they may be of such thin material that the portions embedded in the cores may be readily deformed by the compressing operation, the requirement at the same time being that the projecting portions of the connection members shall be so supported by the plungers that said projecting portions will not be materially deformed by the compressing operation. It will further be observed that regardless of the type of connection member employed, said member presents an aperture for connection with the flexible cable that is to be used to operate the core. It will be understood that the connection members 26 may be of any wire or rod material that has the requisite stability and strength to secure the results above described, whether said material be non-metallic or metallic; in fact, I find that flexible cord of fibrous material can be effectively used to produce connection members of this type, the flexible nature of the material making it unimportant whether or not the projecting loop portion of the connection member is supported against deformation during the compressing operation. Where the connection members are of sheet material, the material may either be non-metallic or metallic, the only requirement being that the material shall be as thin and of as small cross-section as the particular material will permit, while at the same time affording the stability and strength requisite for the purposes described. The important considerations are that the connection members in any case shall be slender and of small cross-section so that even with non-metallic connection members, made for example of Bakelite, the amount of displaced magnetic material of the cores due to the embedded portions of the connection members, shall be a minimum, so that the magnetic action of the cores when used with high frequency inductance coils shall be substantially the same as though there were no disturbance whatever of the uniform distribution of the magnetic material of the core between its ends. Where the connection members are metallic, it is equally important that they shall be slender and of small cross-section, both from the standpoint of displacement of magnetic material in the cores and from the standpoint of presenting possible closed circuit paths for the flow of induced electric currents that might appreciably affect the efficiency of operation of the cores.

When it is realized that the magnetic cores described are frequently as small as $\frac{3}{8}$ " in diameter, and that they may be required to be from 1" to 1½" long for that diameter, it will be better understood why the connection members must be slender and of small cross-section to secure the results described; again, in some cases, the cores may be required to be as short as $\frac{5}{8}$ ", which emphasizes the importance of having but a small amount of embedment of the connection members in the cores. Where the connection members are of the type illustrated in Figs. 8 and 9 and are of metal, I find it desirable to use a wire or rod not more than $\frac{1}{4}$ " in diameter and pref-

erably smaller; and where the connection members are of the type illustrated in Figs. 10-15 inclusive and are of metal, I find it desirable to make them of sheet metal no thicker than $\frac{3}{4}$ " and preferably not over $\frac{1}{4}$ " thick.

By the term slender connection member or connection member of small cross-section as used herein, I mean a member of such small diameter if made of wire, rods or the like, and of such small thickness if made of sheet material, that if metallic, no appreciable losses are added thereby to the operation of the cores at high frequencies, and in any event, of whatever material the connection member may be made, that the quantity or mass of the magnetic material of the core around the connection member, is not substantially reduced by the presence of the member from what it would be without said member; furthermore, the connection members contemplated by the present invention, have small lateral stability, being principally relied upon to withstand the axial strains incident to moving the cores longitudinally for effecting inductance changes as described above.

It will be understood that the compressed cores of the present invention may have any composition, any form of cross-section and any external form that may be adapted to and required by practical manufacture and the purposes for which the cores are intended. It will also be understood that although the end connection members are shown in the drawings as being in substantially the same plane for each of the illustrated cores, the planes of said connection members for any of said cores may have any angular relation to each other, unless the device or the core operating mechanism with which the core is to be used, imposes some restriction in that connection.

While the insert plates 22 above described, constitute a most effective means for providing the plungers and plunger bushings with supporting seats for the portions of the connection members projecting from the finished cores, my invention also includes plungers and plunger bushings of the kinds described, which are not provided with such plates 22, and which have suitable seats for said connection members formed in the material of the plungers and bushings, where and as such constructions may be preferred.

While I have shown my invention in the particular embodiment above described, it will be understood that I do not limit myself thereto as I may employ equivalents without departing from the scope of the appended claims.

Having thus described my invention, what I claim is:

1. A magnetic core of compressed and insulated

ferromagnetic particles for high frequency use and having an outer diameter of the order at most of one-fourth of an inch, having molded in place in at least one of its ends a portion of a connection member having a thickness not more than substantially one-sixth of the outer diameter of the core and of frail material readily deformable under light lateral pressure, the cross-section of said member being sufficiently small so the quantity of magnetic core material in the core with the embedded portion of said member present is not substantially less than it would be with said embedded portion absent from said core, and sufficiently small so no appreciable losses are added to the core at high frequencies by the connection member, said member comprising a metal wire having its end embedded in and having clinching engagement with said core material.

2. A magnetic core of compressed and insulated ferromagnetic particles for high frequency use and having an outer diameter of the order at most of one-fourth of an inch, having molded in place in at least one of its ends a portion of a connection member having a thickness not more than substantially one-sixth of the outer diameter of the core and of frail material readily deformable under light lateral pressure, the cross-section of said member being sufficiently small so the quantity of magnetic core material in the core with the embedded portion of said member present is not substantially less than it would be with said embedded portion absent from said core, and sufficiently small so no appreciable losses are added to the core at high frequencies by the connection member, said member having a portion projecting from the core material for attachment purposes and having another portion fixedly embedded in the material of the core.

3. A magnetic core of compressed and insulated ferromagnetic particles for high frequency use and having an outer diameter of the order at most of one-fourth of an inch, having in at least one of its ends a portion of a connection member having a thickness not more than substantially one-sixth of the outer diameter of the core and of frail material readily deformable under light lateral pressure, the cross-section of said member being sufficiently small so the quantity of magnetic core material in the core with the embedded portion of said member present is not substantially less than it would be with said embedded portion absent from said core, and sufficiently small so no appreciable losses are added to the core at high frequencies by the connection member, said member having a portion projecting from the core material for attachment purposes and having another portion fixed in the material of the core.

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