

Sept. 8, 1931.

V. G. APPLE

1,822,261

BAR WOUND FIELD ELEMENT

Filed June 28, 1927

4 Sheets-Sheet 1

Fig. 1

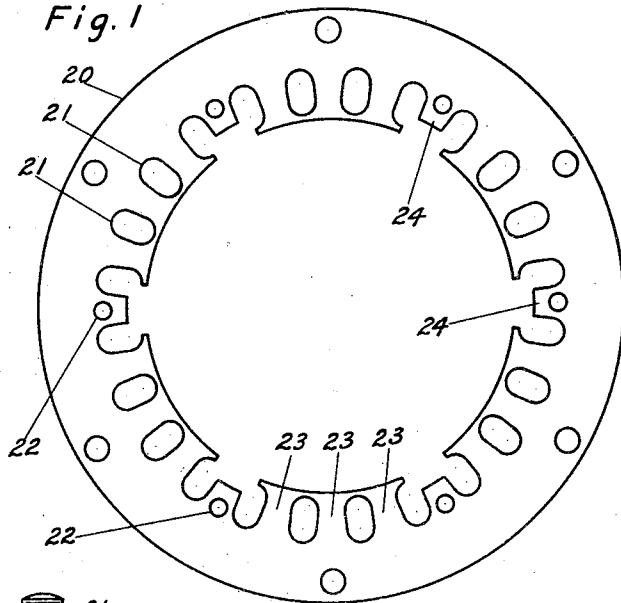


Fig. 2

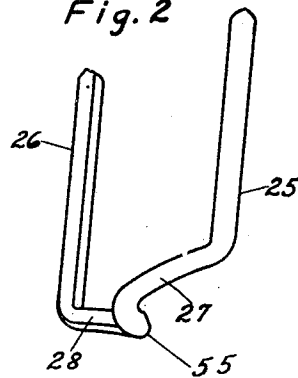


Fig. 4

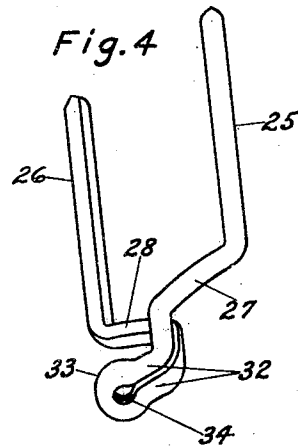


Fig. 3

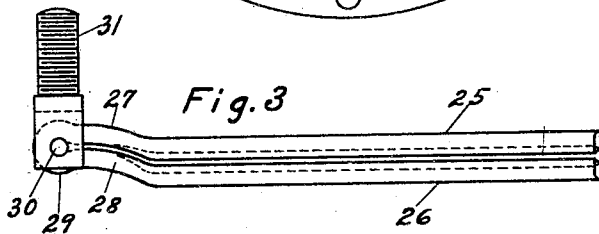


Fig. 5

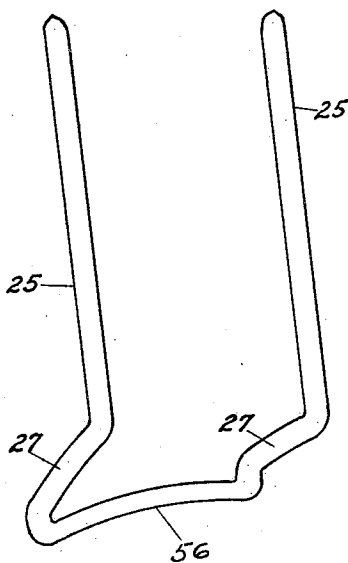
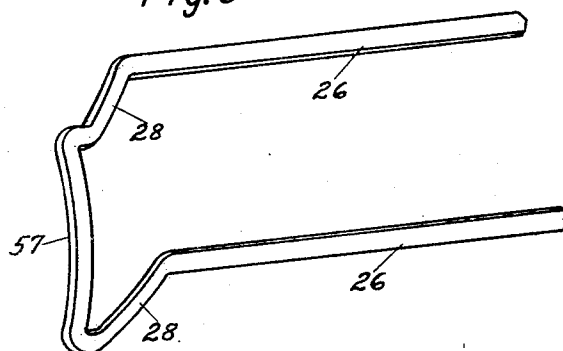


Fig. 6



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4 Sheets-Sheet 2

Fig. 7

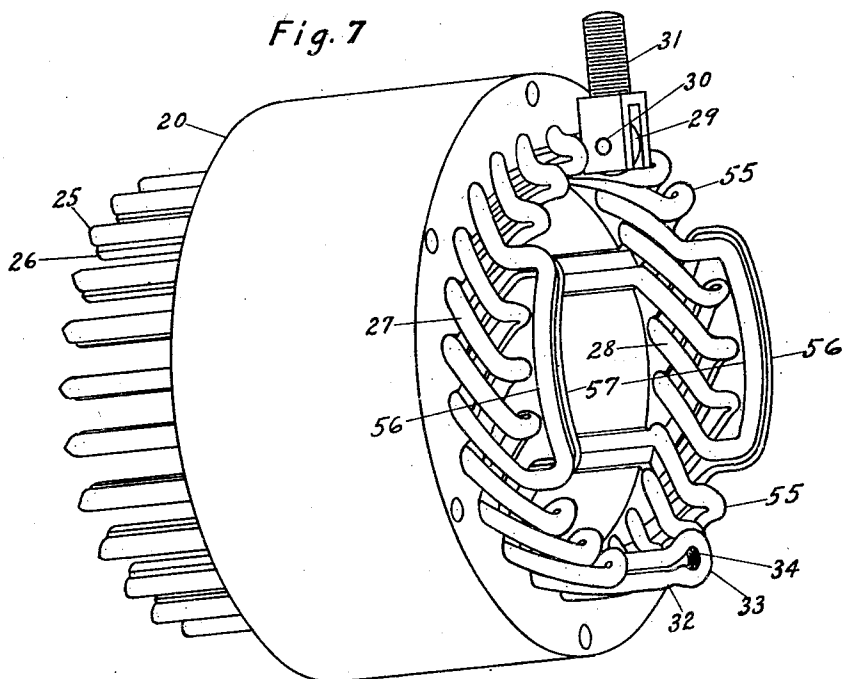
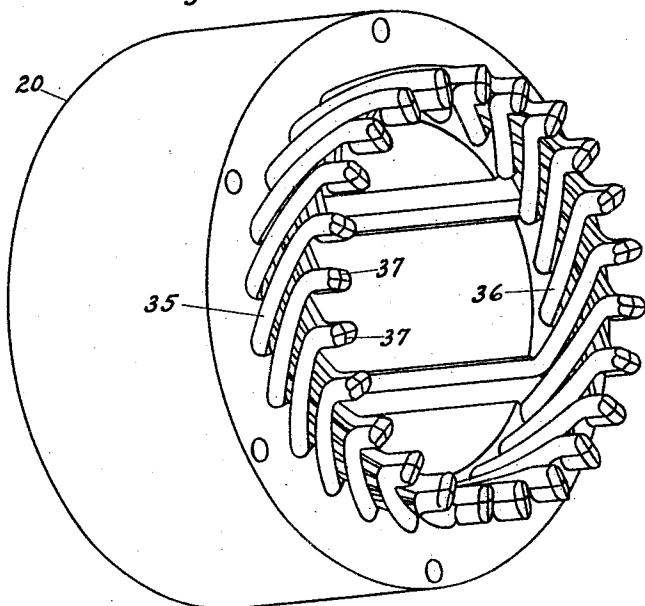


Fig. 8



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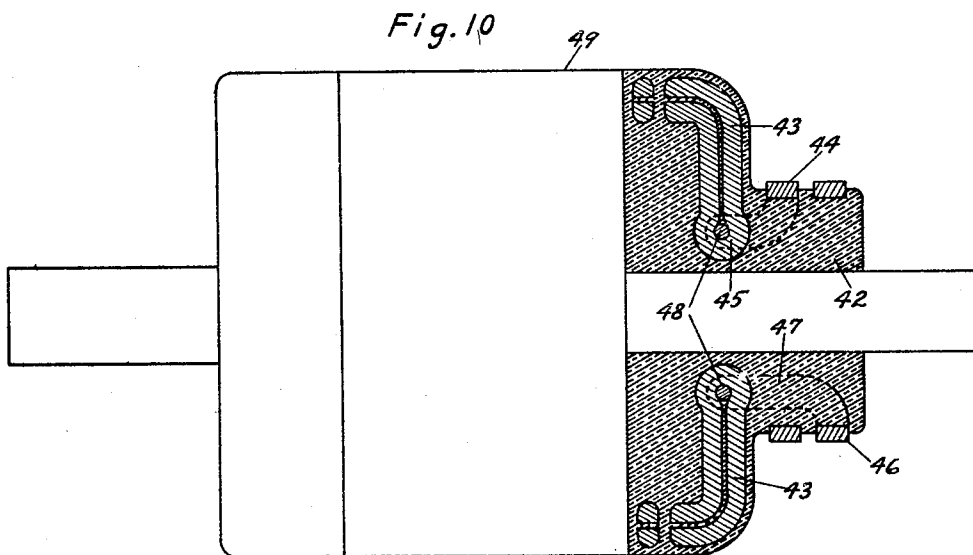
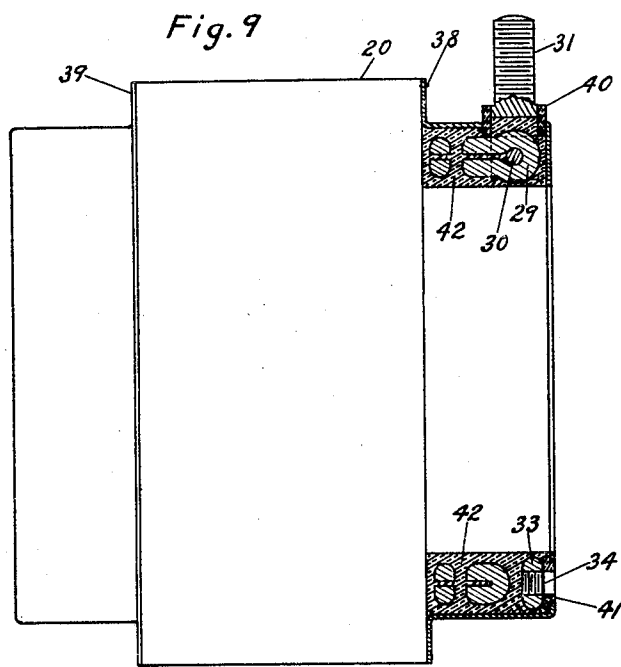
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4 Sheets-Sheet 3



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BAR WOUND FIELD ELEMENT

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4 Sheets-Sheet 4

Fig. 11

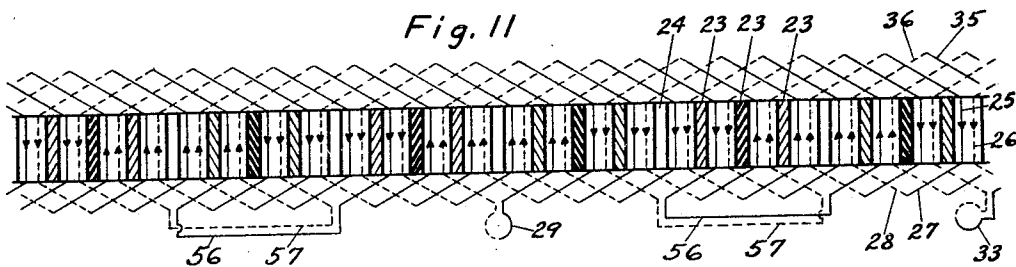


Fig. 12

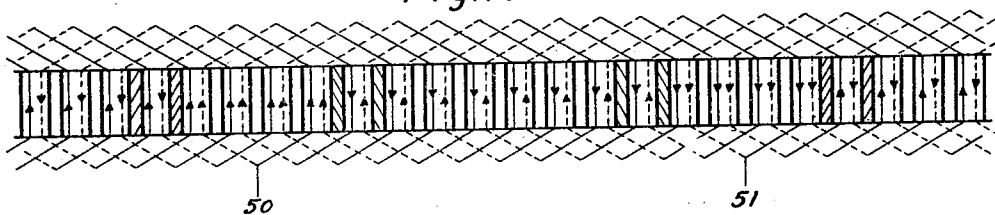


Fig. 13

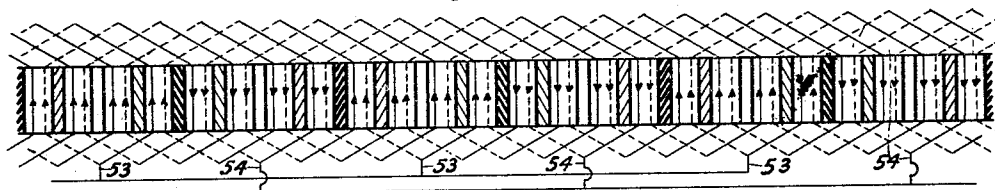


Fig. 14

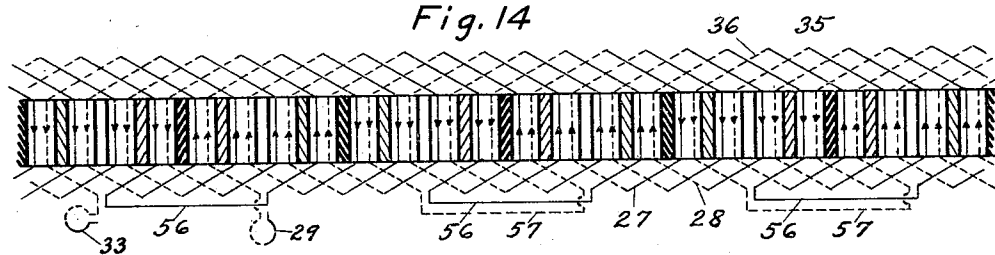
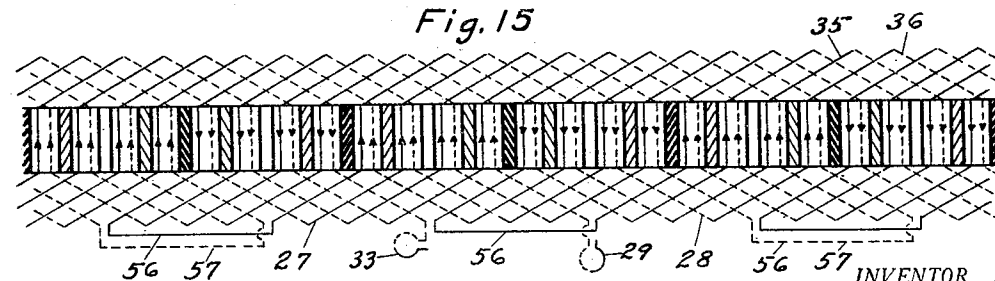


Fig. 15



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UNITED STATES PATENT OFFICE

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BAR WOUND FIELD ELEMENT

Application filed June 28, 1927. Serial No. 202,138.

My invention relates to bar wound field elements comprising a core of magnetic material and a bar winding, and one of the objects of my invention is to provide a structure which will considerably increase the number of applications wherein a bar winding may be employed. Another object is to provide a structure wherein the greatest degree of electrical and magnetic balance and the greatest efficiency, for a given amount of material used, is secured.

A further object is to provide a structure of greatest capacity in minimum dimensions for use where space limitations are imposed. Still another object is to provide a structure having higher efficiency, greater durability and better appearance at less cost than when made by present methods.

These and other objects are more specifically set forth and the manner in which they are attained fully disclosed in the following description, reference being had to the drawings, wherein:—

Fig. 1 is an endwise view of the core of magnetic material.

Figs. 2 to 6 inclusive show different units of the bar winding.

Fig. 7 is a view of a core having winding units assembled therein.

Fig. 8 shows how the projecting ends of the winding units are bent in pairs and joined to complete the winding circuit.

Fig. 9 is a view of the structure after protecting caps are placed on the ends to cover the winding, a cross section being taken thru one cap to show the winding terminals.

Fig. 10 shows how my winding may be applied to a rotating field.

Figs. 11 to 15 inclusive are diagrams showing how a core of a given number of teeth may be wound with winding units of a given span to provide the desired number of poles as well as the desired number of paths thru the winding.

Similar numerals refer to similar parts thruout the several views.

For comparison with my present invention the ordinary two layer single turn bar winding is briefly described. Each turn of such a winding comprises two conductor bars, one

in each layer, spaced apart so as to span a portion of the circumference substantially equal to one divided by the number of poles. At one end of the core these two conductor bars are joined to each other by suitable end connecting portions. At the other end of the core similar end connecting portions join them to succeeding conductors of the circuit. When the winding is lap-connected these succeeding conductors lie adjacent the first pair of conductors, and when it is wave-connected they lie more widely separated therefrom. In order to suitably polarize a core having a lap-connected winding the winding is tapped at as many equidistant points as there are poles, half for positive connection and half for negative connection to the external circuit, which divides the lap-winding into as many parallel paths as there are poles. But the wave-connected winding may be tapped at opposite points, one for positive connection and one for negative connection to the external circuit, and there will be but two parallel paths regardless of the number of poles. It follows that, in two windings, each having an equal number of bars of equal size, if it is, for instance, a six pole winding, the lap-winding has a circuit thru six parallel paths of a certain length, while the wave-winding has a circuit thru two parallel paths of triple that length. The manner of connecting the winding then producing nine times the ohmic resistance in the one as in the other.

Because of the foregoing well known facts a dynamo electric machine element may have a circuit of relatively high resistance even tho it has a two layer single turn bar-winding if the winding is single closed wave connected, while to provide the same resistance in a lap connected winding the single turn bar winding would have to be replaced with a winding having many turns of small wire.

But it is an inherent limitation of a single closed wave winding that its core must have an odd number of winding apertures. This limitation presents no difficulty in an armature, where the polarity constantly shifts around the core, but a multipolar field core having an odd number of winding aper-

tures and a wave connected winding connected to the external circuit at opposite points would be magnetically divided into poles of unequal circumferential extent, and this fault is obviously the more pronounced as the number of poles and the number of teeth per pole becomes less.

From the foregoing it will appear that should a single turn lap connected bar winding be applied to the field of a relatively small motor such as a starting motor for automotive engines, the bars of the winding being of practicable size, the current pressure would of necessity have to be reduced to about one-third the pressure ordinarily used for this purpose. On the other hand if the conventional wave winding was applied to such a core, where the number of poles and the number of teeth per pole was necessarily small and the total number of teeth necessarily odd the winding would be unbalanced.

The foregoing limitations relating to bar windings are well known to those conversant with the art and are here set forth merely to show by comparison how an object of my invention is attained by providing a bar wound multipolar element having a core with an even number of teeth and a bar winding which may be either lap or wave connected without becoming subject to the objections pointed out relative to windings of the conventional type, thus extending the range within which a bar winding may be employed.

To illustrate the principle of my invention I first show a field element for a direct current motor having six equal poles and a two-layer single closed lap connected bar winding. The core or magnetic portion of the field element is in the form of a cylindrical ring 20, Fig. 1. This ring is preferably laminated, tho for clearness of illustration it appears as a solid ring throughout the drawings. Apertures 21, 21 are spaced about the inner circumference of the core and extend lengthwise therethru. Rivets 22, 22 may extend lengthwise thru the core to furnish, in part, the necessary means to compact the laminae when a laminated core is used. In the embodiment shown the number of winding apertures is twenty-four, leaving twenty-four intervening portions or teeth extending inwardly toward the core axis as at 23, 23, 23. The loop form of winding is employed, the bars of a loop being so spaced apart as to magnetically divide the ring into six poles, one north and next south around the inner circumference, each pole comprising three flux carrying teeth 23, 23, 23. Teeth 24, 24, etc., separate the several poles and carry no flux, and, to lessen leakage from pole to pole, these teeth are shortened as shown. By forming a portion of the entire number of loops with special end connecting portions, the

circuit thru the winding is divided into two equal parallel paths, and in Figs. 2 to 6 inclusive I show the several forms of loops required to compose such a winding.

Fig. 2 shows the ordinary winding loop commonly used for a conventional two layer single turn bar winding and is the form of loop herein used to compose the greater portion of my improved winding. This loop consists of a conductor bar 25 adapted to occupy a position in the outer layer of the winding, a suitably spaced conductor bar 26 adapted to occupy a position in the inner layer of the winding, and end connecting portions or leads 27 and 28 joined together at 55.

Fig. 3 shows the special loop which I employ for connection to the external circuit. This loop is similar in all respects to the loop shown in Fig. 2 except that the joint 55 is slightly prolonged to form an eye 29. Binding post 31 is then attached to eye 29 by rivet 30, or, if desired, this binding post may be soldered, welded, or otherwise joined to the loop. Binding post 31 is in the instant case the positive terminal of the winding, and current entering at this point divides between leads 27 and 28 Fig. 3. One only of loops Fig. 3 are used in the winding shown.

Fig. 4 shows the special loop which provides the negative terminal of the present winding. This loop is in all respects similar to loop Fig. 2 except that the joint 55 is considerably prolonged to form an eye 33. This eye is bent over as at 32 and tapped as at 34. With loop Fig. 4 properly placed in the winding a brush holder may be attached by a screw entering hole 34. The two equal parallel paths of the winding join at terminal 33. One only of loops Fig. 4 are used in the winding shown.

Fig. 5 shows a special loop comprising two suitably spaced apart conductor bars 25, both of which are adapted to occupy a position in the outer layer of the winding. Outer layer leads 27 and 27 connect bars 25 thru bridge 56. Two loops Fig. 5 are required in the present winding.

Fig. 6 shows a special loop comprising two suitably spaced apart conductor bars 26, both of which are adapted to occupy a position in the inner layer of the winding. Inner layer leads 28 and 28 connect bars 26 thru bridge 57. Two loops Fig. 6 are required in the present winding.

Loops Fig. 5 and 6 may conveniently be called reversing loops since, in the completed winding, wherever a loop Fig. 5 or 6 is interposed in the circuit the current changes from clockwise around the teeth to counter clockwise and vice versa. Since both bars of a reversing loop are of the same layer of the winding, the leads connecting them are necessarily in the same angular direction which requires that the leads be connected by

bridges 56 and 57 instead of by the plain joint 55 used in the regular loops Fig. 2.

When sufficient loops for the winding have been provided they are stacked in cylindrical formation and simultaneously endwise entered into the core apertures. In stacking the loops prior to entry into the core it may be found advantageous to stack all of the loops except loops Fig. 5 and 6, then bring loops Fig. 5 from the outside radially inward and loops Fig. 6 from the inside radially outward.

After the winding and core are assembled, the structure appears as in Fig. 7, where the ends of bars 25 and 26 extend thru and beyond the core 20. It will be seen that these ends are all alike, and the problem of bending them to form leads is no different than in a winding composed entirely of regular loops Fig. 2. By means of a suitable machine, such as is described in my Patent No. 1,332,154, the outer row of conductor ends are displaced circumferentially in one direction and the inner leads circumferentially in the other direction to form outer leads 35 and inner leads 36 Fig. 8, the ends of which are joined, preferably by welding, as at 37, 37.

As some form of insulation is required between the conductor bars and the core apertures this may be provided prior to assembly, by lining the apertures with insulating material or by applying same to the conductor bars.

The method of stacking and endwise entering an entire winding into the core apertures is of great advantage since it permits the use of core apertures which are partly or entirely closed, thus eliminating the wedges and other devices commonly employed to hold the bars of a winding in position when cores having open slots are used, which, in elements rotating at high velocity, must be carefully and accurately fit or be a constant menace to safety in operation, and said method advantageous, even when open slots are used, since slots which receive the two legs of a winding loop, being spaced apart around a circumference, are at a considerable angle to each other, making it extremely difficult in some cases to radially enter the bars of a loop therein, but while the method of endwise entry is greatly to be preferred, radially entering combinations of the several types of loops which I show, thereby achieving a result similar to that disclosed, is considered to come within the scope of this invention.

After the entire winding is assembled with the core as shown in Fig. 8, I provide two flanged pressed sheet metal caps 38 and 39 and place them over the exposed portions of the windings as shown in Fig. 9. Cap 38 has a squared opening which surrounds the squared portion of binding post 31, leaving space between into which a short piece of square tubing 40 of insulating material is

pressed. Another opening in cap 38 is lined with a bushing 41 of insulating material thru which a screw or stud may extend to make connection to the winding by engaging the threaded hole 34 of eye 33.

Since caps 38 and 39 have an inner diameter substantially equal to the bore of the core, a cylindrical plug may be inserted lengthwise thru caps and core and fluid insulating material may then be poured or pumped into the space left by the windings to extend therebetween and thereabout as at 42, and hardened, or allowed to harden, by heat or otherwise, to form a solid structure wherein the turns of the winding are thoroughly insulated, one from the other, and securely held in their proper positions. A mold or clamp placed over the flanges of caps 38 and 39 may be drawn up so as to somewhat compact the laminae of core 20 to a predetermined length while the insulating material within said caps is being hardened, insuring dimensions of uniform accuracy in the finished structure, and when the insulating material is sufficiently hard the clamp and the cylindrical plug may be removed, when the field element will be complete.

In Fig. 10 I show a longitudinal cross section thru a rotating field wherein my winding is employed. Herein, instead of riveting a binding post to the eye of one terminal loop as in Fig. 3, and bending over the end of another as shown in Fig. 4, two terminal loops are provided by extending the closed ends and bending them toward the axis of the field as at 43. Ring 44 having an extending portion 45 and ring 46 having an extending portion 47 are joined to the loops by rivets 48. Otherwise the loops for this winding are like those shown for the stationary field Fig. 7 and 8 and are therefore assembled in like member, after which the assembled structure may be placed in a mould and insulating material 42 moulded about and thru the windings as hereinbefore described said insulating material further extending within and between rings 44 and 46 to form a support therefor as shown. Current may then be supplied to the winding by brushes bearing on the rings as in any rotating field element.

In order to more clearly show the current paths and the resulting distribution of the magnetic flux, I show in Figs. 11 to 15 inclusive winding diagrams wherein the circumference of the core and the winding is laid out flat for clearness, conductors of the outer layer being represented by solid lines and conductors of the inner layer by dotted lines. Fig. 11 represents a diagram of my improved winding as shown in Figs. 1 to 9 where the several types of loops employed are indicated by the same numerals employed relative to Figs. 2 to 6 inclusive and where the eye 29 is the positive terminal and

the eye 33 the negative terminal of the circuits. The arrowheads indicate the direction of the current thru the conductors and the extent of the shading on the teeth the comparative degree of magnetic saturation of each, the slanting direction of the shade lines indicating, as in common practice in such diagrams, which of the poles are north and which are south. It is obvious from the diagrams that the middle tooth 23 of a pole, being influenced by twice the number of conductors as the two outer teeth 23 of the same pole, carries a proportionately greater amount of the total flux of said pole, and that an intervening tooth 24 being oppositely influenced by an equal number of conductors will carry no flux, that the polarization is equally distributed around the circumference and that the electrical circuit comprises two equal parallel paths.

In Fig. 12 I show a diagram of a six pole lap winding made as in ordinary practice and which therefore does not include special loops as shown in Figs. 5 and 6. By tapping two opposite points in this winding as at 50 and 51 and tracing the direction of current flowing thru the winding between these points it is evident that the proper magnetization of the core is not thus attained, since in the greater portion of the winding apertures the two conductors carry current flowing in opposite direction, so that a large portion of the turns are ineffective and a weak bipolar field is produced from a 6 pole winding.

To properly polarize a winding having loops connected as in Fig. 12 it is usually tapped for connection to the external circuit at six equal points as in Fig. 13, where three points 53 are for positive connection and three points 54 for negative connection. The current then flows thru six equal parallel paths. The circuit as compared to that shown in Fig. 11 is then thru a path of three times the cross section and one third the length, making the resistance nine times as low.

Such a widening is suitable where a large volume of current at very low pressure thru few turns is required, but by comparison it is obvious that the range within which a bar winding may be used is greatly increased by employing my method of interposing special loops at suitable intervals in the winding, as thereby the same sized bars may be employed in units adapted to greatly increased pressure.

Figs. 11, 12 and 13 merely show graphically some of the limitations hereinbefore mentioned relating to bar windings of the ordinary type, and show more clearly how they are overcome by a winding made according to my present invention.

By reference to diagram Fig. 11 it may be seen that where my winding is arranged in

two equal parallel paths to provide a six pole field, two special loops Fig. 5 and two Fig. 6 are used, and without showing further diagrams it is assumed to be understood that a four pole element having two parallel paths would require but one loop Fig. 5 and one Fig. 6, while an eight pole element would contain three loops Fig. 5 and three Fig. 6, there being usually one pair less of these loops than pairs of poles.

In diagrams Figs. 14 and 15 I show a method of further extending the range of my winding by an arrangement of the loops which provides a circuit thru the entire winding in a single path. By using three loops Fig. 5 and three loops Fig. 6 and loops Fig. 2 for the remainder of the winding, the continuous circuit thus made may be cut at any point and the ends thus formed used as terminals whereupon current will flow in a single path from one of such ends to the other and polarize the core in exactly the same manner as in Fig. 11.

In Fig. 14 and 15 the circuit is shown to have been opened by cutting apart a bridge 57 of a loop Fig. 6 and bending one of the ends thus formed to provide an eye 29 for a positive terminal and bending the other end to form an eye 33 for a negative terminal.

The resistance of a winding as shown in Figs. 14 and 15 is of course four times as great as that shown in Fig. 11 or thirty-six times as great as the ordinary lap wound connection shown in Fig. 13.

In Fig. 14 the leads 27, 28, 35 and 36 are bent, relative to the bars, as in any lap connected winding while in Fig. 15 their bent relation to the bars are as in a wave connected winding and by reference to Fig. 15 it will be seen that leads 27 and 28 for a wave connected winding are necessarily longer than for the lap connected winding, so that, other things being equal, the lap connected winding Fig. 14 may be preferred. Polarization of the cores is the same whether my windings are connected as in Fig. 11, Fig. 14 or Fig. 15.

The embodiment of my invention shown in Figs. 1 to 9 inclusive is particularly adapted for the field element of an automotive starting motor and when so employed presents many advantages over the type commonly used for this purpose wherein a length of tubing is used as the yoke portion and poles are separately made and bolted to the inner surface of the tube. The structure shown and described provides flux paths of least reluctance for a given diameter of field, because of the large amount of magnetic material remaining when a sufficient amount has been removed to provide space for the windings, and because there are no joints in the magnetic circuit to increase the magnetic reluctance. The magnetic joints made when poles are bolted to a yoke are objectionable

not only because they require careful and accurate machining but further because they add considerable reluctance to the magnetic circuit, which varies in similar motors, or in different parts of the same motor, according to the degree of accuracy attained.

Applied to a field element, my winding provides the shortest possible path for the electric current for a given number of turns, thereby effecting economy in the use of copper, since the average length of a turn is shorter and the ineffective portions of the circuit have been reduced to a minimum. Since no two turns of the winding are immediately adjacent, a better means is afforded to convey the heat from the conductors, so that the motor may be operated at maximum effort for a greater period of time.

The spaced apart relation of the turns of the winding, one with another, permits of a considerable amount of insulating material being moulded therebetween and thereabout, thus providing a maximum of insulation between the turns, forming a rigid structure, and protecting the winding against the effect of oil and moisture as well as from physical injury.

In a two path winding such as I show in Fig. 11 both paths are of equal resistance resulting in an electrical balance which tends to produce a corresponding magnetic balance. The magnetic balance is further assured because of uniformity in the density of the magnetic material, in the length of the pole tips, in the thickness of the teeth and because of the absence of joints in the magnetic circuit.

The balance in a field of this character produces better conditions in the armature used therewith, so that when in ordinary practice equalizer rings may be required in an armature structure, they may more safely be omitted when a better balanced field is provided.

While I have herein shown my improved winding as embodied in field elements, which in consequence requires structural details adaptable thereto, other embodiments requiring changes in detail may be used with equal effect, as for instance, elements for alternating current machines which may require changes in the terminal loops, and while the bars of my winding are shown as having end connecting portions of the diamond type, the ends of the bars may be joined by separate or integral end connecting portions of involute or other form as long as they connect the spaced apart bars of a turn without interference, one end connecting portion with another.

Many other changes in structural detail, incident to its diverse applications must be considered within the scope of the invention defined in the following, wherein, I claim—

1. A two-layer bar winding, the greater

part of the turns of which are composed of loops comprising a bar of one layer joined to a spaced apart bar of the other layer by the closed end of the loop, the remaining turns being composed of loops having two bars in the same layer.

2. A bar wound element of a dynamo electric machine comprising a cylindrical core of magnetic material having a plurality of longitudinally extending winding apertures spaced about a circumference, said apertures containing a winding composed of a plurality of conducting bars and end connecting portions, part of said end connecting portions joining bars of one layer to spaced apart bars of another layer and the remaining end connecting portions joining spaced apart bars of the same layer.

3. A bar wound element of a dynamo electric machine comprising a cylindrical core of magnetic material having a plurality of longitudinally extending winding apertures spaced about a circumference, said apertures containing a plurality of conducting bars, suitably spaced apart pairs of which are joined by end connecting yokes to form turns of the winding, a portion of the total number of said yokes joining bars of different layers of said winding and the remaining yokes interspersed thruout the circuit joining bars of the same layer, thus providing an electrical circuit thru which current may progress in the same direction about the core as long as successive turns embody the one kind of yoke but must alter the direction in which it progresses about the core each time that it passes thru one of the other kind of yokes.

4. A bar wound element of a dynamo electric machine comprising a cylindrical core of magnetic material having a plurality of longitudinally extending winding apertures spaced about a circumference, said apertures containing a plurality of conducting bars, suitably spaced apart pairs of which are joined by end connecting yokes to form turns of the winding, a portion of the total number of said yokes joining bars of different layers of said winding and the remaining yokes interspersed thruout the circuit joining bars of the same layer, thus providing an electrical circuit thru which current may progress in the same direction about the core as long as successive turns embody the one kind of yoke but must alter the direction in which it progresses about the core each time that it passes thru one of the other kind of yoke, the spaced apart relation of the bars being such, and the reversing yokes being interposed in such positions as will magnetically divide the core into an even number of poles, one north and the next south around the circumference.

5. In a multipolar winding, conductor bars in two concentric layers, integral leads ex-

tending helically in one direction from bars of the one layer, integral leads extending helically in the other direction from bars of the other layer, integral joints where helical leads of the bars of the one layer meet the helical leads of suitably spaced apart bars of the other layer, except of intervals of one pole span where helical leads of a layer are joined by an integral bridge to the helical leads of suitably spaced apart bars of the same layer for reasons set forth.

6. A bar wound element of a dynamo electric machine comprising a cylindrical core of magnetic material having a plurality of longitudinally extending winding apertures spaced apart about a circumference so as to leave an equal number of teeth therebetween, the teeth being equally divided into an even number of poles having a shortened tooth between each pair of said poles, said apertures containing a plurality of conducting bars, pairs of which, spaced apart a distance suitable to the number of poles, are joined by end connecting yokes to form turns of the winding, a portion of the total number of said yokes joining bars of different layers of said winding and the remaining yokes interspersed thruout the circuit joining bars of the same layer, the spaced apart relation of the conducting bars being such, and the reversing yokes being interposed in such positions as will induce magnetic flux in alternate direction in successive poles but will induce no magnetic flux in the shortened teeth which separate the poles.

7. A multipolar dynamo electric machine element comprising a core, a winding composed of a number of loops, each having a conductor bar occupying a place in the outer layer of the winding, a conductor bar occupying a place in the inner layer of the winding, and a yoke connecting the two bars, said number being equal to the winding apertures of the core less the number of poles in the element, two oppositely located terminal loops similar to the first mentioned loops except for having terminal connection at the closed ends, and loops for the remaining spaces composed of bars of the same layer joined by end connecting yokes.

8. A dynamo electric machine field element comprising, a core of magnetic material having an axially extending opening therethru adapted to receive an armature, a plurality of longitudinally disposed winding apertures at its inner diameter, a bar winding in said apertures and extending axially beyond the core, metal covers attached to the ends of said core and enclosing the axially extending ends of said winding, and molded insulating material filling the space within said covers not occupied by said axially extending ends.

9. A bar wound element of a dynamo electric machine comprising a core of magnetic

material having a plurality of longitudinally extending winding apertures spaced about a circumference, a plurality of loops each having a conductor bar of the inner layer of the winding and another suitably spaced apart conductor bar of the outer layer of the winding which together compose a winding turn, the number of said loops being less than the number of said apertures, those missing being at intervals about the circumference corresponding to one pole span, the span left by the first kind of loops being taken by other loops having two spaced apart conductor bars in the same layer of said winding.

10. A method of making a dynamo electric machine element which consists of providing a core of magnetic material, placing a winding thereon, placing caps over those portions of said winding which extend beyond the core, introducing fluid insulating material into the space within the caps not occupied by said winding and hardening the insulating material to insulate the windings and bind the entire structure together and to the said caps.

11. A bar wound dynamo electric machine element comprising, a core having a plurality of winding apertures divided into a lesser number of poles, and a two layer bar winding in said apertures composed in greater part of integral loops having one leg in each layer and in lesser part of integral loops having both legs in one layer, the number of said one layer loops being equal to the number of poles less two.

12. A bar wound dynamo electric machine element comprising, a core having a plurality of winding apertures divided into a lesser number of poles, and a two layer bar winding in said apertures composed in lesser part of integral loops having both legs in the same layer, and in greater part of integral loops having a leg in each layer, the number of two layer loops being equal to two more than the number of apertures less the number of poles.

13. A bar wound dynamo electric machine element comprising, a core having a plurality of winding apertures adapted to compose a lesser number of poles, and winding loops equal to the number of apertures each integrally comprising two legs spaced apart a distance of one pole span and integral ends joining said legs, said winding loops being entered in the core apertures with the closed ends of the loops all at one end of the core and the open ends all brought together and joined in pairs at the other end of the core, loops equal to the number of poles less two having both of their legs in the same layer and the remaining loops having one leg in each layer.

In testimony whereof, I hereunto set my hand this 27th day of June, 1927.

VINCENT G. APPLE.