June 29, 1937. M. F. JONES 2,085,099

LOW LOSS ARMATURE COIL

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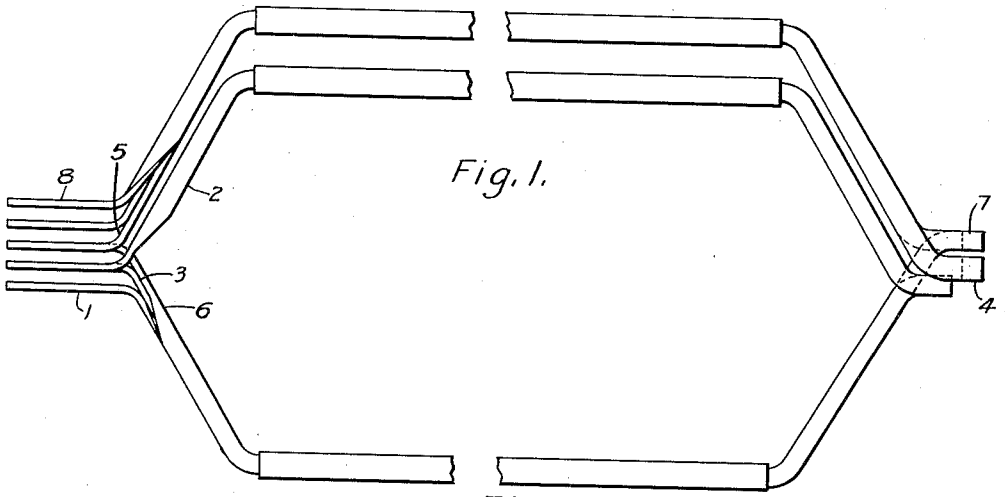


Fig. 1.

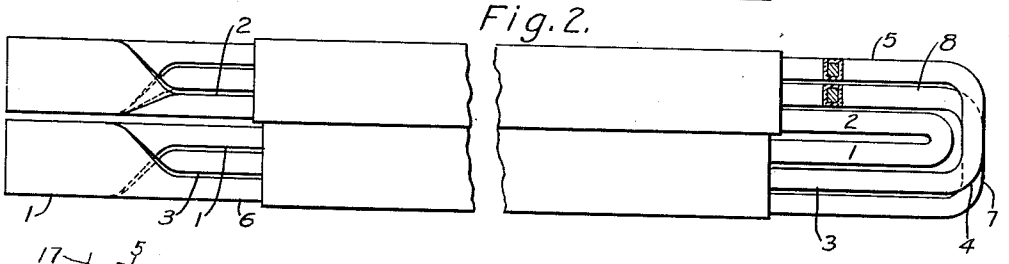


Fig. 2.

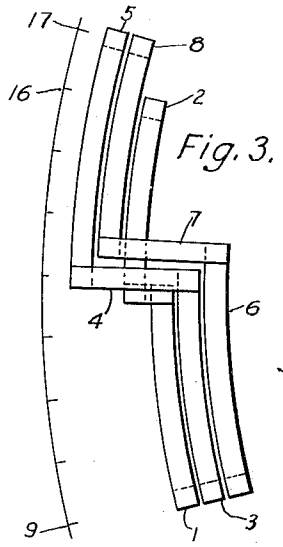


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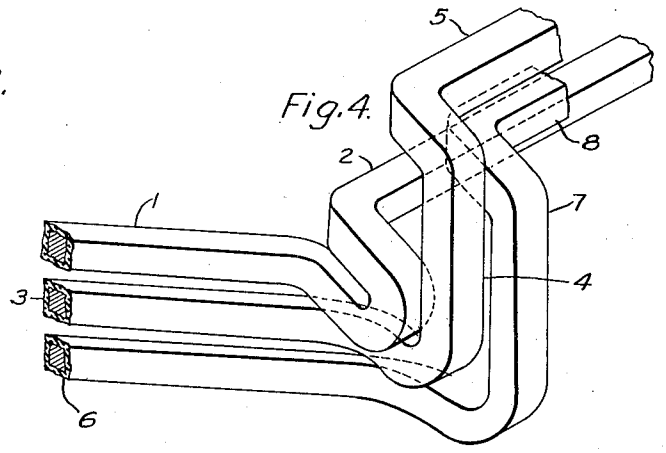


Fig. 4.

WITNESSES:
Robert C. Milham
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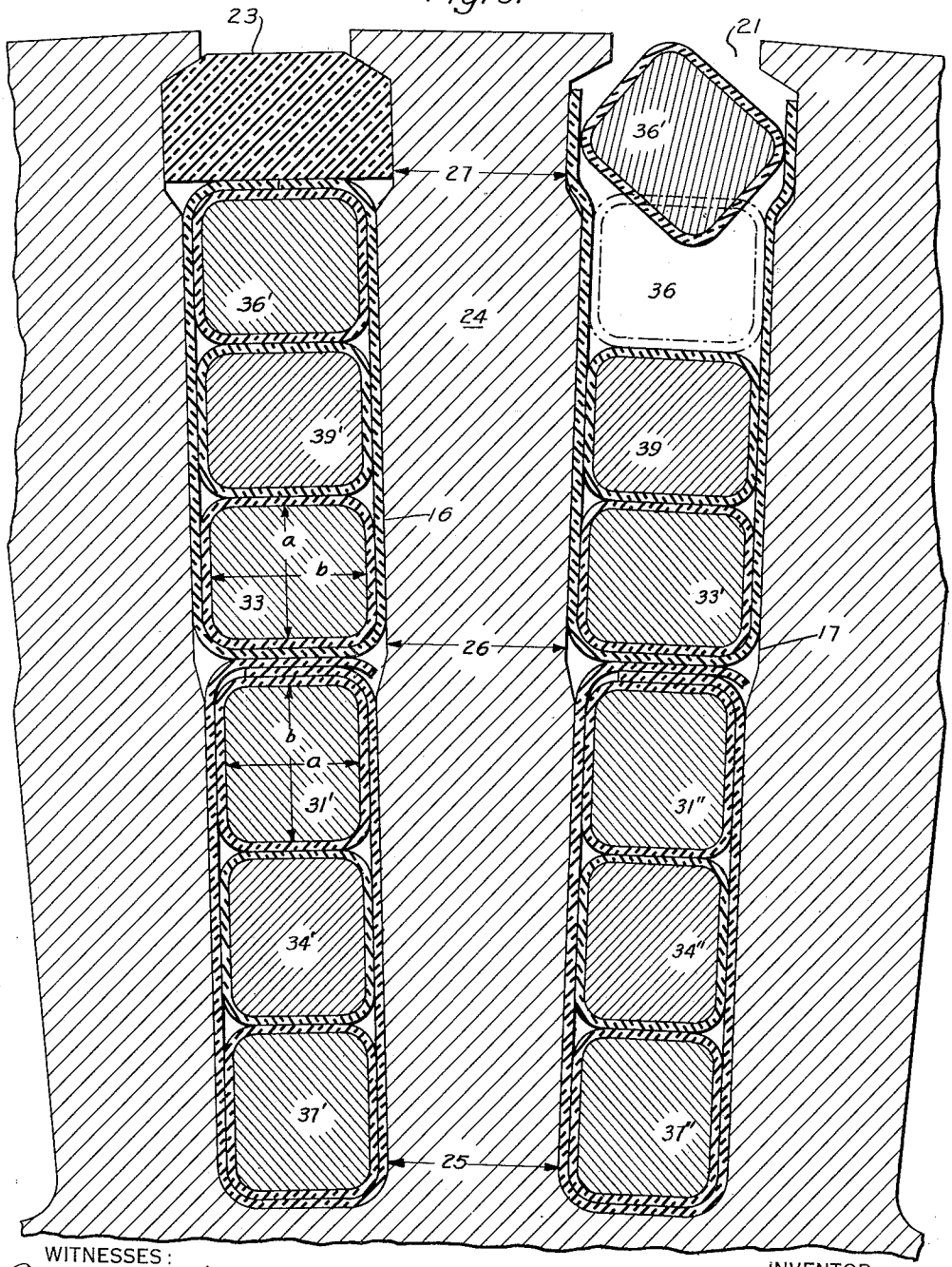
INVENTOR
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June 29, 1937. M. F. JONES 2,085,099

LOW LOSS ARMATURE COIL

Filed Nov. 11, 1933 8 Sheets-Sheet 2

Fig. 5.



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June 29, 1937. M. F. JONES 2,085,099

LOW LOSS ARMATURE COIL

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Fig. 6.

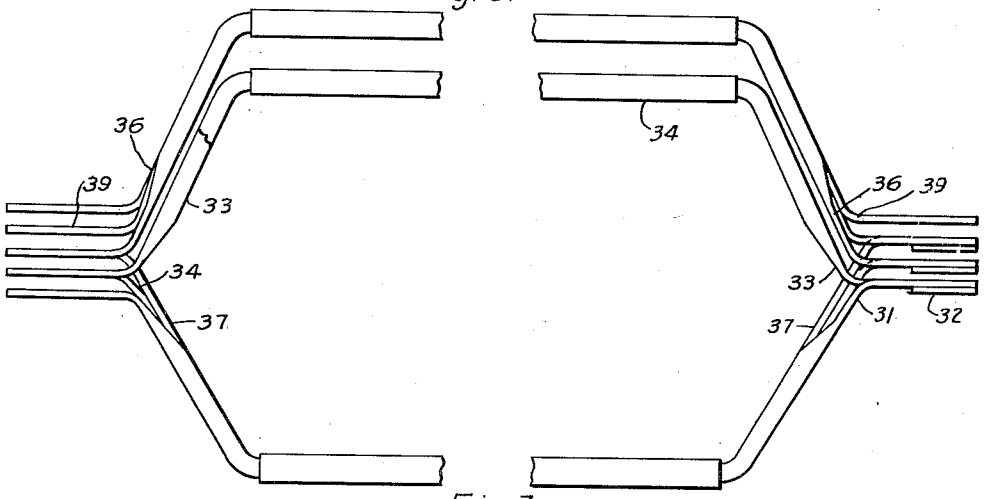
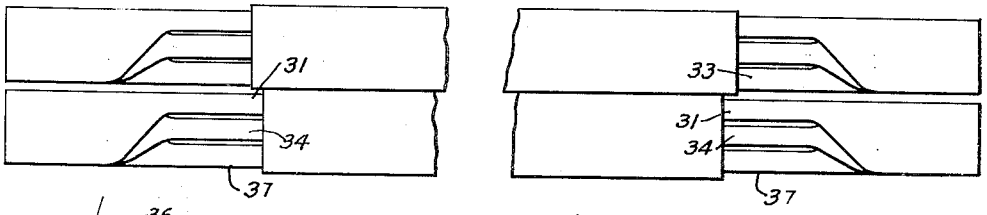


Fig. 7.



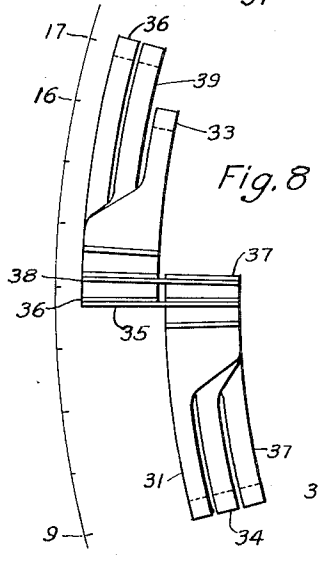
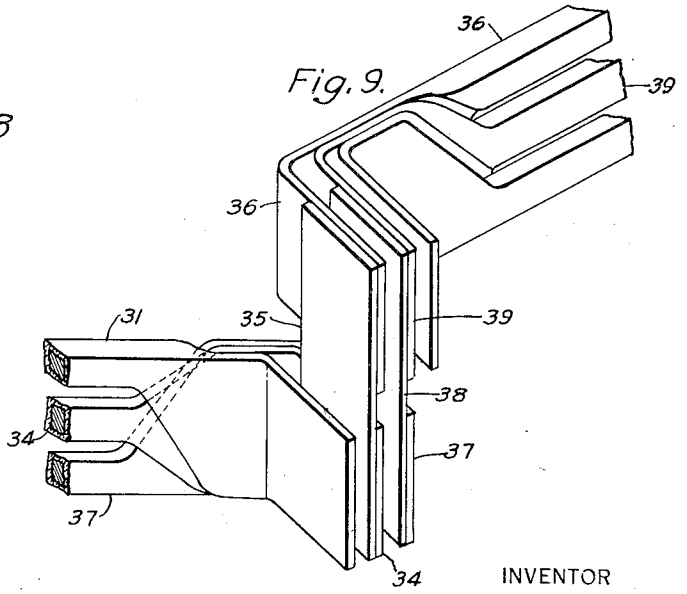


Fig. 8

Fig. 9.



WITNESSES:
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June 29, 1937. M. F. JONES 2,085,099

LOW LOSS ARMATURE COIL

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Fig. 10.

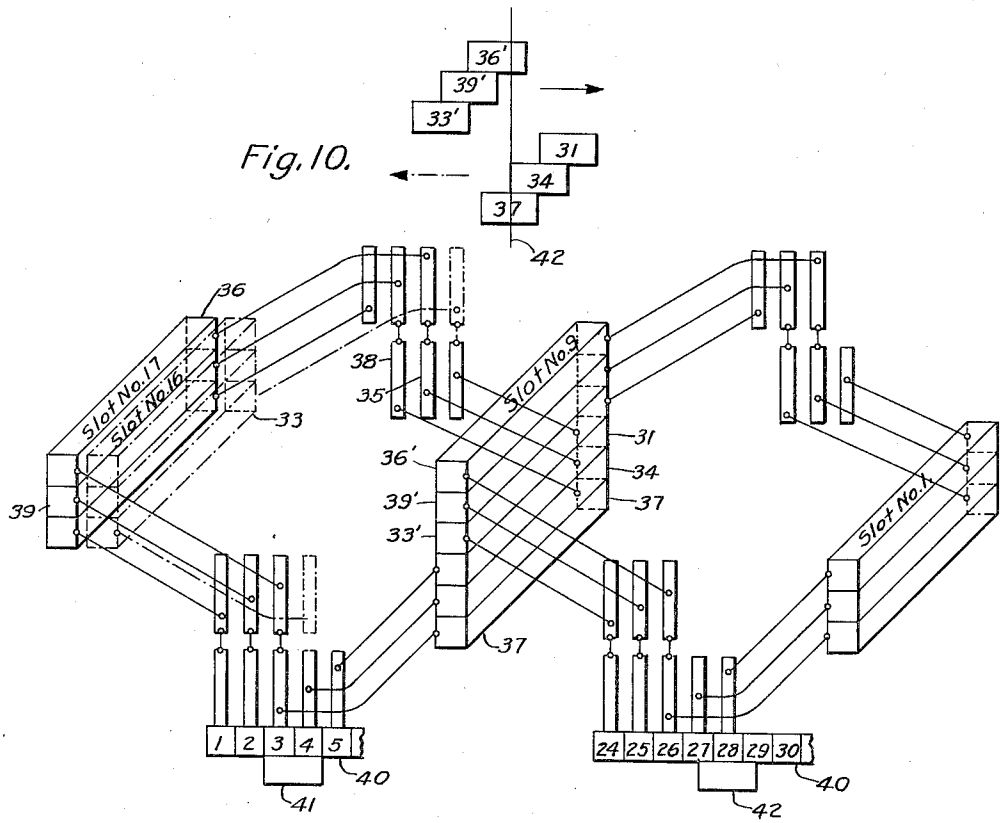
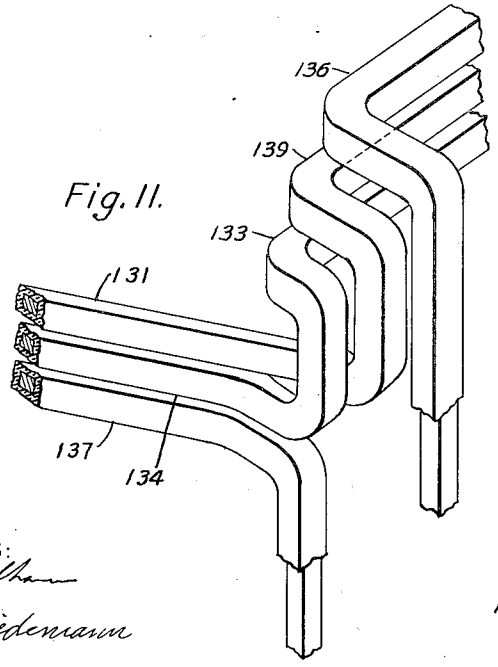


Fig. 11.



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June 29, 1937. M. F. JONES 2,085,099

LOW LOSS ARMATURE COIL

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Fig. 12.

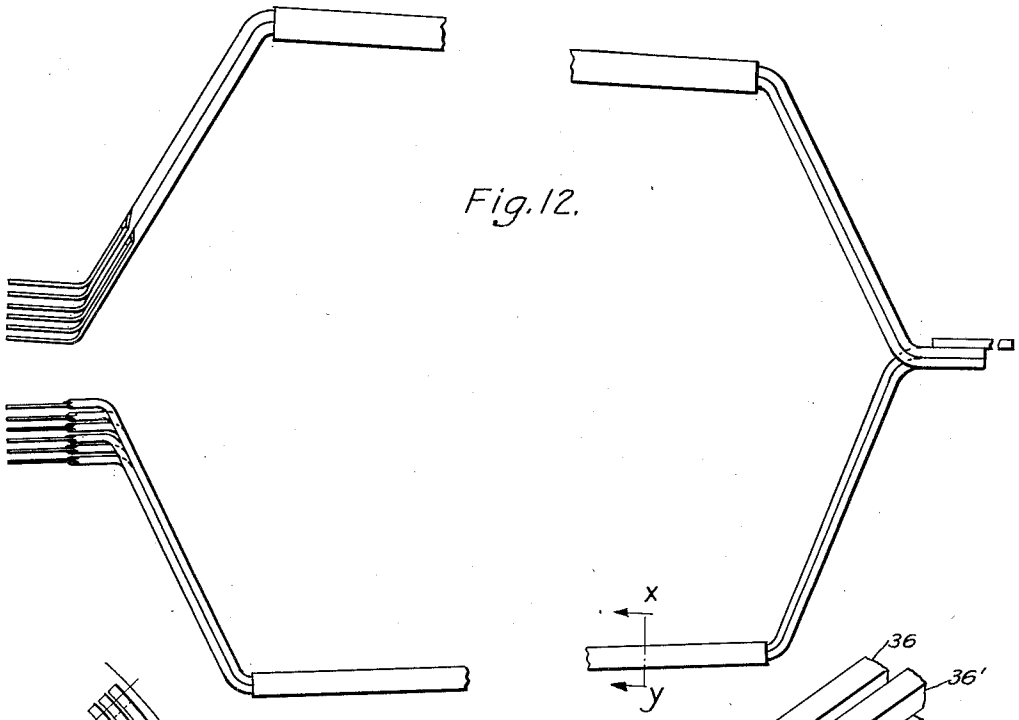


Fig. 13.

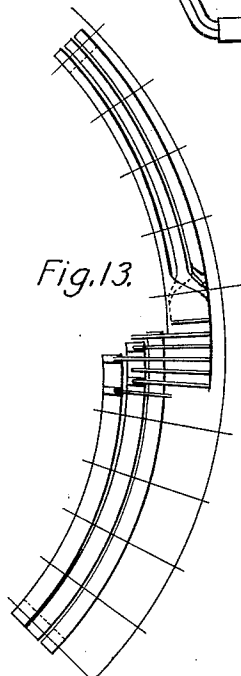


Fig. 14.

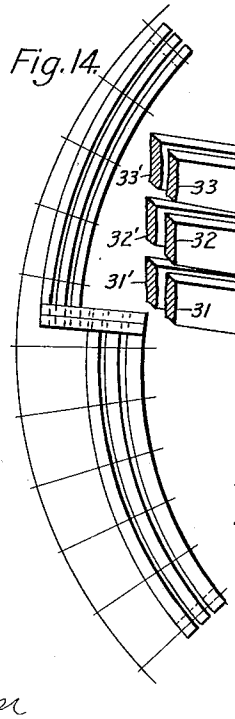


Fig. 15.

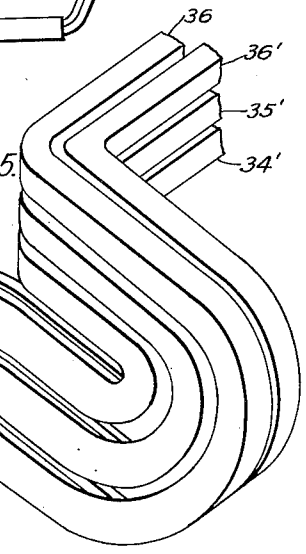
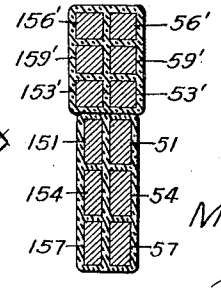


Fig. 16.



WITNESSES:

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June 29, 1937. M. F. JONES 2,085,099

LOW LOSS ARMATURE COIL

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Fig. 17.

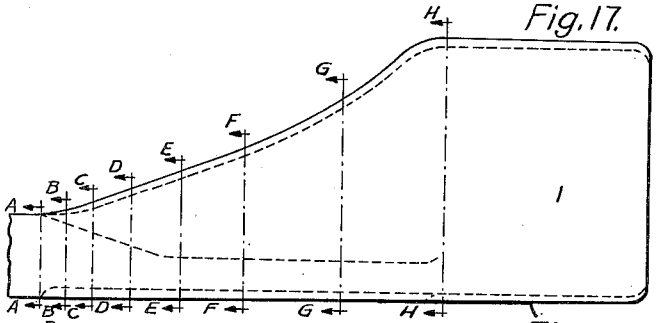


Fig. 18.

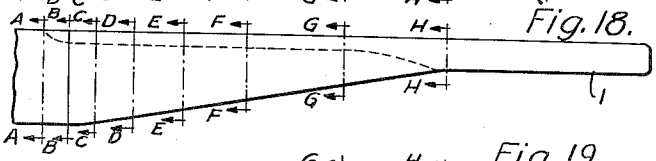


Fig. 19.

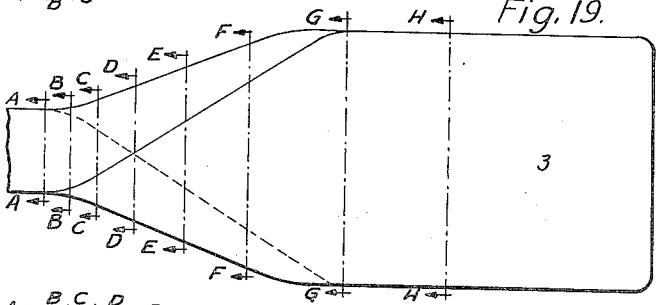


Fig. 20.

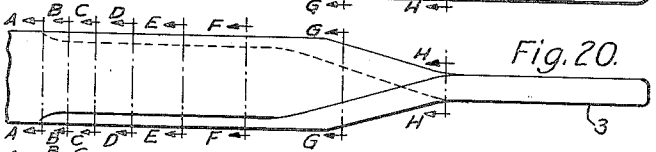


Fig. 21.

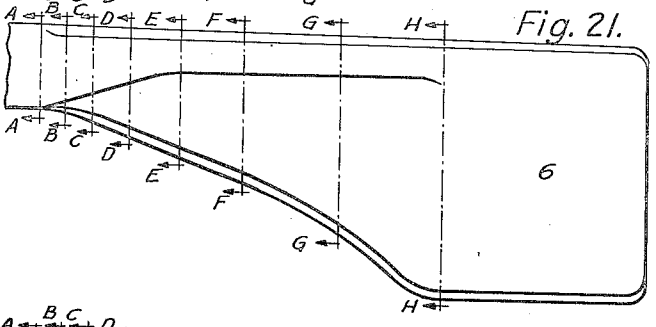


Fig. 22.

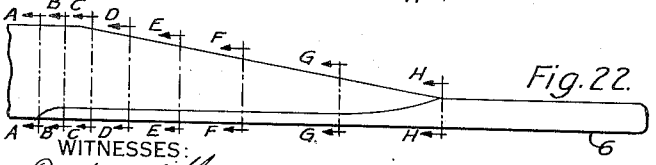


Fig. 23.

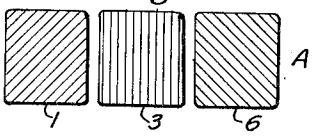


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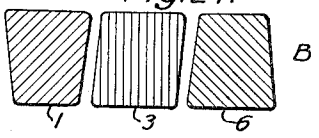


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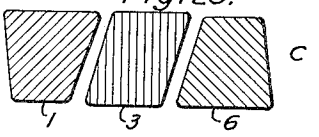


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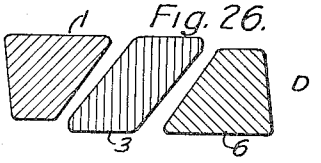


Fig. 27.

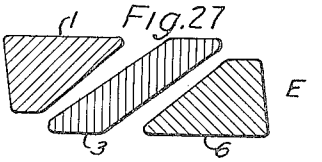


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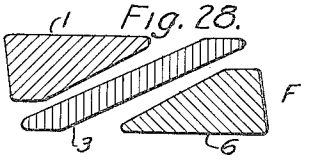


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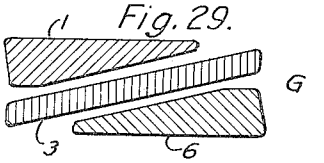
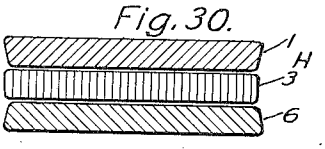


Fig. 30.



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LOW LOSS ARMATURE COIL

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Fig. 31.

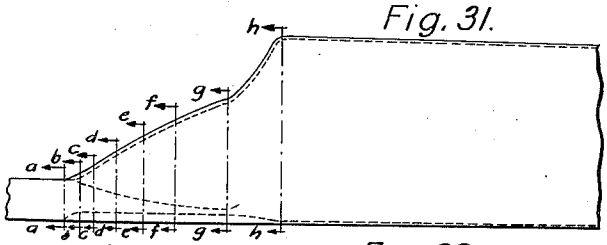


Fig. 32.

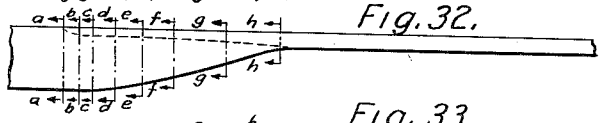


Fig. 33.

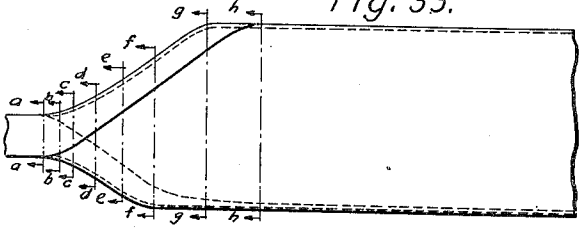


Fig. 34.

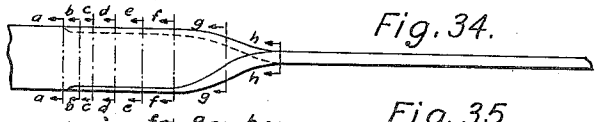


Fig. 35.

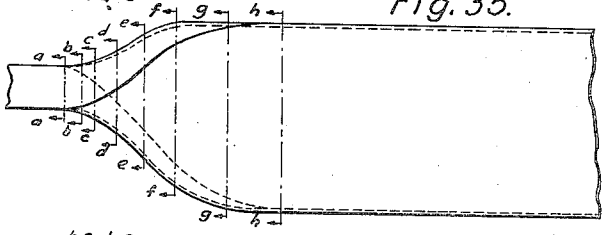


Fig. 36.

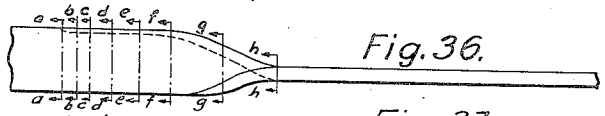


Fig. 37.

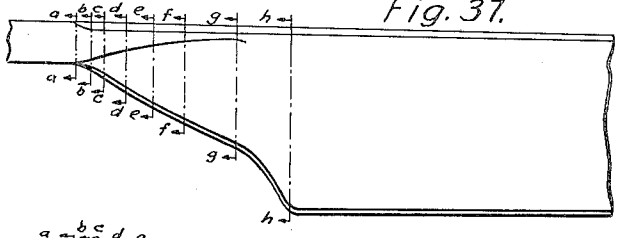


Fig. 38.

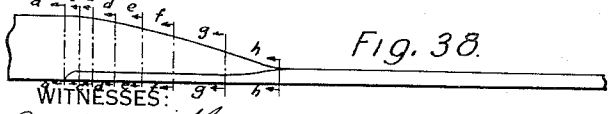
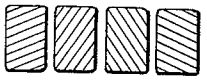


Fig. 39.



a

Fig. 40.



b

Fig. 41.



c

Fig. 42.



d

Fig. 43



e

Fig. 44.



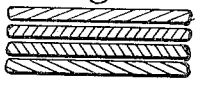
f

Fig. 45.



g

Fig. 46.



h

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LOW LOSS ARMATURE COIL

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Fig. 47.

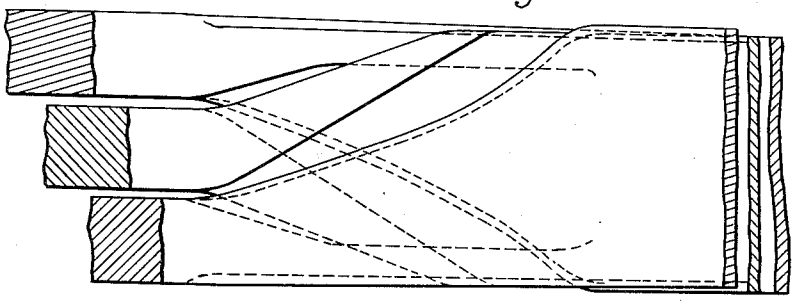


Fig. 48.

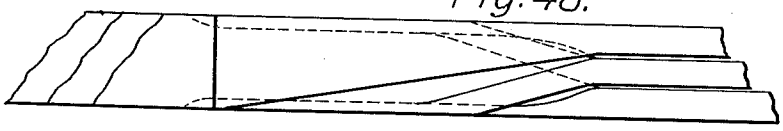


Fig. 49.

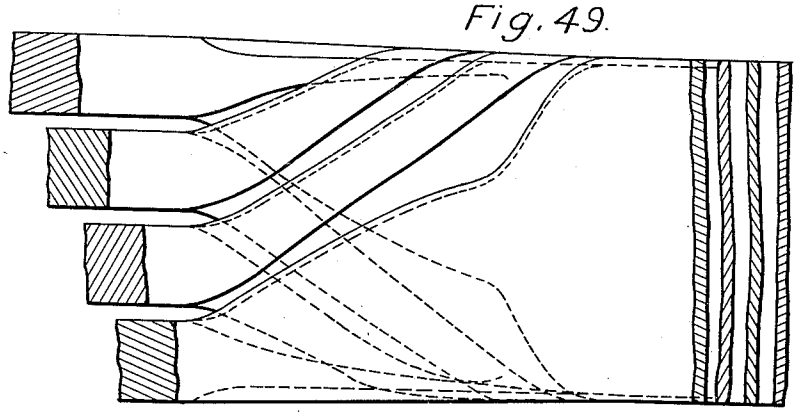
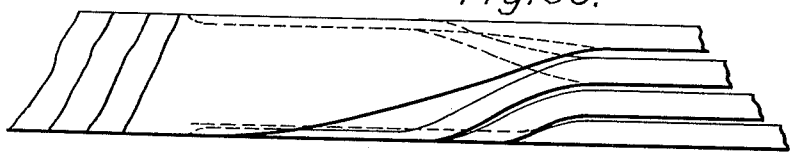


Fig. 50.



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Patented June 29, 1937 2,085,099

UNITED STATES PATENT OFFICE

2,085,099

LOW LOSS ARMATURE COIL

Maurice F. Jones, Edgewood, Pa., assignor to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Application November 11, 1933, Serial No. 697,596

22 Claims. (Cl. 171—228)

My invention relates to the combination of armature windings, slot structure, and commutation for dynamo-electric machines of the commutator type.

One object of my invention is to provide for minimizing the inductive disturbances in coils undergoing commutation whereby commutation is materially improved.

A more specific object of my invention, relative to commutation, is to reduce the slot leakage and to improve the sequence of commutation of the conductors in a slot, whereby the commutation of a dynamo-electric machine is improved.

Another object of my invention is to secure for coils in the slots of a dynamo-electric machine a substantially maximum space factor for any given slot and also secure a substantially minimum copper loss and a minimum eddy current loss in the coil windings.

It is also an object of my invention to design the slots and conductor cross-section in such a manner that the conductors are as shallow in the rotor as can be provided for a machine of a given rating to thus reduce the eddy currents to a minimum.

Another object of my invention is to provide a novel coil structure that may be easily manufactured and wherein the ratio of depth to thickness is less for that part of the coil in the armature slot than for the part of the coil of the end connection, whereby the eddy currents are kept at a minimum and the end connections are simplified.

A further object of my invention is to provide for a gradual transition from the arrangement of a plurality of conductors, having a rectangular section, disposed in a superposed relation in the active portion of the conductor in the slot to an edgewise side-by-side relation at the end portion whereby the connection to the risers for the commutator is facilitated.

A broader object of my invention, relative to the transition, is to improve the mechanical strength and increase the minimum section of a coil at the transition point by using curvilinear transition.

A further object of my invention is to position half of the conductors for a given slot, and having a given rectangular, but not square, section, in edgewise relation in the bottom of the slot and in flatwise relation in the top of the slot, thus providing a stepped slot whereby the flux density in the armature teeth is maintained substantially constant throughout the length of each tooth.

A further broad object of my invention relative to the armature slot design is to provide a slot structure so designed at the opening that the coils disposed in the slot may be very securely retained therein with retaining wedges in which the stress is largely one of compression and whereby a greater mechanical retaining force is provided to act against the centrifugal force acting on the coils during operation of the armature.

A still further object of my invention is to provide a stepped-slot armature of the lap-coil type in which the conductor is twisted or rotated through 90° in passing from the top of one slot to the bottom of another, so that there is no fixed relation between the widths of the top and bottom portions of the stepped slot, thus making it possible to change these dimensions, to suit the conditions of design by the simple expedient of changing the shape and the cross section of the copper bars.

Other objects not specifically set forth above, but yet falling within the scope of my invention, will become more apparent from a study of the following specification when considered in conjunction with the accompanying drawings, in which:

Figure 1 is a plan view of an assembly of a triple-deck coil;

Fig. 2 is a side view of the coil assembly shown in Fig. 1;

Fig. 3 is an end view of the coil, looking from the right toward the left in Fig. 1, and showing the armature core of a dynamo-electric machine diagrammatically;

Fig. 4 is a perspective view of a portion of the subject matter shown in Fig. 3;

Fig. 5 shows how a triple-deck coil, embodying one modification of my invention, may be positioned in a special type of armature slot;

Fig. 6 is a plan view of an assembly of a triple-deck coil of the type that can be positioned in a slot such as is shown in Fig. 5;

Fig. 7 is a side view of the coil assembly shown in Fig. 6;

Fig. 8 is an end view of the coil, looking from right toward the left in Fig. 6, and showing the armature core of a dynamo-electric machine diagrammatically;

Fig. 9 is a perspective view of a portion of the subject matter shown in Fig. 8;

Fig. 10 is a diagrammatic development view of a coil arrangement illustrating the end-connections and commutator-bars and showing the improved sequence of commutation hereinafter described in detail;

Fig. 11 is a perspective view somewhat similar to that shown in Fig. 4 of a still further modified end connection for a triple-deck coil assembly;

Fig. 12 is a plan view of an assembly of a double triple-deck coil, representing a further modification of my invention;

Fig. 13 is an end view of the coil assembly shown in Fig. 12, looking from left toward the right, namely, as viewed from the commutator end of the coil assembly, and showing the armature core diagrammatically;

Fig. 14 is an end view, looking from the right toward the left, of the subject matter shown in Fig. 12, and also showing the armature core diagrammatically;

Fig. 15 is a perspective view of part of the subject matter shown in Fig. 14;

Fig. 16 is a cross-section of all the conductors in a single slot when using a coil assembly, such as is shown in Fig. 12;

Fig. 17 shows a side view of the end portion of one outside conductor of a triple-deck coil illustrating the transition from the active part of the conductor at the left to the portion for the connection of the risers leading to the commutator bars;

Fig. 18 is a plan view of the showing of Fig. 17;

Fig. 19 is a side view, similar to that shown in Fig. 17, of the end portion of the middle conductor of a triple-deck coil;

Fig. 20 is a plan view of the conductor end shown in Fig. 19;

Fig. 21 shows a side view of the end portion of the other outside conductor of a triple-deck coil illustrating the transition from the active part of the conductor at the left to the portion for the connection of the riser leading to the commutator bars;

Fig. 22 is a plan view of the showing of Fig. 21;

Figs. 23 to 30, inclusive, show sections along lines A, B, C, D, E, F, G, and H, respectively, of the three conductors shown in Figs. 17 to 22, inclusive, showing them in assembled relation;

Figs. 31 to 38, inclusive, show the transition portions, similar to the showings in Figs. 17 to 22, inclusive, of a quadruple deck coil;

Figs. 39 to 46, inclusive, show the four conductors of the quadruple deck coil, shown in Figs. 31 to 38, in assembled relation when considered along section lines *a*, *b*, *c*, *d*, *e*, *f*, *g*, and *h*, respectively;

Figs. 47 and 48 are a side view and plan view, respectively, of the transition portions of an assembly of a triple-deck coil; and

Figs. 49 and 50 are a side view and a plan view, respectively, of the transition portions of a quadruple deck coil.

The coil constructions shown in all of the above-mentioned drawings are suitable for any type of commutator dynamo-electric machine of medium and large capacity, but are particularly adapted for use in machines for railway use, and especially for single phase railway motors because of the need to utilize the space and weight to the maximum advantage in all railway machines, and because of the special commutation features of the single phase motor.

In single-phase commutator motors, the problem of commutation is rendered extremely difficult, especially at starting, because of the fact that the field flux alternates and thus induces a transformer voltage in the coils which are, during commutation, short circuited by the brushes. The voltage induced causes short-circuit currents, for the coils being commutated, to flow in said coils and, when contact is broken at the brush and the short-circuit current is broken, a harmful spark is produced at the corresponding commutator segment. This spark will increase in intensity with an increase of the self-induction of the short-circuited coil. For example, for the six conductors shown in Fig. 5, the one in the bottom of the slot, namely, conductor 3′′′, is the one most difficult to commutate sparklessly because it has the highest self-inductance.

The magnetic flux causing self-induction in the short-circuited coils extends from one side of the armature slot to the other and also from the top of a tooth to the stator iron and back to the top of the next tooth. It is thus evident that the conductors in the bottom part of the slot are surrounded by more lines of flux than those in the top and thus have a greater self-inductance. These magnetic lines must necessarily die out whenever the short-circuit of a coil is broken, and the disappearance of the flux induces a voltage in the conductor which adds to the short-circuit voltage and increases the commutator spark. If it so happens, however, that, when the short-circuit current in a conductor in one slot is dying out, one or more other conductors in the same slot form part of a coil which is at that instant also being commutated and, therefore, is short-circuited by the brushes, there will be induced a damping current in this coil and the voltage induced in the first-mentioned conductor is thereby very greatly reduced. This second condition prevails during the process of commutating the various conductors in the slot with the exception of the last one of the conductors in a slot to commutate. When the last conductor is being commutated, however, there is no such damping circuit available, so that the voltage induced and consequently the spark produced is worse, or at its maximum, for this last coil than for any other.

A very desirable feature is, therefore, that the self-inductance of the last conductor to commutate be as small as possible. Therefore, one further object of my invention is to provide for a reversing dynamo-electric machine a sequence of commutation of the conductors such that the last one to commutate be the one that is as near the top of the slot as possible.

To minimize sparking because of self-inductance, the conductors of a coil may be placed in the slots as shown in Figs. 1 to 4, inclusive. It will be noted that the conductor or coil portion 1 is in the third position from the bottom in slot No. 9 (see Fig. 3) and the conductor portion 2, a continuation of 1, enters the fourth position in slot No. 16. Conductor portion 3 is in the second position in slot No. 9 and after making the bend 4 enters the top or sixth position of slot No. 17, the slot adjacent the slot No. 16. Conductor portion 6 is in the first position in slot No. 9 and after making the bend 7 enters the slot No. 17 as conductor 8, in the fifth position. By the arrangement shown the self-inductance of the last conductor to commutate in the lower group is much reduced since such last conductor for one direction of rotation is the uppermost conductor in the lower group. For the other, or reverse direction of rotation, the last conductor to commutate is the lowermost conductor in the top group. Regardless of the direction of rotation of the motor the commutation difficulties will be reduced to a minimum. This will become more apparent from a later discussion of Fig. 10.

Conductors 1 and 2, being in the third and fourth slot positions, respectively, will have approximately the same self-inductance. Further, the commutation is improved since conductor 2 is in a different slot with reference to the remaining conductors that may undergo commutation at the same time. Since conductors 3 and 5 have slot positions two and six, respectively, and conductors 6 and 8 have slot positions one and five, respectively, the voltages induced in the respective conductors are balanced against each other. The commutation is thus improved and such improvement is obtained for either direction of rotation of the motor.

While the above discussion refers specifically to the case of the single phase motor, the advantages of having this preferred sequence of commutation holds for all other types of commutator machines, as will be readily understood by those skilled in the art.

To increase the rating of a given machine and also to prevent magnetic leakage and thus high flux densities, and to secure other advantages that will be pointed out presently, the type of slot and triple deck coil shown in Figs. 5 to 9, inclusive, is provided.

As heretofore pointed out in connection with Figs. 1 to 4, inclusive, the six conductors shown in Fig. 5 may be so connected as to improve commutation. The last conductor, that is, 37'', (referring, for the present, only to slot No. 17 in Fig. 5) is obviously the one most difficult to commutate sparklessly. The self induction of the six conductors 37'', 34'', 31'', 33', 39, and 36 is not the same; the conductor 37'' has the greatest self induction and the top conductor 36 has the least self induction; while conductors 31'' and 33' have intermediate values and there is relatively little difference between the two. As many types of commutator machines, such as railway motors, operate in either a forward or a reverse direction, the commutating field strength must be adjusted for the average of the two conditions, and the most ideal arrangement is to have conductor 31'' to commutate last in one direction and conductor 33' to commutate last in the other direction.

The shape of the slots shown in Fig. 5 is favorable to commutation, first, because of its low slot constant, i. e., permeance for leakage flux across the slot, resulting from the fact that the narrowest portion of the slot is at the bottom where the ampere turns are the least and the widest portion of the slot is near the top where the ampere turns are a maximum, and second, because of the narrow slot opening 21 at the air gap which thus reduces the variations in the permeance of the commutating pole air gap as the armature teeth 24 pass under this pole.

Referring more particularly to Fig. 5 and especially to slot No. 16 of Fig. 5, all the conductors are shown as having the same cross-sectional dimensions. The longer transverse dimension, as shown at conductors 31' and 33, is *b* and the shorter transverse dimension is *a*.

The bottom of the slot is dimensioned so that three conductors, plus the insulation needed, may be positioned therein on edge, that is, conductors 37', 34', and 31' have, in Fig. 5, their shorter, or *a* dimension, in a horizontal position and their longer, or *b* dimension, in a vertical position. The size of the upper portion of the slot is such that conductors 33, 39', and 36' may be placed flatwise, that is, with their longer, or *b* dimension, horizontal and their shorter, or *a* dimension, vertical.

This new type slot has the following further advantages.

(1) By proper selection of the ratio of the dimension *a* to the dimension *b* the overall depth of the slot, compared to slots heretofore used, can be reduced.

(2) By a proper choice of the difference in the width and thickness of the copper conductors, or even by using a differentially shaped conductor for the top group than for the bottom group, depending on the size of the armature and number of slots, the tooth width can be approximately the same at the three narrow points 25, 26 and 27. This approaches a tooth of uniform section, which, as is well known, gives the minimum of both iron loss and magnetizing ampere turns, for a given flux, depth of slot, and volume of iron.

(3) The shape of the conductors in the slot, and the arrangement of the conductors in the slot give a very high space factor and a very low copper eddy current loss; that is to say, the conductors, though oblong in section, have only slightly more perimeter than a square conductor having the best space factor, while the deeper conductor in the bottom part of the slot where the slot flux is low, with the shallower conductor in the top part where the slot flux is higher gives a copper eddy loss about as low as if the shallower conductor had been used throughout. However, the narrower slot allows a smaller slot pitch at the root for the same flux density, thereby permitting a smaller armature diameter for the same rating.

A further advantage of the type of coil and slot shown in Fig. 5 is the matter of wedging the coils in the slots. With open type slots which were necessary with series multi-decked windings, prior to my invention, it was deemed necessary to supplement the fiber or micarta wedges with short metallic wedges as a safety measure in case the fiber wedges should loosen or become brittle or slightly charred through overheating. The new design, since the slot opening 21 is no greater than the dimension *a* plus the insulation about the conductor, can be adequately wedged with fiber wedges only, as the wedge material 23 is subjected to compression stresses very largely.

A further important feature of the new slot design is the method of placing the conductors in the slot. The conductors 37'', 34'', and 31'', referring to slot No. 17, are placed in the bottom of the slot without any special movements but the three upper conductors 33', 39 and 36 are moved through the upper or restricted portion 21 of the slot while the shorter dimension *a* is in a horizontal position and then, as shown for conductor 36, each conductor is turned through an angle of 90° in the hollowed out portion 22 at the upper end of the slot. After making the turn the conductors are forced into place. Conductors 33' and 39 are shown in position, whereas conductor 36' is shown in full line in the turning position and in dotted line when in working position.

When the arrangement of the conductors in the slots and the configurations of the conductors and the slots are to be as shown in Fig. 5 then the coils, as a whole, cannot be form wound. Each conductor is separately formed and properly shaped at the transition so that each group of conductors may interfit in the manner indicated in Figs. 23 to 30, inclusive, and in Figs. 39 to 46,

inclusive, or in the manner indicated in Figs. 47 to 50, inclusive.

Since each conductor must be turned about its own axis in the working range of the conductors the curvilinear transition must be provided for both the front, or commutator end of the armature and the back end of the armature. Figs. 6, 7, 8, and 9 show the coil arrangement when the type of slot shown in Fig 5 is used.

It should be noted that the top or third conductor, or top coil-side, in the bottom half of slot No. 9 has a back connector, or neck 32, connecting 31 to the lowermost, namely number four, coil-side, or conductor 33, in the top half of slot No. 16. The second coil-side 34 in the bottom of slot No. 9, by connector 35, is connected to the coil-side 36 in the sixth position of slot No. 17, and the number one coil-side, i. e., the conductor in the bottom of slot No. 9, by connector 38, connects to the coil-side in the fifth position of slot No. 17. The commutating sequence for the type of coil shown in Figs. 6, 7, 8, and 9, is thus exactly like that for the coil shown in Figs. 1 to 4, inclusive.

Two important advantages of the type of coil shown in Figs. 6 to 9, inclusive, over the one shown in Figs. 1 to 4, inclusive, are (1) that a stepped slot, such as shown in Fig. 5 can be utilized, and (2) the smaller slot opening reduces flux pulsations and provides a more secure wedging of the coils.

The clearest understanding of the sequence of commutation can probably be had from a study of the diagrammatic showing in Fig. 10. The diagram shows the entire slot, No. 9, showing all its coil sides in superposed relation, and it shows conductors in the top half of slots, Nos. 16 and 17, and the bottom half of slot No. 1. If the movement of the conductors, namely, the armature core, be assumed to be in the direction indicated by the full line arrow shown in the upper portion of the figure, then it should be noted that the commutator brush 41 has just passed out of contact with number 5 commutator segment. In other words, the short-circuit for commutator segments 4 and 5 through brush 41 is just broken and the result is that commutation ceases for conductor 31 in the third position of slot No. 9 and conductor 33 in the fourth position of slot No. 16. At the left, segments numbered 3 and 4 are shown completely in contact with brush 41. Commutator segment number 3, through conductor 37 in the lowermost position of slot No. 9, and connector 38 is shown connected to the fifth coil-side in the top half of slot No. 17, that is to conductor 39. Similarly the commutator segment number 4 is connected through conductor 34, in the second position in slot No. 9, and connector 35 to the sixth coil-side, that is the conductor 36 in the uppermost position in slot No. 17.

The uppermost conductor, or coil-side 36, in slot No. 17 and the conductor 34, in the second position of slot No. 9, undergo commutation at the same time; the conductor 39 in slot No. 17 and conductor 37, in the bottom of slot No. 9, undergo commutation at the same time; and conductors 31 and 33 in slots No. 9 and No. 16, respectively, undergo commutation at the same time. When segment 3 breaks contact with brush 41 the short circuit opened is between conductor 36 having good commutation characteristics and conductor 37 having the poorest commutation characteristics. Similarly, when the contact between the brush 41 and the segment numbered 4 is broken the short-circuit broken is between conductor 36 having the best commutation characteristics and the conductor 34 having poor commutation characteristics. When the commutator segment number 4 and brush 41 break contact, the short-circuit between conductors 31 and 33 is broken. Since these two conductors have adjacent positions with reference to the slots, the commutation is good.

At the back, as has been stated, the lowermost coil-side in slot No. 9 is connected to the coil-side in the fifth position of slot No. 17. When the circuit for the lowermost coil-side, for the direction of rotation assumed, is broken the stored energy in the conductor is transferred to the coil-side number five in the upper portion of slot No. 17 still undergoing commutation.

When contact between segment 4 and the brush 41 is broken, the stored energy in coil-side number two in the slot No. 9 is transferred to the uppermost coil-side or conductor 36 in the slot No. 17. Similarly, when contact between the brush 41 and segment number 5 is broken, the stored energy of coil-side number three in the lower half of the slot No. 9 is transferred to the coil-side number four position in the slot No. 16.

From the foregoing discussion, the order in which the conductors in a given slot are subjected to commutation should be apparent. For the direction of rotation assumed, which may be designated the forward direction, the conductors 31, 34, 37, 36', 39', and 33' in slot No. 9 undergo commutation in the order named as shown in the upper portion of Fig. 10. With reference to the slot itself, counting position from the bottom up as indicated in Fig. 10, the order is 3, 2, 1, 6, 5, and 4.

When the rotation of the machine is reversed, the sequence of commutation will be changed. The conductors 33', 39', 36', 37, 34, and 31 in slot No. 9 will be commutated in the order named. With reference to the slot itself the order for reverse operation of the machine will be 4, 5, 6, 1, 2, and 3. The coil-side last to commutate will thus never be the one in the bottom of the slot. In the forward direction it will be conductor 33', or the one in the fourth position, and in the reverse direction it will be conductor 31, the one in the third position.

Fig. 11 shows in perspective how the conductors may be connected at the back end of the machine to also secure improved commutation. It should be noted that conductor 131, which will be in the top, or number three position in the lower half of a slot is connected to conductor 139 in the fifth position of another slot. Conductor 134, in position two of one slot, connects to conductor 133 in the fourth position of another slot. Conductor 137 connects to a conductor in the sixth position whereas conductor 136 connects to a conductor in the first position in a slot adjacent to the slot that would be housing conductors 137, 134, and 131.

My invention is not limited to triple-deck coils as hereinabove described but it is susceptible to be embodied in quadruple-deck coils, or n-deck coils, or a twelve-conductor triple-deck coil as shown in Figs. 12 to 16, inclusive, or m-conductor n-deck coils.

In Figs. 12, 13, 14, and 15, the conductors are shown as disposed with reference to a slot as the six conductor triple-deck shown in Figs. 1, 2, 3, 4, and 5. The commutating advantages are thus also secured. Further a new type slot, somewhat like the slot shown in Fig. 5, may be used as is apparent from a study of Figs. 15

and 16 where conductors 57, 54, 51, 157, 154, and 151, are shown to be positioned edgewise in the bottom of the slot whereas conductors 53', 59', 56', 153', 159', and 156' are shown as square, thus taking up much less space radially of the slot. The upper conductors may be flat, or rectangular, and positioned flatwise in the top of the slot.

One of the valuable improvements of my invention is the design of the conductors so that they have a certain, nearly square, section in the active portion thereof and are disposed flatwise in the slot and have a flat rectangular section at the commutator end of the conductors, said rectangular portions being turned through an angle of 90° with reference to the section in the slot so that a smooth curvilinear transition is secured with substantially no decrease in section of the conductors at the transition region. Stress concentration is thus avoided and danger of breakage due to bending during the process of insulating and winding or due to long continued vibration in service is greatly reduced.

For the modification shown in Figs. 1 to 4, inclusive, three conductors are grouped in one insulating sheath. The end connections, where the risers for the commutator bars are to be connected, are of different configuration as is necessary where three conductors are wound as a unit and yet are required to occupy a minimum of space at the end and at the same time provide an effective, simple and efficient connection.

Figs. 17 and 18 show the change from left to right, in configuration for the end of conductor 1; Figs. 19 and 20 show the change from left to right, in configuration for the end of conductor 3; and Figs. 21 and 22 show the change, from left to right in the configuration of conductor 6.

The change in the configuration for each conductor may, of course, be effected by forming a separate piece for each conductor and welding such pieces onto the conductors. The preferred method of producing the change in configuration is to drop forge or hot press the ends of each conductor separately. The conductors may also be assembled as a unit and the ends then first flattened, next twisted 90°, and finally pressed into the shape desired. With this last process, the ends automatically take the shape desired and fill a rectangular space of the same cross sections throughout the transition.

For instance, Figs. 23 to 30, inclusive, show the change in the shape of the cross-section of each conductor, when the three conductors are considered as assembled and while so assembled are turned and rolled out to the desired shape. It should be noted that the cross-sectional area of each conductor for Figs. 23 to 30, inclusive, which represent sections on lines A to H, respectively, remain substantially the same. Further there is no abrupt change in the section nor configuration of each conductor. The copper losses at the transition are thus kept at a minimum and no hot spots are found at this region during operation. Moreover the mechanical strength of the conductor at the transition is unimpaired, particularly since no stress concentration occurs.

Further advantages secured by the transition explained are that no additional space is needed to make the transition and no vacant pockets are produced just back of the commutator necks or risers of the motor, and the taping of the conductor as for example with mica tape is facilitated due to no abrupt change in shape.

A square conductor has the maximum space factor but such conductors require slots that may be deeper than is desired, and further decrease the section of the magnetic material in the teeth at the bottom of the slots to such an extent that the flux density is high, iron losses are great and the magneto-motive force is excessive.

No lengthy discussion of Figs. 31 to 46 and Figs. 49 and 50, showing a quadruple-deck coil, is thought to be necessary in view of the detailed discussion heretofore given of a triple-deck transition structure. Figs. 31 to 46 correspond to Figs. 17 to 30, inclusive.

Figs. 47 and 48 show a side view and plan view respectively of an assembled triple-deck coil at the transition, such as was discussed hereinabove whereas Figs. 49 and 50 show a side view and plan view respectively of an assembled quadruple-deck coil at the transition, such as was generally referred to hereinbefore.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that still other modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. In a dynamo-electric machine having a magnetizable core member provided with slots, each slot having a rectangular bottom portion of a given area and a given depth, an upper rectangular portion of substantially the same area but of lesser depth, and a top portion having a lower relatively wide portion and a top neck portion whose width is substantially equal to the width of the bottom portion, a plurality of conductors, provided with insulation disposed to fit in the bottom portion, and a like number of conductors, provided with insulation disposed to fit in the upper portion of the slot.

2. A commutator-type dynamo-electric machine having a slotted armature core and an armature winding having n coils per slot, n being greater than two, half of the coil-sides, hereinafter called "top coil-sides", being disposed in the top halves of the slots, and the other half of the coil-sides, hereinafter called "bottom coil sides", being disposed in the bottom halves of the slots, each bottom coil-side being electrically continuous with a corresponding top coil-side, the bottom coil-sides in any slot being disposed in a plurality of superposed ranks, a group of n top coil-sides in any given slot being connected to n consecutive commutator bars, the bottom coil-sides corresponding to both the 1st and nth of these n top coil-sides, being disposed in a rank or ranks other than the bottom rank.

3. A commutator-type dynamo-electric machine having a stepped slot armature core and an armature winding having n coils per slot, n being greater than two, half of the coil-sides, hereinafter called "top coil-sides", being disposed in the top halves of the slots, and the other half of the coil-sides, hereinafter called "bottom coil-sides", being disposed in the bottom halves of the slots, the bottom halves of the slots being deeper and narrower than the top halves of the slots, each bottom coil-side being electrically continuous with a corresponding top-coil-side, the bottom coil-sides in any slot being disposed in a

plurality of superposed ranks, a group of n top coil-sides in any given slot being connected to n consecutive commutator bars, the bottom coil-sides corresponding to both the 1st and nth of these n top coil-sides being disposed in a rank or ranks other than the bottom rank.

4. A dynamo-electric machine comprising an armature winding and a slotted armature core, characterized by the coil-sides of one pair of armature-winding coils being disposed in superposed edgewise relation in the bottom portion of one slot and in superposed flatwise relation in the top portion of another slot.

5. A dynamo-electric machine having a rotor member comprising a core having stepped slots, the top portion of the slots being shallower than the bottom portion but having a sectional area substantially equal to the sectional area of the bottom portion of the slots, and an armature winding cooperating therewith, said armature winding being composed of portions of uniform rectangular cross-section in the active portions thereof, said winding being arranged with a plurality of portions disposed on edge and in superposed relation in the bottom portions of the slots, and with a corresponding plurality of portions disposed in flatwise and in superposed relation in the top portions of the slots.

6. A dynamo-electric machine having a rotor member comprising a core having stepped slots, the top portion of the slots being shallower than the bottom portion but having a sectional area substantially equal to the sectional area of the bottom portion of the slots, and an armature winding cooperating therewith, said armature winding being composed of portions of uniform rectangular cross-section in the active portions thereof, said rectangular section having a longer "b" dimension and a shorter "a" dimension at right angles to the "b" dimension, said winding being arranged with a plurality of portions in superposed edgewise relation in the bottom of the slots, and with a corresponding plurality of portions disposed in superposed flatwise relation in the top portion of the slots, said slots having outer openings whose circumferential dimension is nearly equal to the said "a" dimension.

7. A dynamo-electric machine having a rotor member comprising a core having stepped slots, the top portion of the slots being shallower than the bottom portion but having a sectional area substantially equal to the sectional area of the bottom portion of the slots, and an armature winding cooperating therewith, said armature winding being composed of portions of uniform rectangular cross-section in the active portions thereof, and end windings of the diamond type formed to shape prior to placing of said winding in said slots, said winding being arranged with a plurality of portions in superposed edgewise relation in the bottom of the slots, and with a corresponding plurality of portions disposed in superposed flat-wise relation in the top of the slots, said slots having outer openings whose circumferential dimension is less than the circumferential dimension of the top portion of the slots.

8. A commutator-type dynamo-electric machine having a slotted armature-core and an armature winding having n coils per slot, n being greater than two, half of the coil-sides, hereinafter called "bottom coil-sides", being disposed in superposed relation in the bottom halves of the slots, and the other half of the coil-sides, hereinafter called "top coil-sides", being disposed in superposed relation in the top halves of the slots, a group of n bottom coil-sides in any given slot being connected to n consecutive commutator-bars and being electrically continuous, respectively, with a corresponding group of top coil-sides all lying in the top halves of other given slots, characterized by the two top coil-sides which correspond to the $(n-1)$th and nth coil-sides of said group of n bottom coil-sides being disposed in the top portion and bottom portion, respectively, in the top halves of said slots with the remaining coil-side or coil-sides in the top half of said slots disposed between the top coil-sides that correspond to the said $(n-1)$th and nth coil-sides.

9. A commutator-type dynamo-electric machine having a slotted armature core and an armature-winding having n coils per slot, n being greater than two, half of the coil-sides, hereinafter called "top coil-sides", being disposed, in superposed relation, in the top halves of the slots, and the other half of the coil-sides, hereinafter called "bottom coil-sides", being disposed in superposed relation in the bottom halves of the slots, a group of n top coil-sides in any given slot being connected to n consecutive commutator-bars and being electrically continuous, respectively, with a corresponding group of bottom coil-sides all lying in the bottom halves of other given slots, characterized by the two bottom coil-sides which correspond to the first and $(n-1)$th coil-sides of said group of n top-coil sides being disposed in the top portion and bottom portion, respectively, in the bottom half of said slots, with the remaining bottom coil-side or sides disposed between said two bottom coil-sides.

10. A commutator-type dynamo-electric machine having a slotted armature-core and an armature-winding having n coils per slot, n being greater than two, half of the coil-sides, hereinafter called "top coil-sides", being disposed in the top halves of the slots in a plurality of tiers of superposed coil-sides, and the other half of the coil-sides, hereinafter called "bottom coil-sides", being disposed in the bottom halves of the slots in a corresponding number of tiers of superposed coil-sides, a group of n top coil-sides in any given slot being connected to n consecutive commutator-bars and being electrically continuous, respectively, with a corresponding group of bottom coil-sides all lying in the bottom halves of other given slots, characterized by the two bottom coil-sides in one tier which correspond to the first and $(n-1)$th coil-sides of said group of n top coil-sides being disposed in the top portion and bottom portion, respectively, of a given tier in the bottom half of said slots, with the remaining bottom coil-side or sides of each tier disposed between said two bottom coil-sides.

11. A commutator-type dynamo-electric machine having a slotted armature-core and an armature winding having n coils per slot, n being greater than two, half of the coil-sides, hereinafter called "bottom coil-sides", being disposed in superposed relation in a plurality of tiers the bottom halves of the slots, and the other half of the coil-sides, hereinafter called "top coil-sides", being disposed in superposed relation in a corresponding plurality of tiers in the top halves of the slots, a group of n bottom coil-sides in any given slot and tier being connected to n consecutive commutator-bars and being electrically continuous, respectively, with a corresponding group of top coil-sides all lying in the top halves of other given slots, characterized by the two top coil-sides

which correspond to the $(n-1)$th and the nth coil-sides of said group of n bottom coil-sides in a given tier being disposed in the top portion and bottom portion, respectively, of a given tier in the top half of said slots, with the remaining top coil-side or coil-sides corresponding, respectively, to the first and $(n-2)$th bottom coil-sides disposed between said two top coil-sides.

12. A commutator-type dynamo-electric machine having a slotted armature-core and an armature-winding having n coils per slot, n being greater than two, half of the coil sides, hereinafter called "bottom coil-sides", being disposed in the bottom halves of the slots, and the other half of the coil-sides, hereinafter called "top coil-sides", being disposed in the top halves of the slots, the bottom coil-sides in any slot being disposed in superposed relation the bottom coil-side of the first coil being in the lowermost position in the bottom half of the slot and the remaining bottom coil-sides being consecutively positioned in the slot so that the bottom coil-side for the nth coil is in the uppermost position of the bottom half of the slot, the top coil-sides connected to the nth coil-side in the bottom halves of the slots are positioned in the bottom portion of the top halves of the slots and the top coil-sides from the nth down to the second are positioned in the top halves of other slots and are connected, respectively, from the $(n-1)$th down to the first coil-sides in the bottom halves of the slots, whereby the sequence of commutation is such that the coil-sides in the bottom of the slots are not commutated last.

13. A commutator-type dynamo-electric machine having a slotted armature-core and an armature winding having n coils per slot, n being greater than two, the active portions of said armature winding being rectangular in section, half of the coil-sides, hereinafter called "bottom coil-sides", being disposed in superposed edgewise relation in the bottom halves of the slots, and the other half of the coil-sides, hereinafter called "top coil-sides", being disposed in superposed flatwise relation in the top halves of the slots, a group of n bottom coil-sides in any given slot being connected to n consecutive commutator-bars and being electrically continuous, respectively, with a corresponding group of top coil-sides all lying in the top halves of other given slots, characterized by the two top coil-sides which correspond to the $(n-1)$th and nth coil-sides of said group of n bottom coil-sides being disposed in the top portion and bottom portion, respectively, in the top half of said slots, with the remaining top coil-side or top coil-sides corresponding, respectively, to the first and $(n-2)$th bottom coil-side or coil-sides disposed between said two top coil-sides.

14. A commutator-type dynamo-electric machine having a slotted armature-core and an armature winding having conductors rectangular in section in the active portion thereof, and having n coils ped slot, n being greater than two, half of the coil-sides, hereinafter called "bottom coil-sides", being disposed in superposed relation in a plurality of tiers and in edgewise relation in the bottom halves of the slots, and the other half of the coil-sides, hereinafter called "top coil-sides", being disposed in superposed flatwise relation in a corresponding plurality of tiers in the top halves of the slots, a group of n bottom coil-sides in any given slot and tier being connected to n consecutive commutator-bars and being electrically continuous, respectively, with a corresponding group of top coil-sides all lying in the top halves of other given slots, characterized by the two top coil-sides which correspond to the $(n-1)$th and nth coil-sides of said group of n bottom coil-sides in a given tier being disposed in the top portion and the bottom portion, respectively, of a given tier in the top half of said slots, with another top coil-side or coil-sides corresponding respectively, to the first and the $(n-2)$th bottom coil-side or coil-sides disposed between said two top coil-sides.

15. In a commutator-type dynamo-electric machine, having a slotted armature-core and an armature winding having conductors rectangular in section in the active portion thereof and having n coils per slot, n being greater than two, half of the coil sides, hereinafter called "bottom coil-sides", being disposed in superposed edgewise relation in the bottom halves of the slot and in side-by-side relation in the non-active portion thereof, the transition from the active portion to the non-active portion being effected by rotating the group, one to n, inclusive, through an angle of 90° and having the ends thereof flattened to thus be in a plurality of radial planes with reference to the armature-core, and the other half of the coil-sides, hereinafter called "top coil-sides", being disposed in superposed flatwise relation in the top halves of the slots and in side-by-side relation in the non-active portion thereof, the transition from the active portion to the non-active portion being effected by rotating the group, one to n inclusive, through an angle of 90° and having the ends thereof flattened to thus lie in a plurality of radial planes with reference to the armature-core, a group of n bottom coil-sides in any given slot being connected to n consecutive commutator-bars and being electrically continuous, respectively, with a corresponding group of top coil-sides all lying in the top halves of other given slots, characterized by the two top coil-sides which correspond to the $(n-1)$th and nth coil-sides of said group of n bottom coil-sides being disposed in the top portion and bottom portion, respectively, in the top half of said slots, with the remaining top coil-side or coil-sides corresponding, respectively, to the first and the $(n-2)$th bottoms coil-side or coil-sides disposed between said two top coil-sides.

16. In a commutator-type dynamo-electric machine having a slotted armature-core and an armature winding having conductors rectangular in section in the active portion thereof, a plurality of coil-sides in each slot, the coil-sides in the bottom portion of the slot being positioned on edge and the coil-sides in the top portion of the slot being positioned flatwise, said conductors being turned through an angle of 90° and changed in configuration in the non-active portion of the conductors so that a smooth curvilinear transition is effected without any abrupt change in configuration or substantially any change in sectional area whereby the conductors are positioned in a side-by-side relation in the non-active portion thereof.

17. A dynamo-electric machine comprising an armature winding and a slotted armature core, characterized by the coil-sides of one pair of armature-winding coils comprising flat conductors disposed in superposed edgewise relation in the bottom portion of one slot and the respective sides of each coil of a pair displaced from said one slot by no less than 90 electrical degrees nor more than 270 electrical degrees and disposed in super-

posed flatwise relation in the top portion of other slots.

18. A dynamo-electric machine comprising an armature winding and a slotted armature core, characterized by the coil-sides of one pair of armature-winding coils being disposed in superposed edgewise relation in the bottom portion of one slot and in superposed flatwise relation in the top portions of other given slots displaced substantially 180 electrical degrees from the first mentioned slot.

19. In a commutator-type dynamo-electric machine having a slotted armature-core and an armature winding having conductors rectangular in section in the active portion thereof, a plurality of coil-sides in each slot, the coil-sides in the bottom portion of the slot being positioned on edge and the coil-sides in the top portion of the slot being positioned flatwise, said conductors being turned through an angle of 90° and changed in configuration in the non-active portion of the conductors so that the conductors are disposed in side-by-side relation.

20. In a commutator-type dynamo-electric machine having a slotted armature-core and an armature winding having conductors rectangular in section in the active portion thereof, a plurality of coil-sides in each slot, the coil-sides in the bottom portion of the slot being positioned on edge and the coil-sides in the top portion of the slot being positioned flatwise, said conductors being turned through an angle of 90° and changed in configuration in the non-active portion of the conductors so that the conductors are disposed in a side-by-side relation and the turned portion presents a smooth curvilinear transition.

21. In a dynamo-electric machine having a magnetizable core or armature member provided with slots, and conductors in each slot, each conductor being substantially rectangular in section and having longitudinal and transverse dimensions of the section equal to b and a, respectively, and where a is less than b and where a and b represent numbers designating a dimension in a system of linear measurements, each of said slots having a rectangular bottom portion having a depth equal to nb and a width equal to a and a top rectangular portion having a depth equal to na and a width equal to b, where n designates the number of conductors in a file counting from bottom to top disposed in the said bottom portion of the slot.

22. In a dynamo-electric machine having a magnetizable core or armature member, provided with slots, and conductors in each slot, each conductor being substantially rectangular in section, and having longitudinal and transverse dimensions at the sections equal to b and a, respectively, and where a is less than b and where a and b represent numbers designating a dimension in a system of linear measurements, each of said slots having a rectangular bottom portion having a depth equal to nb and a width equal to ma and a top rectangular portion having a depth equal to na and a width equal to mb where n designates the number of conductors in a file, counting from bottom to top, disposed in the said bottom portion of the slot, and where m designates the number of conductors in a row, counting from side to side of the slot, disposed in the slot.

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