No. 705,935. Patented July 29, 1902.

J. C. LEE & E. H. COLPITTS.

MAGNETIC CORE FOR INDUCTANCE COILS.

(Application filed Nov. 30, 1901.)

(No Model.) 2 Sheets—Sheet 1.

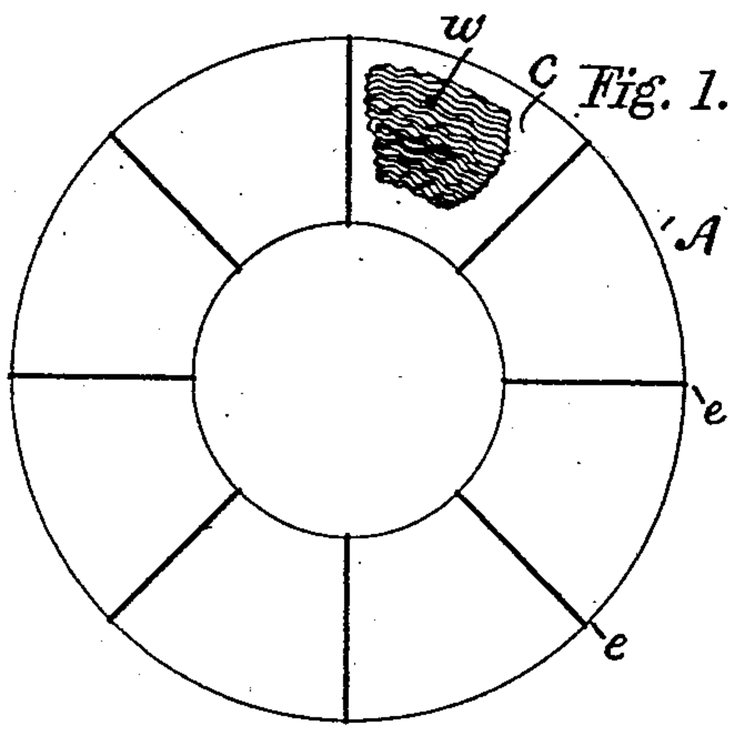

Fig. 1.

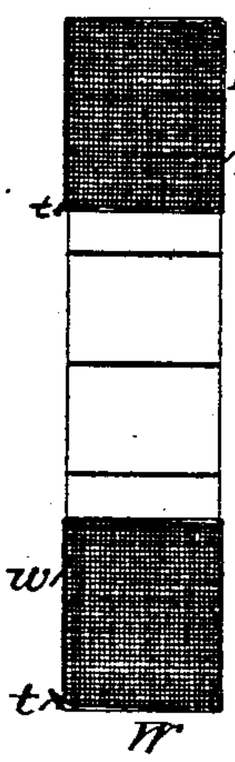

Fig. 2.

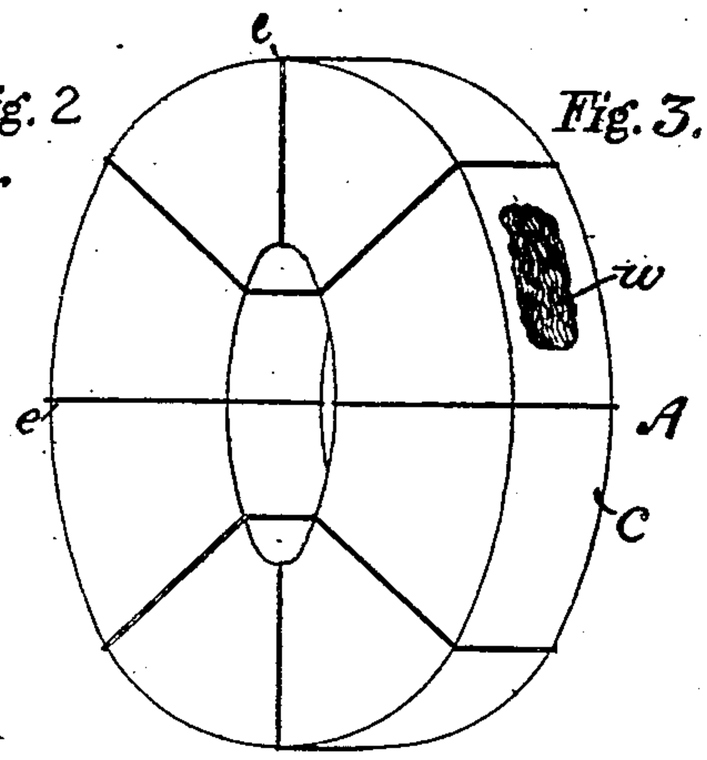

Fig. 3.

Fig. 4.

Fig. 5.

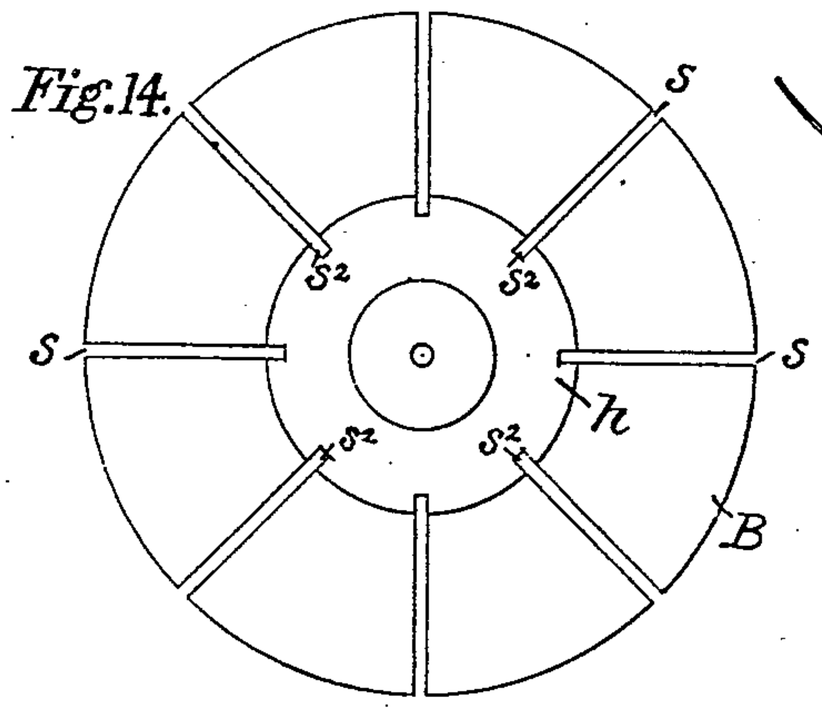

Fig. 14.

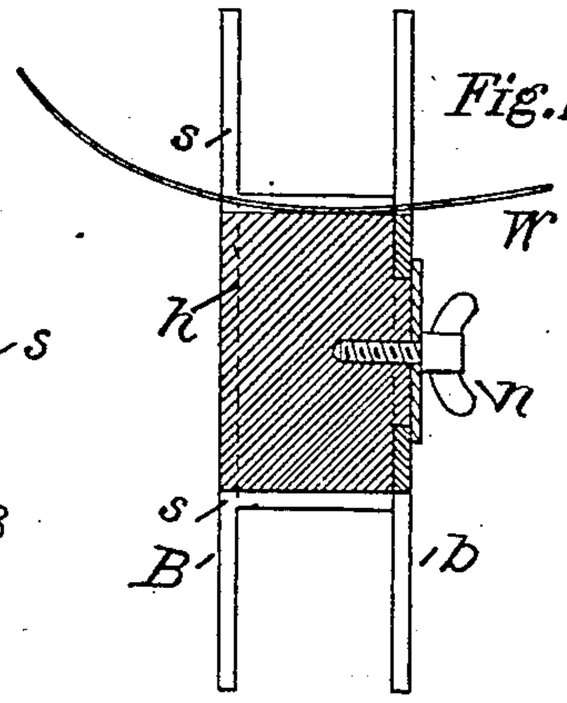

Fig. 15.

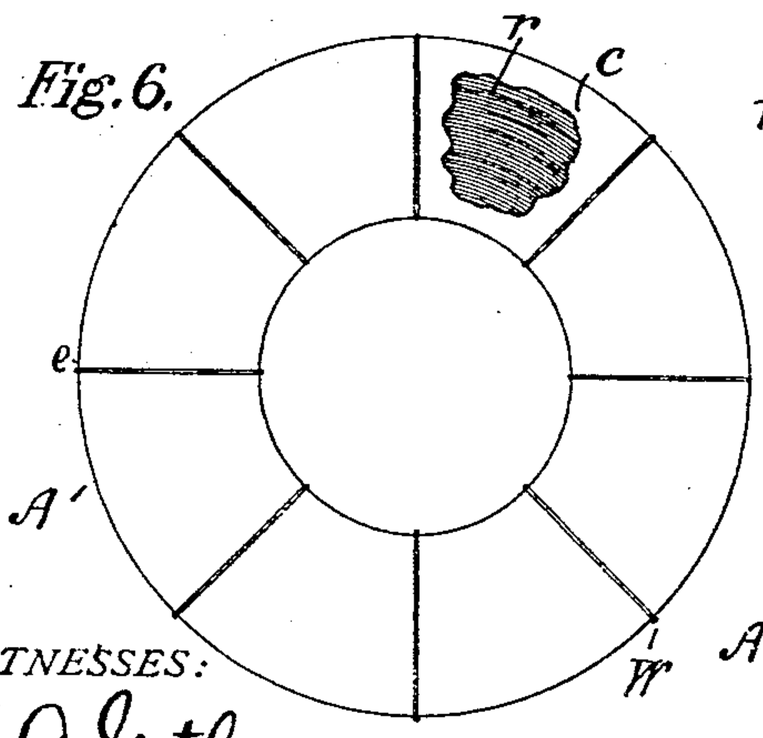

Fig. 6.

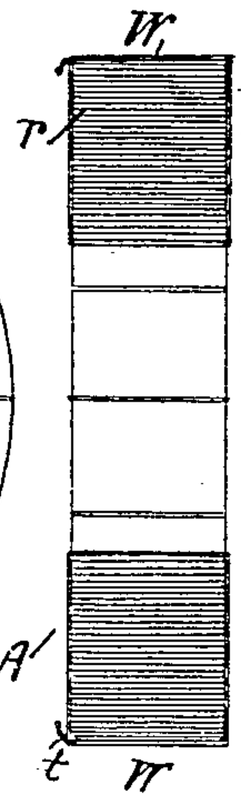

Fig. 7.

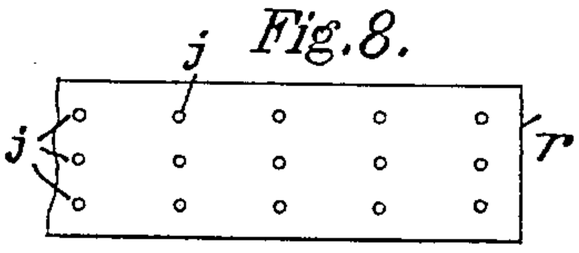

Fig. 8.

Fig. 9.

WITNESSES:

Joseph A. Gately

Frank C. Lockwood.

INVENTORS

John C. Lee

Edwin H. Colpitts

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MAGNETIC CORE FOR INDUCTANCE COILS.

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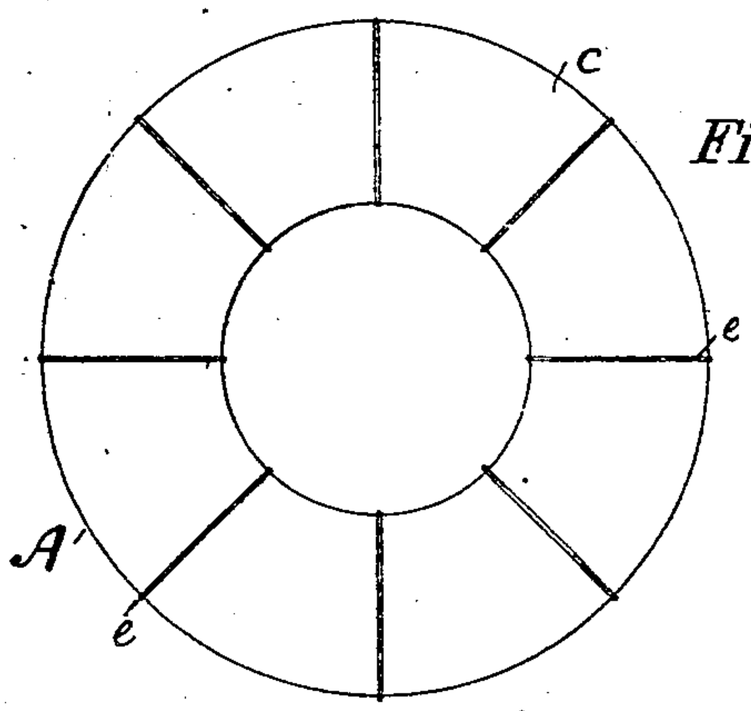


Fig. 10.

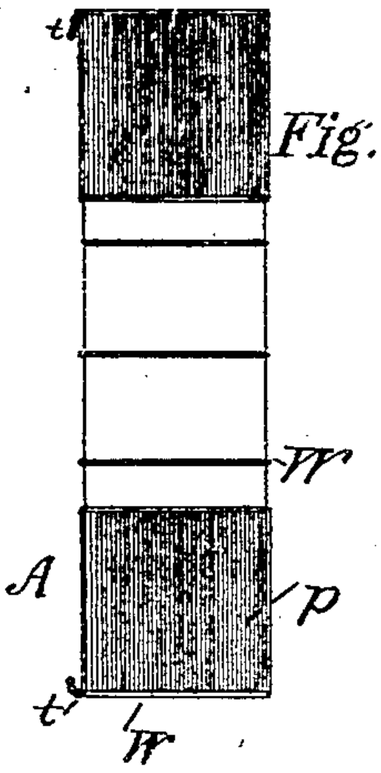


Fig. 11.

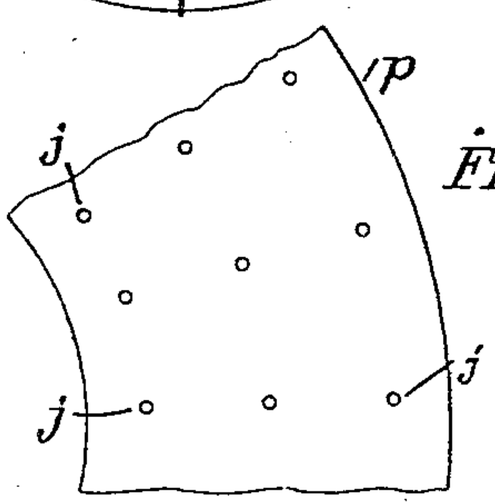
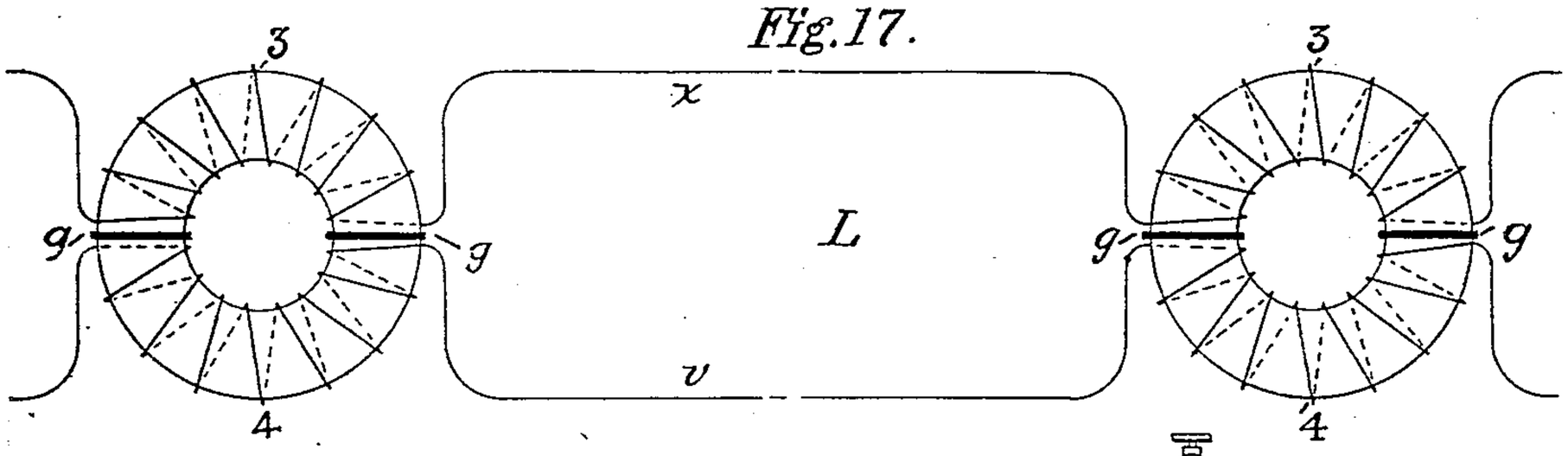


Fig. 12.

Fig. 13.

Fig. 17.



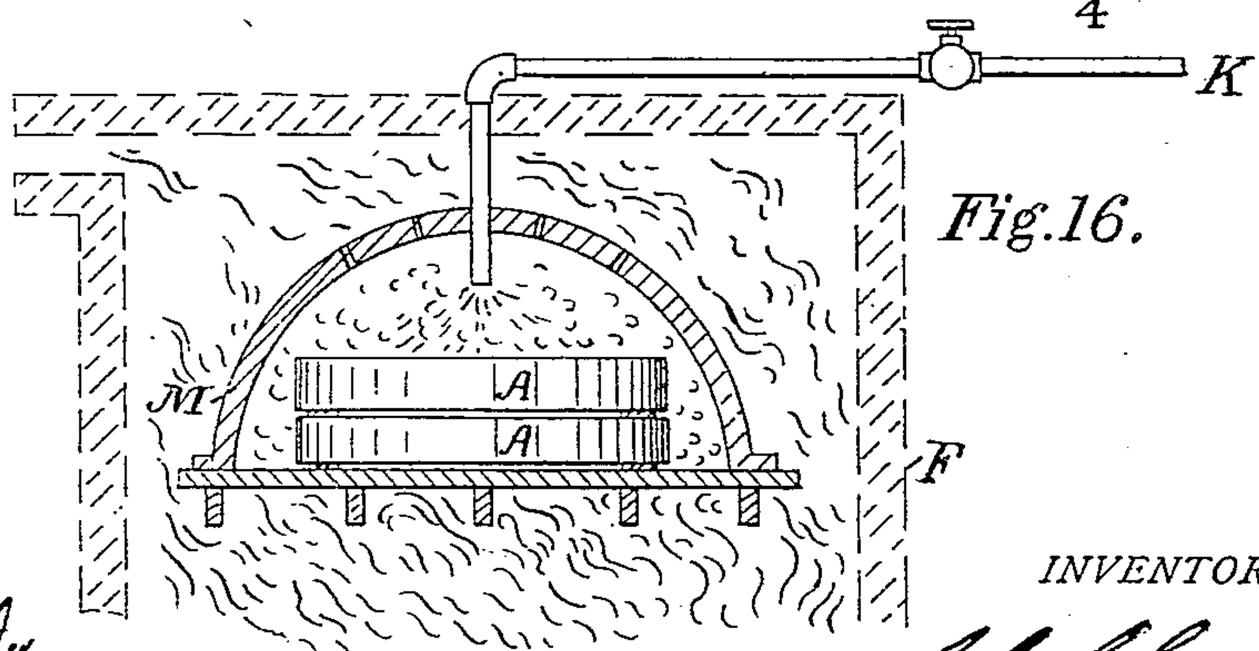


Fig. 16.

WITNESSES:

Ralph A. Gately

Frank C. Lockwood.

INVENTORS

John C. Lee

Edwin H. Colpitts

UNITED STATES PATENT OFFICE.

JOHN C. LEE, OF BROOKLINE, AND EDWIN H. COLPITTS, OF BOSTON, MASSACHUSETTS, ASSIGNORS TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

MAGNETIC CORE FOR INDUCTANCE-COILS.

SPECIFICATION forming part of Letters Patent No. 705,935, dated July 29, 1902.

Application filed November 30, 1901. Serial No. 84,199. (No model.)

To all whom it may concern:

Be it known that we, JOHN C. LEE, residing at Brookline, in the county of Norfolk, and EDWIN H. COLPITTS, residing at Boston, in the county of Suffolk, State of Massachusetts, have invented certain Improvements in Magnetic Cores for Inductance-Coils, of which the following is a specification.

This invention relates to self-induction coils such as are employed in loading electric circuits, and more particularly concerns the magnetic cores employed in conjunction with the electrical winding of such coils and constituting wholly or in part the magnetic circuits thereof.

Two main requirements of a loading-coil are that the resistance of its winding shall be low and that its inductance shall be high, and it is evident that the easiest and most practical way of attaining these qualifications is to provide the coil with a core formed of material possessing high magnetic permeability, since the magnetic circuit of the coil is thereby shortened, its field intensified, and its action exalted, so that the required inductance may be obtained with a smaller number of turns of the copper winding, and the coil consequently made much smaller than otherwise would be possible.

Heretofore the magnetic cores of loading or inductance coils and, in fact, also of induction-coils and other electromagnetic apparatus have been formed exclusively of metallic iron, and as concerns permeability the use of iron as a material for such cores leaves little to be desired; but when coils containing iron cores are employed in circuit where, as in telephone-circuits, the periodicity of the current traversing the coil-winding is high it becomes evident that the conductivity of the iron is a disadvantageous attribute thereof, since it facilitates the generation and development of parasitic or eddy currents in the conductive substance of the core, involving a fruitless and wasteful expenditure of the available electrical energy of the circuit, indicated by an undue and abnormal fall of potential in the coil or by an excessive apparent resistance between the terminals thereof, the said eddy-currents in the core being developed at the expense of losses in the working current of the circuit, which is correspondingly weakened.

To reduce the conductivity of iron cores or to increase their resistance in the plane of the electromagnetic convolutions surrounding them, and thereby to reduce eddy-currents, and thus avoid as far as possible the losses they represent, it is customary in practice to laminate such cores or in other ways to divide their iron in planes parallel to the direction of magnetization and to insulate the several component plates, strips, or wires of such a divided core from one another; but losses so small as to be negligible when occurring in electromagnetic coils used in connection with heavy currents and with the relatively low periodicity prevailing in the commercial employment of such currents frequently exercise a seriously adverse effect when found in telephone-circuits, wherein the conditions of transmission, including the exceptional feebleness and the extremely high periodicity of the average working current, are essentially different from those of any other system, and in loading-coils for telephonic circuits in order that the core losses may be sufficiently reduced it has been found expedient to divide the iron of the cores to the most radical extent, having each separate element as thin as possible, and to insulate the several component members of said cores with greater care and thoroughness than has in other classes of coil been necessary. Cores for loading-coils have thus been made both by rolling up an iron ribbon and by winding iron wire into the form of a torus, the metal of the ribbon having a thickness of but .00175 of an inch, while the thickness of the wire employed was but .003965 of an inch, the said wire being that known as "No. 38 Brown and Sharpe gage." The ribbon used was insulated on both sides, and the wire when employed was carefully and thoroughly insulated, so that each turn thereof when formed into the ring-core was completely insulated from all other turns. The reduction of iron ribbon and wire to such an attenuated thickness and size is,

however, very expensive, and to perfectly and continuously insulate ribbon or wire so reduced is both expensive and difficult.

The objects of this invention therefore are to provide a practical substitute for iron finely divided and insulated in the above-described manner as a material for the cores of inductance or loading coils from which cores capable of giving substantially improved effects or results can be made at less cost and the ready production from such substitute material of loading-coil cores of proper or suitable form.

It has been discovered that magnetic oxids possess these characteristics and that ferroso-ferric oxid (Fe_3O_4) or magnetic oxid of iron in particular is well qualified for use as a material for the cores of loading-coils, provided that some practical way can be devised for working it, for bringing it into and enabling it to retain such shape and form as to be commercially serviceable, and for maintaining practical continuity in the direction of magnetization.

To this end the invention comprehends a method or process for the production of practical and suitable inductance or loading coil-cores of magnetic oxid and a non-conducting, highly permeable, compact and solid core produced by said method. In the production of cores by the said method thin plates or ribbons or very small wire of magnetic metal are assembled, lapped, or wound into a loosely-built or partly open-work structure of any proper or desired conformation, and the said structure or core-form is then subjected to the roasting action of heat in an atmosphere capable of yielding oxygen to the metal of which it is composed until said metal is reduced or converted into magnetic oxid. This conversion is greatly facilitated by the loose or open-work arrangement of the structure, which affords the said oxygen-yielding atmosphere ready access to the interior surfaces of the metallic mass and enables the oxidation to be effected throughout the said mass and not merely on the exterior thereof, and a practical way of securing the desired supply of such an oxygen-imparting atmosphere is to admit steam or other convenient medium, such as air or carbon dioxid, which will readily give up oxygen to the metal, through a jet into the roasting-oven or muffle containing the core-form during the continuance of the oxidizing process. The core thus made is composed of artificial magnetic oxid and while retaining the form in which it was originally constructed has become dense and compact, its substance during the roasting operation having experienced internal enlargement, or, otherwise stated, its interstices or open-work interior spaces having been gradually filled up by the expansion into them of the core material as its conversion into magnetic oxid has progressed. Moreover, it is a core which with sufficient magnetic permeability combines extremely high specific electrical resistance, and therefore has no tendency to serve as a circuit for the formation and development of eddy-currents.

In the drawings which accompany and illustrate this specification, Figures 1, 2, 3, 4, and 5 concern a core initially prepared by winding wire of magnetizable metal, such as iron, into the form desired. Figs. 1, 2, and 3 are respectively a side view, a central cross-section, and a perspective view thereof, a portion of the covering in Figs. 1 and 3 being removed to show the appearance of the wire as laid up. Fig. 4 represents a straight piece of such wire, and Fig. 5 shows two such sections crimped or crinkled and laid up parallel to one another to illustrate the open-work relation of two adjacent turns when wound into proper form. Figs. 6 and 7 are side and sectional views, respectively, of a core-form made by winding or rolling up a strip or ribbon of the said magnetic metal; and Figs. 8 and 9 represent face and edge views of such a ribbon. Figs. 10 and 11 are respectively side and sectional views of a third initial construction, showing a core-form prepared by building plates of magnetic metal; and Figs. 12 and 13 are front and edge views of a portion of the plates. Figs. 14 and 15 are side and sectional views of a drum upon which the wire or ribbon may be wound and the plates piled or built up into the core-form desired. Fig. 16 illustrates the manner of oxidizing the prepared core-forms by heating or roasting them in a suitable chamber or muffle and means for introducing the oxygen-containing medium to said chamber, and Fig. 17 represents a portion of an electric circuit provided with loading-coils containing magnetic cores of the character described herein.

Referring to the drawings, A in Figs. 1 and 3 represents a finished ring-core initially prepared or built of iron wire *w*, wound to the desired form or shape and size. The size of wire employed may be varied within a considerable range, and Fig. 4 may be regarded as indicating generally a size which will be found suitable. In core-forms which we have made wire having a diameter of sixteen millimeters has been used and found satisfactory. Since such core-forms are preferably to be oxidized throughout, it is advisable, in order to facilitate oxidation, that the elements or turns thereof shall be laid up in such manner as to have some slight separation from one another, and thus to constitute a loosely-built mass or partly open-work structure having interstices between its several elements in such communication by suitable channels with the outside of the mass as to afford the oxidizing agency or oxygen-giving atmosphere ready access to the interior surfaces. In the present instance of cores prepared by winding iron wire the desired separation is attained by employing crimped or crinkled wire, as indicated by Fig. 5 and at the parts

of Figs. 1 and 3 where the covering *c* of the finished core is shown as having been removed.

Ribbons or strips of iron may be employed in place of wire in the preparation of the core-forms. Such a construction is represented by Figs. 6, 7, 8, and 9, wherein *r* indicates the said ribbon, a portion thereof being shown separately in Fig. 8. The ribbon is wound or laid up spirally, as shown in the sectional view Fig. 7 and in Fig. 6 at that part of the core A from which the covering has been stripped.

Another alternative plan of preparing the core-forms initially is to employ thin ring-shaped plates or sheet-iron rings built or piled upon one another. Fig. 12 represents a portion of such a plate *p*, and Fig. 13 indicates the way in which the said plates *p* are built up into the form desired. The open-work arrangement or desired separation of the layers or turns in the core-forms prepared from iron tape or sheet-iron rings may readily be attained, as indicated in Figs. 8, 9, 12, and 13, by prick-punches or like indentations *j*, these furnishing a number of projections between each two approximating surfaces and acting to keep such surfaces apart during the earlier stages of the oxidizing operation.

The convolutions or layers of the several core-forms prepared by either plan may be held in place and the form of the core thereby maintained by means of stout binding-wires W, any desired number of which may be threaded through the central opening and brought around to the outside, where the two ends of each such wire may then be twisted together, as at *t*.

Figs. 14 and 15 indicate a form of drum which may conveniently be employed in the preparation of the wire and tape core-forms, and, if desired, in preparing the sheet-iron ring core-form also. The said drum may consist of a hub *h*, a fixed flanged side B, attached thereto, and a detachable side *b*, adapted to be secured to the hub by any suitable device, such as a screw and nut *n*. Radial slits or channels *s* are cut at opposite points in the flanged sides B and *b* at any preferred number of points, and these are continued, as shown at s^2, for a short distance into and across the substance of the hub. These slits provide means for attaching the binding-wires W around the core-forms before the said forms are taken from the drum or reel. The said binding-wires are readily threaded through the depressions or grooves s^2, which cross the periphery of the hub, as indicated in Fig. 15, and may then be drawn up around the sides of the iron mass and secured by twisting their ends together at any outside point. The core-forms prepared as described are then heated or roasted by subjecting them to a proper temperature in the presence of a constantly supplied or renewed atmosphere capable of yielding oxygen to the iron until the whole or the main part of their metallic substance is converted into magnetic or ferroso-ferric oxid. In carrying out this operation we have, as illustrated in Fig. 16, placed one or more prepared metallic cores A in an oven muffle or oxidizing-chamber M and have brought the whole to the required heat in a reverberatory or other furnace F, steam for the constant replenishment of oxygen being supplied to the said muffle or other heated chamber by means of a pipe K entering the said chamber and extending from a suitable boiler or other generator. The several cores within the heated chamber may be held apart from each other by strips of basic fire-brick or asbestos.

To obtain a product of the required permeability, we find it desirable to convert the metal into magnetic oxid of practically uniform constitution and without any considerable admixture or association of lower oxids, and for such uniform or substantially uniform conversion the heating operation should preferably be continued for several days.

The roasting or oxidizing operation is not restricted to any precise degree of heat and may be properly performed at any high temperature within a comparatively wide range, varying from cherry red to bright orange or even white. We have, however, employed a bright cherry red with good results, our core-forms when subjected thereto for periods of time of from three days to one week having been found satisfactory.

When taken from the heating-chamber the cores are practically unchanged in conformation, but are greatly increased in weight, their substance having been transformed from iron to magnetic oxid, and they have become substantially dense, compact, and coherent, the oxid formed interiorly having expanded into the spaces or interstices originally left between the convolutions or layers. Cores of artificial magnetic oxid produced by this method are sufficiently strong for all practical purposes, are continuous in the direction of magnetization, possess sufficient magnetic permeability, and are of such high electrical resistance that core losses in inductance or loading coils with which they may be associated are so slight that they may be disregarded. The said magnetic-oxid cores when cooled may, if desired, be furnished with any suitable covering *c*—such as a wrapping of strips of stiff paper or linen—which may be secured by a resinous or asphaltic cement or by strong cords or ligaments *e*, which may pass through the central hole and around the substance of the core. The electrical winding may then be applied in any preferred way. Fig. 17 shows one way in which the coils may be wound and connected with a working circuit. Two distinct coil-windings 3 and 4 may be wound over opposite halves of the core in equal portions, separated from one another at the ends by the non-conducting partitions *g*. The said two coil-windings may then be connected, as

shown, in the two main conductors x v, respectively, of the electric circuit L.

While this specification mainly contemplates the use of iron as a magnetizable material to be oxidized for the production of our magnetic-oxid cores and while iron being perfectly adapted for the purpose is generally to be preferred, we desire to point out that the term is not to be understood in any restricted sense and that we regard the use of steel, nickel, alloys of iron and nickel, and other magnetic metals and alloys when employed to serve as the basis of magnetic-oxid cores as being within the spirit or scope of our invention.

In this application we have claimed the new core and the process of making the same. In our application filed of even date herewith, Serial No. 84,200, we have described and claimed a loaded coil, as well as an electrical circuit for the transmission of energy, of which the aforesaid core forms a part.

We claim—

1. The herein-described method of producing non-conducting magnetic cores for electromagnetic apparatus, which consists in subjecting divided magnetic metal assembled or laid up into a loosely-built or open-work mass of desired form to heat in an atmosphere capable of constantly yielding oxygen to the said metal, until the said mass is substantially converted to magnetic oxid.

2. An improvement in the art of producing cores of high electrical resistance and sufficient permeability, for inductance or loading coils, which consists in building plates wires or like thin elements of iron into proper form and size, and then submitting the same as a whole to the action of a high temperature in the presence of an oxygen-yielding atmosphere, until the iron is reduced or converted to ferroso-ferric oxid, substantially as set forth.

3. The hereinbefore-described method of making magnetic oxid cores for loading-coils, which consists in building or laying up iron plates, ribbon, or wire into a structure of desired form having interstitial spaces between the component layers or turns and extending to the exterior of the mass; in subjecting the said mass to strong heat in an oxidizing-chamber; and in supplying to said chamber an oxygen-containing medium such as steam which will readily give up oxygen to the iron, substantially as described.

4. The hereinbefore-described method of producing inductance or loading coil cores which consists in building, laying up or winding iron plates or wire into an open-work core structure of desired conformation; and in then converting the substance of said structure without change of form into a compact and relatively dense mass of artificial magnetic oxid of substantially uniform constitution, by heating or roasting the said structure in the presence of an oxygen-supplying medium such as steam or carbon dioxid, substantially as described.

5. A core for inductance-coils constituted of non-conducting material having high magnetic permeability, substantially as described.

6. A core for inductance or loading coils constituted of artificially-produced magnetic oxid.

7. A magnetic core for inductance or loading coils constituted of ferroso-ferric oxid formed in a compact mass by the substantially uniform oxidation of divided iron.

8. A magnetically-permeable core of high electrical resistance constituted of artificial magnetic oxid prepared in a solid and compact mass of desired conformation by oxidizing a structure built of plates, ribbons or wires of magnetizable metal into such conformation, substantially as described.

9. A magnetically-permeable and non-conducting core for inductance or loading coils composed throughout or mainly of ferroso-ferric oxid in a compact state, and of substantially uniform constitution, prepared by oxidizing a structure consisting initially of iron plates, strips or wire built up or wound into the desired form and size, substantially as set forth.

In testimony whereof we have signed our names to this specification, in the presence of two subscribing witnesses, this 25th day of November, 1901.

JOHN C. LEE.
EDWIN H. COLPITTS.

Witnesses:
GEO. WILLIS PIERCE,
JAMES E. LYNCH.