Jan. 22, 1974 J. E. MILLER Re. 27,893

ARMATURE WINDING AND COMMUTATOR CONNECTION

Original Filed Feb. 9, 1968

7 Sheets-Sheet 1

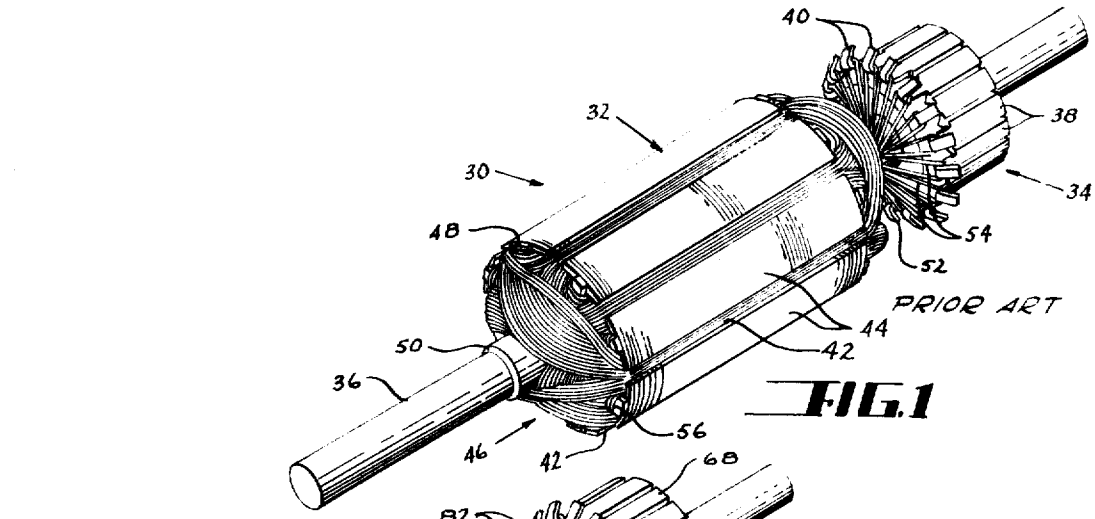


FIG. 1

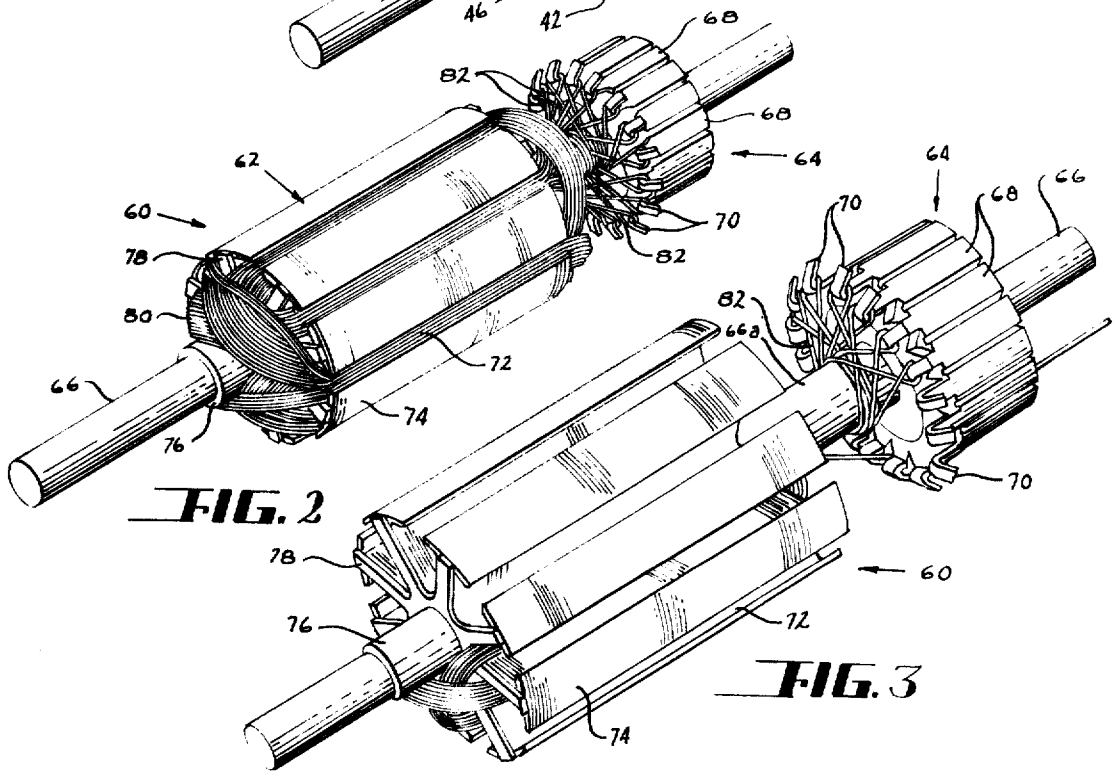


FIG. 2

FIG. 3

INVENTOR.
JERRY E. MILLER

BY Dybvig and Dybvig

HIS ATTORNEYS

ARMATURE WINDING AND COMMUTATOR CONNECTION

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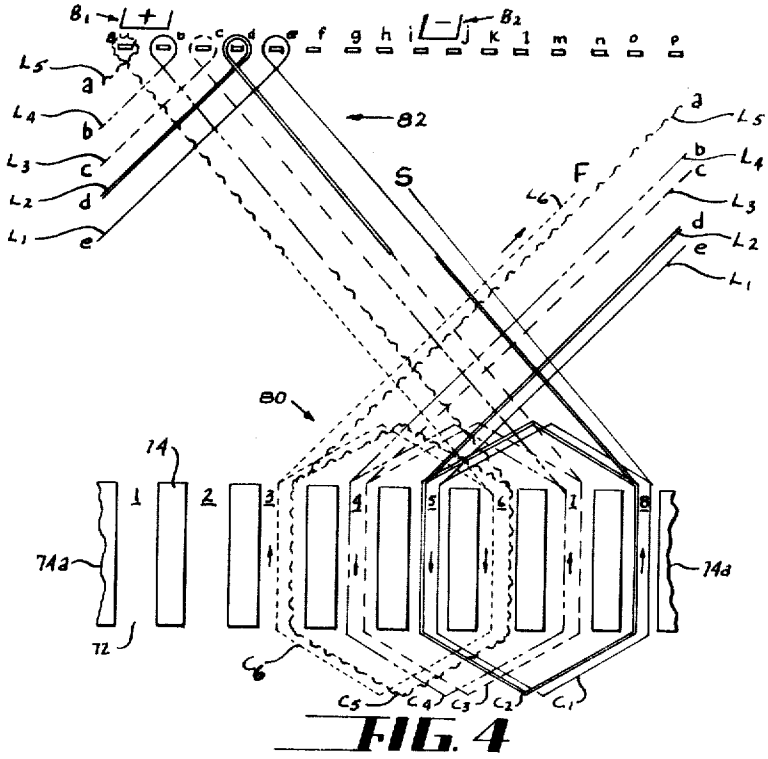


FIG. 4

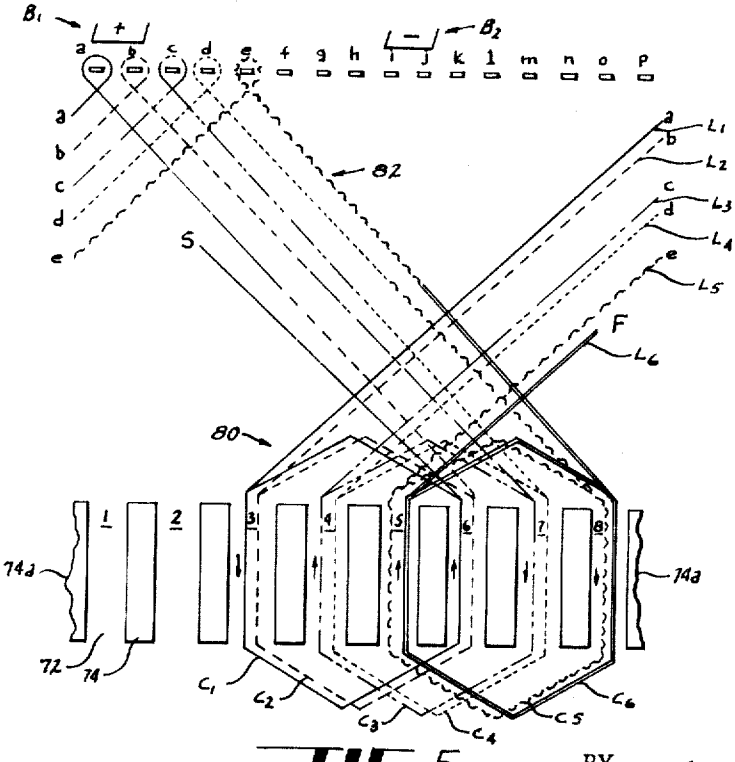


FIG. 5

INVENTOR.
JERRY E. MILLER

BY Dyberg and Dyberg

HIS ATTORNEYS

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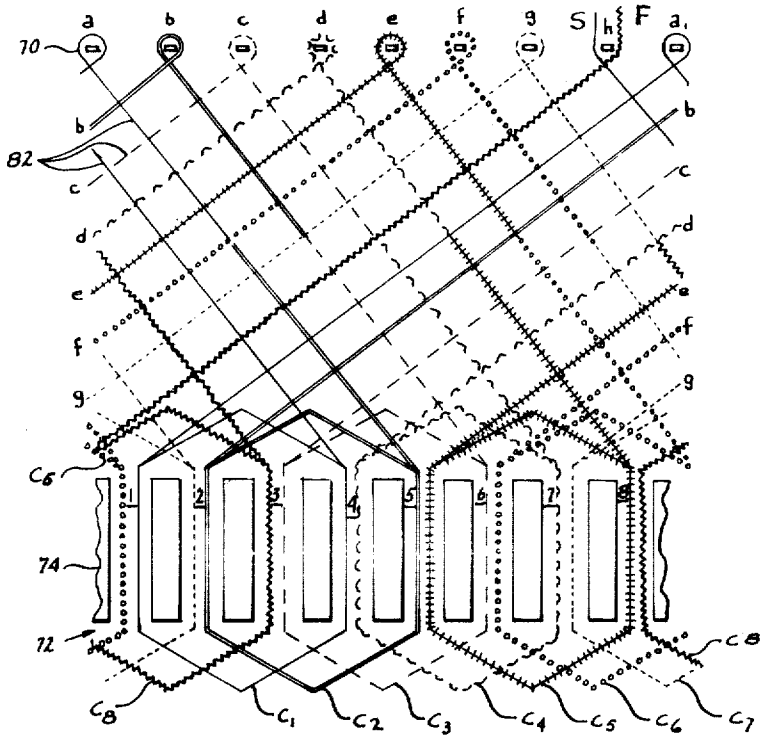


FIG. 6

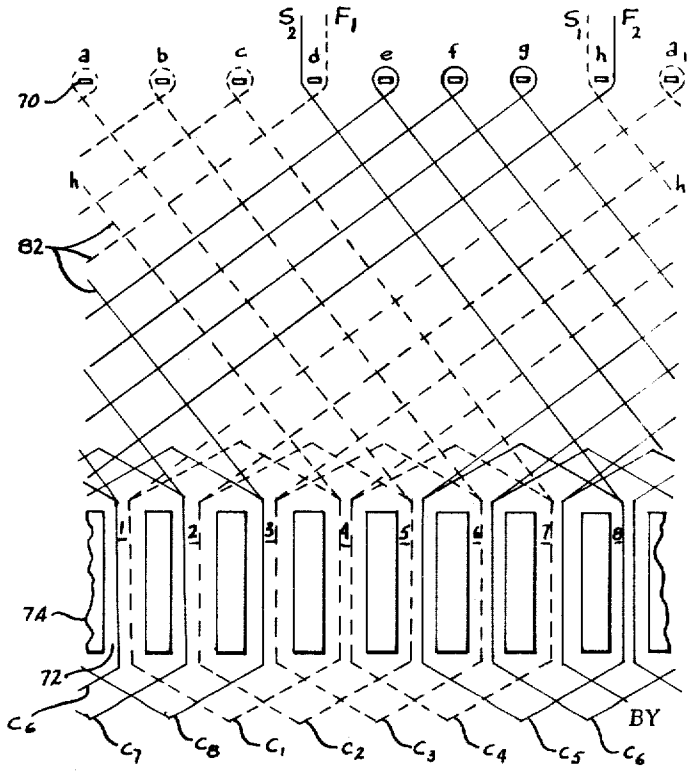


FIG. 7

INVENTOR.
JERRY E. MILLER

BY

Dybvig & Dybvig

HIS ATTORNEYS

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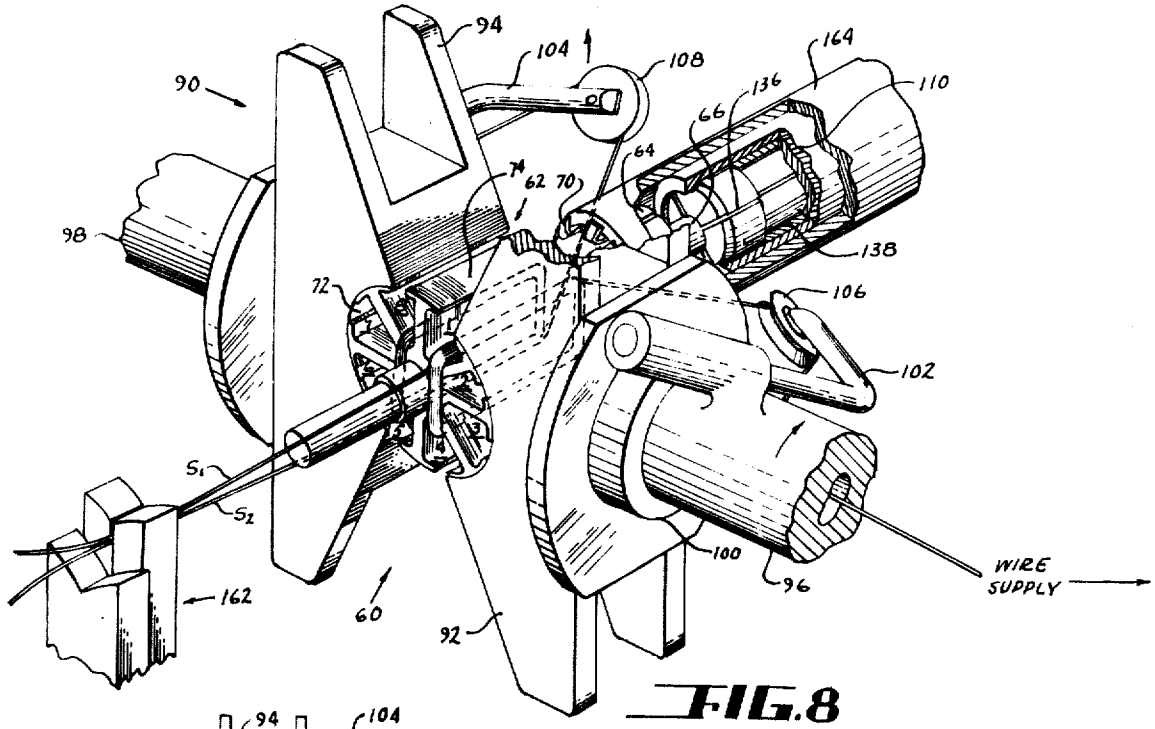


FIG. 8

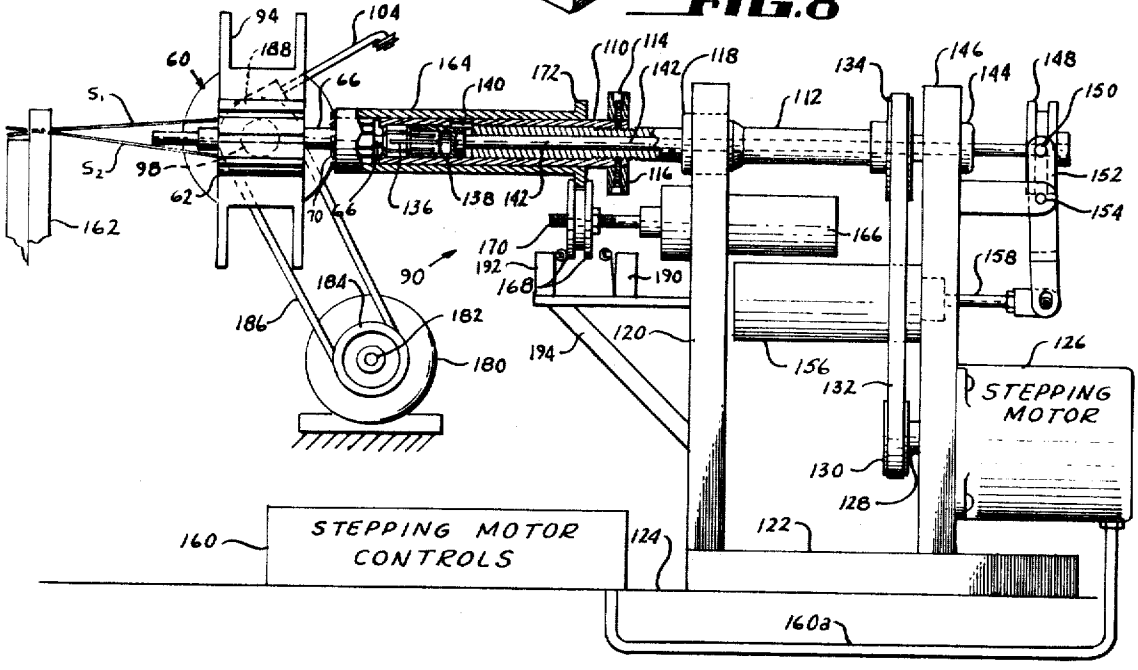


FIG. 9

INVENTOR.
JERRY E. MILLER

BY Dyering & Dyering

HIS ATTORNEYS

ARMATURE WINDING AND COMMUTATOR CONNECTION

Original Filed Feb. 9, 1968

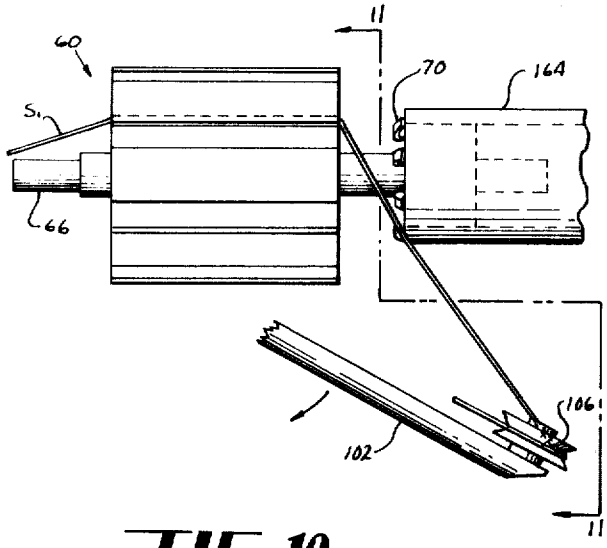


FIG. 10

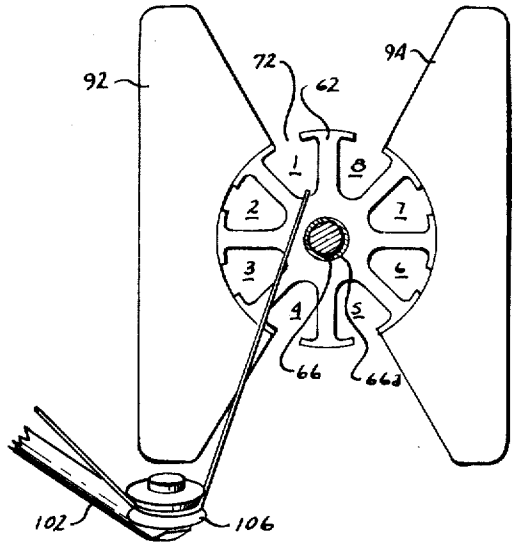


FIG. 11

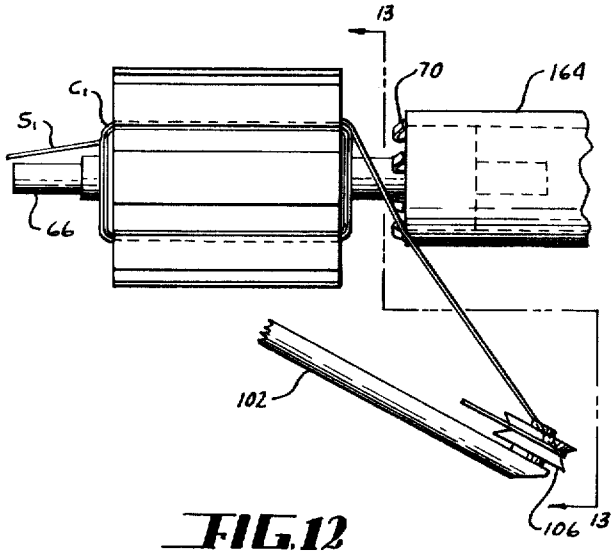


FIG. 12

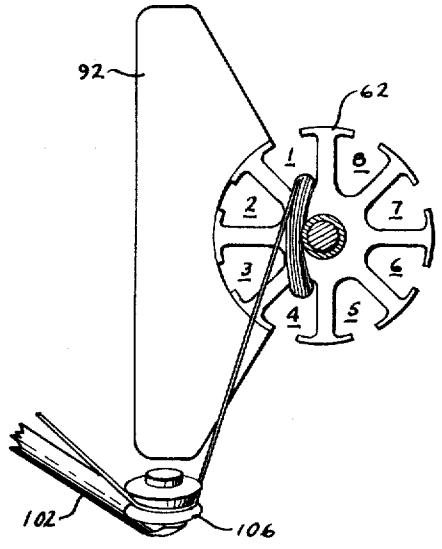


FIG. 13

INVENTOR.
JERRY E. MILLER

BY Dybwig & Dybwig

HIS ATTORNEYS

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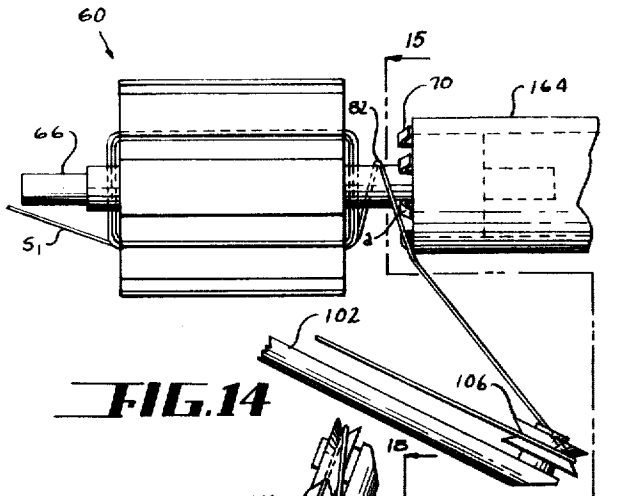


FIG. 14

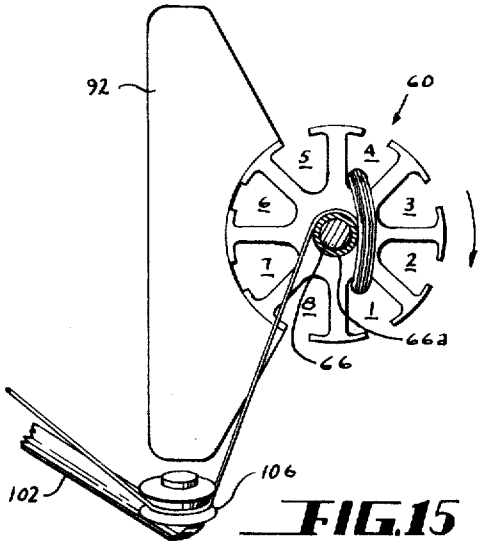


FIG. 15

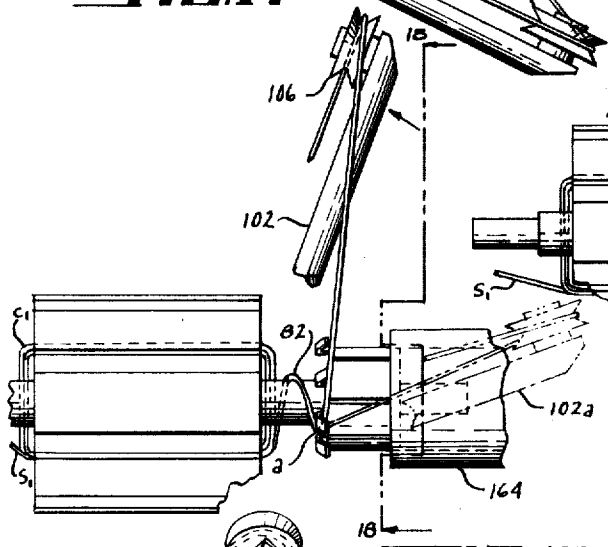


FIG. 17

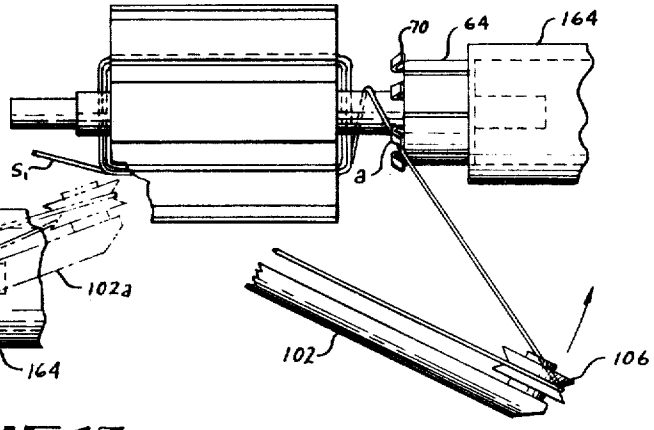


FIG. 16

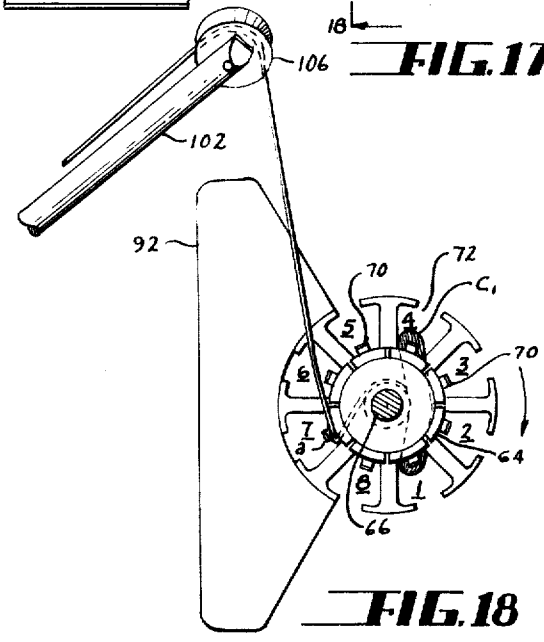


FIG. 18

INVENTOR.
JERRY E. MILLER

BY

HIS ATTORNEYS

ARMATURE WINDING AND COMMUTATOR CONNECTION

Original Filed Feb. 9, 1968 7 Sheets-Sheet 7

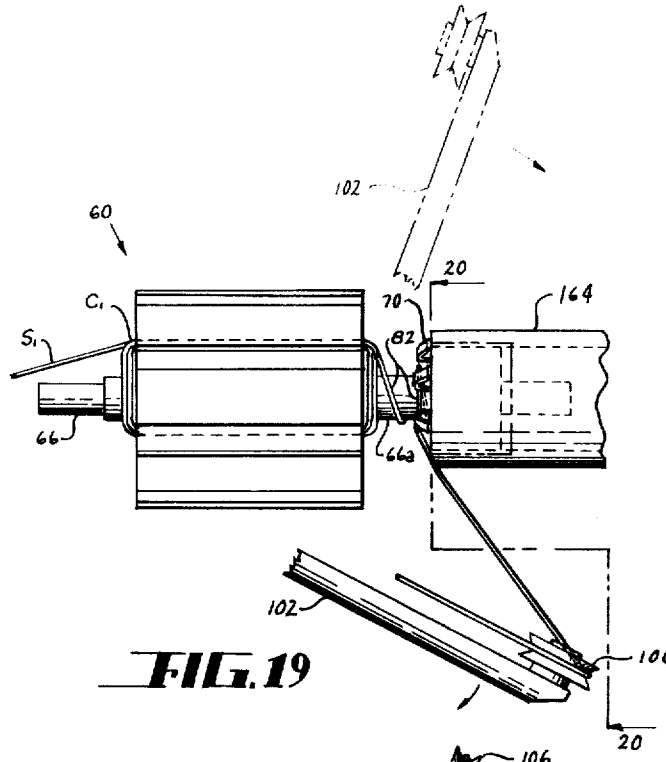


FIG. 19

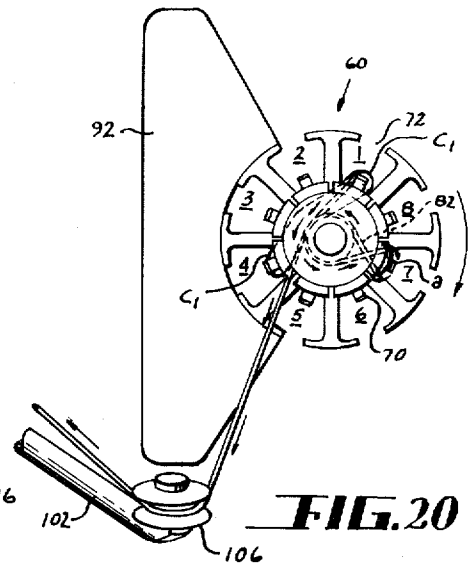


FIG. 20

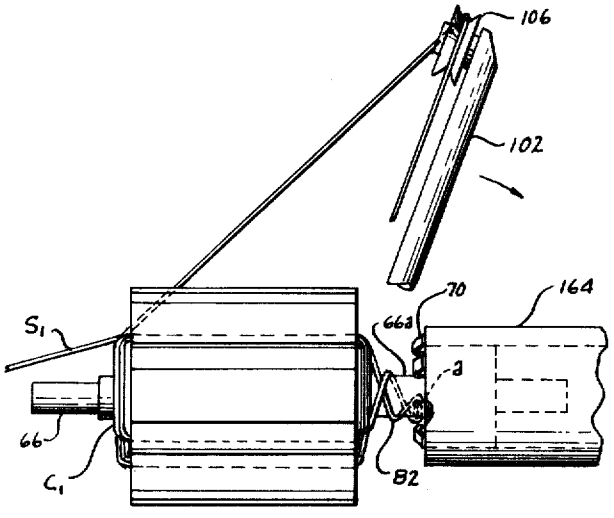


FIG. 21

INVENTOR.
JERRY E. MILLER

BY Dybwig and Dybwig

HIS ATTORNEYS

United States Patent Office

Re. 27,893
Reissued Jan. 22, 1974

27,893

ARMATURE WINDING AND COMMUTATOR CONNECTION

Jerry E. Miller, Dayton, Ohio, assignor to The Globe Tool and Engineering Company, Dayton, Ohio

Original No. 3,506,864, dated Apr. 14, 1970, Ser. No. 704,342, Feb. 9, 1968. Application for reissue Apr. 18, 1972, Ser. No. 245,282

Int. Cl. H02k 3/46

U.S. Cl. 310—234

14 Claims

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

ABSTRACT OF THE DISCLOSURE

Novel winding patterns for armatures having various numbers of slots and either one or two coils per slot are disclosed along with methods and apparatus for winding armatures. Lead wires between coils are wrapped around the armature shaft and looped around commutator tangs. An efficient method of obtaining armatures having opposite polarities is also shown and described.

This invention relates to armature winding and more particularly to the winding of armatures with commutators having tangs. It will become apparent, however, that the invention is not necessarily so limited.

Several types of armature winding machines have been developed and are in use in everyday production. The various types of armature winding machines include machines wherein an armature is rapidly rotated with respect to a wire guide in such a fashion that wire is drawn from a wire supply through the wire guide to form wound coils in pairs of slots in the armature. Another type of armature winding machine employs a wire guide which is reciprocated to traverse the length of an armature. At each end of the armature core the wire guide normally hesitates and the armature is oscillated to present a different slot in position to receive wire from the wire guide. Still another type of armature winding machine incorporates a rotating wire guide or flier which cooperates with a wire guide wing against which an armature core is placed such that when the flier is rotated a coil is wound in a pair of slots in the armature core. Several variations of the three types of machines mentioned above have been used. In each type, machines have been developed which wind more than one coil at a time and in some cases all of the coils for an armature may be wound simultaneously.

A popular type of automatic armature winding machine in present use is known as the "double flier" armature winding machine. This type of machine is relatively simple in construction yet quite versatile and fast operating. A conventional double flier type armature winding machine will normally have wire from two supply reels coursed separately through two spindles on which the fliers are mounted. The start ends of the wires are held by a clamp or clamps adjacent the axis of the armature shaft of the armature core to be wound. When both fliers are subsequently rotated, wire will be guided from the fliers by wire guides or wings into two pairs of armature slots. A double flier machine can readily be tooled and controlled to wind either one coil for each slot, or a total of two coil sides in each slot, or else two coils per slot. Also, as disclosed in United States Patent No. 2,670,145 issued to John M. Biddison on Feb. 23, 1954, double flier armature winding machines can be used to wind coils in armatures having an odd number of slots by temporarily disabling one flier as the first coil (or coils) is wound in a first pair of slots. The coils wound in subsequent pairs of slots are then wound by both fliers.

Various types of patterns of wind for armature coils have been developed taking into consideration the special requirements of a double flier armature winding machine. Between each coil wound by a flier, a commutator lead connection must be formed by the wire. This commutator wire lead connection may be in the form of a lead loop such as described for example in the Harry W. Moore Patent No. 2,627,379, issued Feb. 3, 1953. After the armature is completely wound the lead loops are connected to the commutator segments. In some cases the wire leads are temporarily connected to the commutator segments during the automatic winding cycle of the winding machines. One of the difficulties encountered in armature winding machines is the need to provide for the winding of a coil and the subsequent formation of a lead, whether in the form of a lead loop or a connection to a commutator segment, and then the winding of a second coil by the same flier without uncoiling or unraveling the wire already wound.

To form wire leads yet not unwind previously wound coils during the automatic operation of an armature winding machine, it is now conventional to form what is known as an "anchored lead" between each coil. The anchored lead includes a length of wire coursed through a slot adjacent one of the pairs of slots in which a coil is wound either just before or just after the lead loop or the commutator connection is made. As a result, the lead wire is "anchored" to one of the teeth which separates the armature slots. United States Patent No. 3,191,269 granted to Harry W. Moore on June 29, 1965, illustrates various winding patterns having anchored leads.

There are several drawbacks to the use of anchored leads. The lengths of wire passing through the adjacent slots extend in the opposite electrical direction to the wires forming the coil sides therein and, electrically, these lengths of wire perform no useful function. Some armatures are so small in relation to wire size used therein that they cannot accept the electrically useless wire or wires in each slot. The electrically useless wire or wires in each slot invariably added to the total length of wire used in winding an armature. Further, the movements of the fliers and of armatures being wound when the leads are being formed have been quite complex and time consuming partly because of the necessity of placing the useless wire in the sots. In fact, because the fliers can be rotated at extremely fast speeds when winding coils, a quite significant portion of the automatic cycle for winding a typical armature is consumed during the intervals in which the leads are formed.

A preferred type of connection of a wire lead to a commutator segment is the tang type. Risers or slots in commutator segments are typically difficult to produce and the final connection may not have the strength of the tang type connection. Temporary tang type connections can conveniently be made during the automatic cycle of a winding machine by appropriate movement of the armature being wound, the flier or fliers, and a tang shield which is used to prevent accidental hooking of the wire to the tang during the winding of the coils. The final permanent connection is readily and easily made by applying a hot stake to the upturned end of the tang which fuses the lead to the tang and at the same time burns off or evaporates the insulating coating from the wire lead.

As discussed in the aforementioned Moore Patent No. 3,191,269, the problem arises that wire leads connected to the commutator tangs during the early part of the automatic winding cycle may be wound under coils subsequently formed and the first formed leads are placed under considerable tension by coils wound thereover. In the extreme, this could result in breakage of the leads and in every case the danger exists that the insulating

coating on some of the leads may be destroyed during the winding cycle, or when additional strain, due to the centrifugal forces acting thereon, is exerted on the leads when the armature is in operation. For these reasons, the Moore Patent No. 3,191,269 discloses leads extended partially around an armature shaft to commutator segments remote from the slots from which the leads extend. The leads thus formed are less likely to be placed under tension by coils subsequently wound and will be at least partially supported by the armature shaft.

Some armatures, and especially armatures having two coils per slot, have not had tang type connections because space limitations between adjacent tangs would result in mutual engagement of lead wires quite close to the tangs. During the hot staking of the leads, the insulating coating of the touching lead wires would often be destroyed. Even if not destroyed during the hot staking operation, the lead wires may constantly abrasively rub against one another because of the centrifugal forces acting thereon when the armature is in use, and the insulation may ultimately be weakened or destroyed.

An object of this invention is to provide an improved winding pattern for armatures. The winding pattern of this invention requires less wire and has a lead which is more fully supported by the armature shaft than conventional prior art commutator leads. It does not have the electrically useless wires extending through any of the slots. As a result, the armature is both mechanically and electrically superior to prior art armatures automatically wound. This object is accomplished by wrapping the wire leads completely around the armature shaft whereupon the armature shaft rather than the teeth between armature slots serves to anchor the leads. This winding pattern is well suited for use with commutators having tangs. However, the winding pattern may also be useful with commutators having slots or risers for lead connections. Furthermore, the winding pattern is adaptable for use in winding armatures having either an odd or an even number of slots whether or not one or two coils per slot are formed.

Another object of this invention resides in the provison of an improved commutator lead connection for tang type commutators. This is accomplished by looping a lead wire under and then over and back under its associated tang. The lead wire thus crosses over itself immediately beneath the tang. Destruction of the insulation at this point, either from the hot staking process or from mutual abrasion of the crossed wires, is harmless because the crossed wires are electrically identical. The points of crossover of lead wires between adjacent commutator segments are spaced reatively far from the commutator and thus are unaffected by the heat generated during the hot staking operations.

Further, it is an object of this invention to advantageously utilize the aforementioned improved lead connections in the aforementioned improved winding pattern. As a result the support of lead wires by the armature shaft is maximized and, accordingly, the adverse effects of the centrifugal forces acting thereon minimized.

Other objects and advantages will become apparent from the following description. For example, as will be described below, the winding pattern in accordance with this invention is advantageously adapted to wind armatures having opposite polarities with very little change in the winding pattern.

Referring to the drawings:

FIGURE 1 is a perspective view of an armature having a prior art winding.

FIGURE 2 is a perspective view of an armature wound in accordance with the present invention.

FIGURE 3 is an enlarged perspective view of the armature of FIGURE 2 when partially wound.

FIGURE 4 is a portion of a possible winding diagram for the armature of FIGURE 2.

FIGURE 5 is a portion of a winding diagram of the same type of armature as FIGURE 4 but wound with the opposite polarity.

FIGURE 6 is a completed winding diagram of another pattern of wind in accordance with this invention. In FIGURE 6, one strand of wire forms the entire winding.

FIGURE 7 is a winding diagram of a pattern of wind for an armature electrically identical to the pattern of wind of FIGURE 6 but wound from two strands of wire.

FIGURE 8 is a perspective view, with parts broken away and shown in cross section, of a portion of an armature winding machine in accordance with this invention and illustrating a partially wound armature.

FIGURE 9 is a side elevational view of the machine of FIGURE 8 with parts omitted, broken away and in cross section and illustrating additional parts of the machine.

FIGURE 10 is a side elevational view of an armature and a portion of the winding machine of FIGURE 8 and the wire used in forming the armature windings, as these parts appear near the beginning of a winding operation.

FIGURE 11 is a cross sectional view taken through the armature shaft between the armature core and the commutator and showing an end view of a portion of the winding machine of FIGURE 8 as viewed in the direction of arrows **11—11** of FIGURE 10.

FIGURES 12 and 13 are views similar to FIGURES 10 and 11, respectively, but at the completion of the winding of a coil.

FIGURES 14 through 20 illustrate the sequence of steps for forming a wire commutator lead connection in accordance with this invention. FIGURES 14, 16, 17 and 19 are side views similar to FIGURES 10 and 12. FIGURES 15, 18 and 20 are views similar to FIGURES 11 and 13, taken along section lines **15—15**, **18—18** and **20—20** of FIGURES 14, 17 and 19, respectively. In FIGURES 18 and 20 the commutator is shown in end view with a tang shield removed.

FIGURE 21 is a side elevational view similar to FIGURE 10 illustrating the position of parts at the beginning of the winding of a second coil.

Referring to the drawings in greater detail, FIGURE 1 illustrates an armature **30** of the type having a laminated core **32** and a commutator **34** mounted on an armature shaft **36**. The commutator **34** has a plurality of circumferentially spaced commutator segments **38** terminating in hook-shaped tangs **40** adjacent one end of the laminated core **32**. The core **32** has a plurality of radially extending slots **42** separated by T-shaped teeth **44** which receive coil windings **46**. As well known, the coil windings **46** are wound from insulated wire. To prevent electrical contact between the windings **46** and the other parts of the armature **30** which might be caused by rubbing of the insulated wire on the metal parts of the armature during the winding process or during subsequent use of the armature, the windings **46** are completely isolated from the armature, core **32** and the shaft **36**. Thus, there will be a U-shaped slot insulator (not shown) in each of the slots **42**. Both ends of the commutator **34** are covered by insulating end pieces **48**. An insulating sleeve **50** surrounding the shaft **36** abuts the end **48** farthest from the commutator end of the armature **30** and a similar insulating sleeve **52** extends between the commutator **34** and the adjacent end of the armature core **32**.

The armature **30** is of the type having two coils per slot. Since each coil has two coil sides, one in each of two slots, a total of four coil sides are located in overlapping relation in each slot **42**. Between each coil of the coil windings **46** there is a wire lead **54** formed from the same wire as the coil windings **46**. The wire leads **54** in FIGURE 1 are of the type illustrated in the aforementioned Moore Patent No. 3,191,269. Accordingly, each wire lead **54** projects out of one of the slots **42** and partially around the armature shaft **36** to a selected commutator tang **40**, over the selected tang **40**, and then back along a generally parallel path to either the same or an adjacent slot **42**. Each wire

lead **54** is partially supported by the armature shaft **36** by engaging the sleeve **52**. In addition, each wire lead **54** includes or is accompanied by a length of wire extending through a slot adjacent to one of the slots in which either the previous coil or the subsequent coil is wound, whereupon the strand of wire is hooked about one of the teeth **44** to "anchor" the leads **54** in position and thereby prevent unraveling of the wire during subsequent winding operations. The portions of the wires between coils hooked about the teeth **44** are indicated by the reference character **56** in FIGURE 1. Because there are two coils per slot in the armature of FIGURE 1, there are also two hooked portions **56** wrapped about each tooth **44**. There are eight slots in the armature of FIGURE 1. Accordingly, sixteen commutator segments **39** with tangs **40** are required for the sixteen wire leads **54**. As already menitoned, the basic winding pattern of FIGURE 1 as well as the basic winding pattern to be described below can be used in winding armatures having a different number of slots as well as in armatures wherein there is to be only one coil in each pair of slots.

Those skilled in the art will recognize that the armature **30** of FIGURE 1 is not completely finished. Further finishing operations would include the insertion of insulating wedges or ropes at the top of the slots **42** and, frequently, the impregnation of the windings **46** with varnish or like material. Also, the commutator tangs **40** would be subjected to heat and pressure as by a hot staking operation to fuse the wire leads **54** thereto and at the same time to burn insulation off from the wire forming the leads **54**.

The commutator lead arrangement of FIGURE 1 is satisfactory for many purposes. It is apparent, however, that a considerable portion of each of the wire leads **54** is unsupported. Also, in cases where the commutator tangs are closer together than shown in FIGURE 1, or the wire diameter is greater than that shown in FIGURE 1, adjacent leads **54** would be quite close together and may even be in mutual engagement close to the tangs **40**. In such cases, the hot staking operation may cause the wire insulation to be burned off to the point of mutual engagement whereupon wire leads to adjacent tangs **40** would be shorted. Also, the armature of FIGURE 1 suffers from the drawbacks resulting from the lengths of wire between coils hooked around the armature teeth **44**. Since these lengths of wire are electrically useless, it is apparent that electrically equivalent armatures could be made if these were omitted. Omission of the electrically useless lengths of wire would obviously result in a lesser amount of wire required to wind an armature and, therefore, could result in a considerable cost savings in the mass production of armatures. Some armatures, especially those employing large diameter wires, cannot be wound as illustrated in FIGURE 1 because the slots **42** are completely filled by the coil turns to meet power requirements and there is insufficient space in the slots **42** for the electrically useless lengths of wire.

An armature of the type made in accordance with this invention is illustrated in FIGURE 2. In FIGURE 2, the armature, generally designated **60**, has a laminated core **62** and a commutator **64** mounted on an armature shaft **66**. The commutator **64** has sixteen commutator segments **68** with tangs **70** adjacent one end of the laminated core **62**. The eight radial armature slots **72** of the armature **60** are separated by armature teeth **74**. As before, a completed armature **60** would have insulators such as the insulating sleeve **76** and end-piece **78**. Thus, except for the coil windings, designated **80**, and the wire leads, designated **82**, the armature **60** may be identical to the armature **30**.

In FIGURE 2 the wire leads **82** are wrapped more than 360 degrees around the shaft **66** and are also looped completely about the commutator tangs **70**. For this reason, each wire lead crosses over itself immediately beneath its associated tang **70**. The wrapping of the wire leads **82** about the shaft **66** serves to anchor them and, accordingly, there are no dead or electrically useless wires in the armature **60** of FIGURE 2 corresponding to the wire portions designated **56** in FIGURE 1.

FIGURE 3 shows a portion of the armature **60** of FIGURE 2 when partially wound. The wrapping of the wire leads **82** about the shaft **66** is clearly illustrated in FIGURE 3. It will be observed that each wire lead **82** is projected out of a radial armature slot **72** partially around the shaft **66** and beyond its associated tang **70**, then wrapped or looped back over its associated tang **70**, and then continued about the shaft **66**. The extension of each wire lead **82** first beneath its associated tang **70** and then over the same tang **60** and then on around the shaft **66** results in each wire lead **82** being wrapped about the shaft **66** close to the commutator **64**. Accordingly, the leads **82** formed during the early part of the winding operation are not wound under or placed under tension by the subsequently wound coil forming the windings **80**. In the final finishing operations, wherein the tangs **70** are hot staked, the likelihood that adjacent leads **82** will be in mutual engagement sufficiently near the hot stake to cause shorting is considerably reduced. It is possible that heat applied to the tangs **70** will remove insulation to the point where each lead **82** cross itself. Removal of the insulation at this point of each lead **82** is harmless because the two crossing wire portions are electrically identical.

FIGURES 4 and 5 are winding diagrams, either of which may be used as the winding pattern of the armature of FIGURES 2 and 3. For reasons which will be discussed later, the windding diagram of FIGURE 4 may be referred to as "retrogressive" and the winding diagram of FIGURE 5 as "progressive." For convenience, six coils, designated C_1 through C_6, forming part of the windings **80**, are shown in FIGURES 4 and 5 as if wound from a single strand of wire beginning with a start end S and ending in a finish end F which forms part of a wire lead L_6. If the complete winding pattern were illustrated, there would be sixteen coils shown between the start end S and the finish end F. The individual armature slots **72** are labeled **1** through **8** and the individual tangs **70** are labeled *a* through *p*. As conventional, the winding diagrams of FIGURES 4 and 5 represent armatures "laid flat" with the sixteen tangs **70** shown side-by-side and the slots **72** separated by eight teeth **74** shown side-by-side. In order to completely show each of the eight slots **72**, one tooth, designated **74***a*, is shown on each side of FIGURES 4 and 5. The wire leads **82**, designated L_1 throuhg L_5, are shown progressing out of the slots **72** and toward the right side of FIGURES 4 and 5 to the positions designated *a*, *b*, *c*, *d* and *e* conforming to the particular tangs **70** to which the wire leads **82**, designated L_1 through L_5, are shown progressing out looped about the armature shaft **66** (not shown in these diagrams), the same positions *a*, *b*, *c*, *d* and *e* are duplicated on the left side of FIGURES 4 and 5. It will be understood that the wire leads **82** are continuous and not broken, it being impossible to clearly illustrate the wrapping or the looping of the wire leads about the shaft **66** in a winding diagram of this type.

Referring specifically to FIGURE 4, proceeding from the start wire S, wire is wound downwardly through slot **8** and upwardly through slot **5** to form the coil C_1. (The arrows in the armature slots **72** refer to the direction of current flow and not to the direction of wind.) By convention, the entire coil C_1 is represented by a single line. In practice, the coil C_1 would normally be formed from many turns of wire, each turn progressing downwardly through slot **8** and upwardly through slot **5** with its end turns spanning the end of the armature core between slot **8** and slot **5**. After the appropriate number of turns have been wound, the wire lead designated L_1 projects out of slot **5** and in the same direction as the wire turns forming the coil C_1 and, thence, around the armature shaft **66** to the tang **70** designated *e*. After being looped about the

tang *e* in the manner previously described, the wire is continued about the shaft **66** and again downwardly through the slot **8** and upwardly through the slot **5** to form the coil C_2. To distinguish between the coils C_1 and C_2, the coil C_2 is shown as a double line. After the appropriate number of turns of wire have been wound in slots **8** and **5** to form the coil C_2, the wire lead L_2 is extended from slot **5** in a direction generally parallel to the wire Lead L_1 partially around the shaft and is then looped about the tang d and continued around the shaft. Two coils have now been wound in the pair of slots **8** and **5**. From the tang d the wire progresses downwardly through slot **7** and upwardly through slot **4** to form the coil C_3 in these slots, the coil C_3 being pictorally represented by a dash line. After the appropriate number of turns, the wire lead L_3 projects from slot **4** to the tang c and subsequently the coil C_4, which is designated by a broken line, is formed in the same pair of slots **7** and **4** with the wire lead L_4 projecting therefrom and looped about the tang b. Following the same winding pattern, the coil C_5 is then wound in slots **6** and **3** with the wire lead L_5 projecting therefrom looped about the tang a and the coil C_6 is formed in the same pair of slots with the wire lead L_6 projecting therefrom. As mentioned above, the winding diagram of FIGURE 4 is only partially completed. If the winding diagram were complete, the wire lead L_6 would be shown looped about the tang p with subsequent wire leads being looped about tangs o, n, m, and so forth.

In FIGURE 5 the coils C_1 and C_2 are shown wound in slots **6** and **3** with the wire lead L_1 therebetween looped about the tang a. The wire lead L_2 extending from the coil C_2 is looped about the tank b and enters into slot **7** to the start of coil C_3 wound in slots **7** and **4**. The location of the coils C_4, C_5 and C_6, follow the same pattern as that of FIGURE 4 except that, in FIGURE 5, the coils C_5 and C_6 are wound in a pair of slots **8** and **5** to the right of slots **7** and **4** which receive the coils C_3 and C_4. The wire leads L_3, L_4 and L_5 are, in the case of FIGURE 5, connected or looped about the tangs c, d and e. Wire lead L_6 in FIGURE 5, of course, would be connected to tang f and the winding would progress if the completed winding pattern were shown in FIGURE 5 with the next coil wound in slots **1** and **6**.

It should be noted in connection with both FIGURES 4 and 5 that, after the windings are complete, the start and the finish ends of the wire would lose their identity. Thus, in FIGURE 4 the start end and the finish end would ultimately be connected together around the tang f and together would form another wire lead **82**. Similarly, in FIGURE 5 the start and finish ends of the wire would be wrapped together around tang p to form a wire lead **82**. As will be further described below, the windings may conveniently be formed from two strands of wire with the start end of one strand connected to the finish end of the other strand and vice versa. The winding patterns of FIGURES 4 and 5 are suited to flier type winding machines and especially double flier armature winding machines and the foregoing description has proceeded with the assumption that the winding would commence with the start end illustrated. It will be appreciated by those skilled in the art, however, that the winding pattern need not be accomplished by a flier type winding machine.

Also illustrated in FIGURES 4 and 5 are a pair of commutator brushes B_1 and B_2 positioned as brushes may be positioned when fully wound armatures of the type illustrated therein are in use in an electric motor. For purposes of discussion it is assumed in both FIGURES 4 and 5 that, at a given instant, the brushes B_1 span tangs a and b and are the positive brushes while the brushes B_2, spanning tangs i and j, are the negative brushes. Conventional current flow, that is from positive to negative, is also assumed. Although there appears to be very little difference between the armatures of FIGURES 4 and 5 it will be obvious that the two armatures illustrated therein are of opposite polarities. With the brush connections illustrated in FIGURE 4, the coil C_5 in slots **6** and **3** is the commutated or shorted coil because the wire leads at each end of the coil C_5, being connected to the tangs a and b, are connected to the positive brush B_1. Current flow in coil C_8 is upwardly through slot **3** and downwardly through slot **6**. Current flow through the other coils is as indicated by the arrows in the slots **72** of FIGURE 4. In FIGURE 5, the shorted or commutated coil is coil C_2 which is also in slots **3** and **6**. However, current flow is downwardly through coil C_1 in slot **3** and upwardly through slot **6** and, as indicated by the arrows appearing in the slots **72** of FIGURE 5, the current flow through each of these slots **72** is opposite to that shown in FIGURE 4. As will be discussed below, the same flier type armature winder, with only a minor change in a control setting, can be used to wind either the pattern of FIGURE 4 or that of FIGURE 5.

FIGURES 6 and 7 are complete winding diagrams of eight slot armatures having one coil per slot and, accordingly, eight tangs, wound with wire leads **82** wrapped around the armature shaft (not shown in these figures) in accordance with this invention. In FIGURE 6, each of the coils, marked C_1 through C_8, are shown in distinctively different types of lines so that the individual coils and the lead wires between coils can be more easily identified. The slots **72** between the teeth **74** are again labeled **1** through **8** and the tangs labeled a through h. Tang a is shown on both sides and is labeled a_1 on the right side of both FIGURES 6 and 7. FIGURE 6 illustrates the manner in which an armature can be wound from one strand of wire beginning with its start end S at tang h. Proceeding from tang h, the wire is coursed downwardly through slot **4** and upwardly through slot **1** to form the coil C_1. After the appropriate number of turns have been wound, the wire is then projected to the tang a, looped under and around the tang a, and then coursed downwardly through slot **5** and upwardly through slot **2** to form the coil C_2. The winding pattern of FIGURE 6 is completed by continuing the looping of the wire about the tangs **70** and the coursing of the wire through the slots **72** in the manner just described until the coil C_8 has been completed, at which time the finish end F of the wire is brought from the slot **8** to tang h. As part of the finishing operation, the start and finish ends S and F, respectively, are twisted together about the tang h.

FIGURE 7 illustrates the winding pattern of FIGURE 6 but wound from two strands of wire rather than one strand of wire. In FIGURE 7 the coils C_1, C_2, C_3 and C_4 are wound from a first strand of wire, shown by dash lines, and the coils C_5 through C_8 are wound by a second strand of wire shown as a solid line. The start end of the first strand of wire, labeled S_1, is, as in FIGURE 6, located at the tang h and coursed downwardly through slot **4** and upwardly through slot **5** to form the coil C_1 and the winding of coils C_1 through C_4 progresses as in FIGURE 6. The finish end F_1 of the first strand of wire projects from the side of coil C_4 in slot **4** to tang d. The start end, labeled S_2, of the second strand of wire is coursed from tang d downwardly through slot **8** and upwardly through slot **5** to form the coil C_5. After the coils C_5 through C_8 have been formed, the finish end F_2 of the second strand of wire is brought to tang h. Subsequently, the start end S_1 and the finish end F_2 are twisted together about tang h, whereas the start end S_2 and the finish end F_1 are twisted together about the tang d. Once completed, the armatures represented by the wiring diagrams of FIGURES 6 and 7 will be mechanically and electrically identical.

A double flier armature winding machine, generally designated **90**, which may be used to wind armatures having winding patterns of the types shown in FIGURES

2 through 7, is illustrated in FIGURES 8 and 9. In FIGURE 8 the laminated core **62** of the armature **60** is shown abutted by a pair of wire guide wings **92** and **94** mounted on the ends of flier spindles **96** and **98**, respectively. Bearings (not shown) mounted in housings, such as the housing **100** between the flier spindle **96** and the guide wing **92**, permit rotation of the flier spindles **96** and **98** while the wire guide wings **92** and **94** are held stationary due to their engagement with the laminated core **62**. The fliers **103** and **104** are mounted on and rotated with the spindles **96** and **98**, respectively. The wire strands used in forming the coils may, as usual, be coursed through the spindle shafts **96** and **98** and around pulleys **106** and **108** on the ends of the fliers **102** and **104**, respectively. The fliers **102** and **104** are synchronously rotated in opposite directions such that they pass each other on the same side of the wings **92** and **94** at the horizontal plane containing the longitudinal centerline of the armature shaft **66**. Suitable hydraulic or electro-mechanical drives for synchronously rotating fliers are known and in use and, therefore, the drive mechanisms for the fliers **102** and **104** are not illustrated in detail herein. For example, United States Patent No. 3,013,737, issued to Harry W. Moore on Dec. 19, 1961, is illustrative of a hydraulic drive mechanism which could readily be adapted for use with the apparatus of FIGURES 8 and 9. The same patent shows an air actuator arrangement for moving the wire guide wings into and out of engagement with armature cores which could be used in the apparatus of FIGURES 8 and 9.

To provide for a rotary drive for the armature **60** after each coil is wound, the end of the armature shaft **66** adjacent the commutator **64** is clamped to a drive shaft sleeve extension **110** of a hollow armature drive shaft **112**. The sleeve extension **110** is threaded on the drive shaft **112** and fixed for rotation therewith by set screws **114** in an annular ring **116** affixed to the sleeve extension **110**. The drive shaft **112** is mounted by a bearing **118** in a first support stanchion **120** supported by a plate **122** on a table **124** or the like and is driven by a stepping motor **126** having a drive shaft **128** with a drive pulley **130** mounted thereon connected by a timing belt **132** to a driven pulley **134** affixed to the drive shaft **112**. Shown connected to the stepping motor **126** is an electrical control cable **160a** leading from a stepping motor control housing **160**. Suitable controls located in the housing **160** for sequentially pulsing stepping motors are well known and, hence, not illustrated in detail herein. It will be appreciated that the sequences of operation of the apparatus of FIGURES 8 and 9, to be described below in connection with FIGURES 10 through 21, will be achieved through the motor controls and through suitable sensing switches (not shown) properly located to sequentially detect events occurring throughout the automatic operation of the apparatus.

Clamping of the armature shaft **66** to the sleeve extension **110** may take any convenient form. Illustrated for this purpose in FIGURES 8 and 9 is a split collet sleeve **136** which receives the armature shaft **66** and which is cammed into clamping engagement therewith by a cup-shaped collet clamp member **138** keyed to the sleeve extension **110** by a key **140** and mounted upon a collet actuator shaft **142** which passes axially through the drive shaft **112** and is mounted in a bearing **144** in a second support stanchion **146**. On the rearward end of the collet actuator shaft **142**, that is the end farthest to the right in FIGURE 9, the actuator shaft **142** has a yoke ring **148** clamped thereto which receives confronting drive pins **150** of a yoke **152**. The yoke member **152** is pivoted about a bracket **154** by an air actuator **156** having an air driven piston rod **158** and mounted on the second stanchion **146**. As apparent, the armature shaft **66** can be clamped by the collet mechanism upon movement of the piston rod **158** to the right as viewed in FIGURE 9 at the beginning of the winding procedure to be described below. The fully wound armature, at the end of the winding procedure, is released upon movement of the piston rod **158** to the left. The air actuator **156** can be operator controlled by a conventional push button switch control of electrically operated air valves (not shown) or be entirely automatically controlled in response to certain machine operations, all as well known to those skilled in the art.

In FIGURE 8 the armature slots **72** have been labeled **1** through **8** to correspond to the labeling of the slots in FIGURE 7. The coil C_1 is shown wound in slots **1** and **4** by the right hand flier **102** while the coil C_5 is shown wound by the left hand flier **104** into slots **5** and **8**. The start wire ends S_1 and S_2 may conveniently be clamped by a combined wire clamp and cutter **162**, which is only schematically illustrated in FIGURES 8 and 9, and which may be entirely conventional. As with present practice, the start ends S_1 and S_2 remain clamped until the armature is fully wound at which time they will be coursed through slots **4** and **8**, respectively, to the appropriate tangs **70**. During the winding of the coils by the fliers **102** and **104**, the wire strands follow paths which would cause them to be hooked over exposed tangs **70**. For this reason, a cylindrical tang shield **164** is mounted concentrically with and upon the drive shaft **112** and has one end thereof abutted against the commutator tangs. In some cases, the tang shield **164** may overlie the tangs **70**. The external diameter of the shield **164** is greater than the total diameter of the commutator **64** with its tangs **70**. Hence, the wire strands, when coils are being wound, are cammed away from the tangs **70** by the shield **164**. When it is desired to hook the wire leads to the tangs **70**, as will be described, the shield **164** is drawn away from the tangs **70** by an air actuator **166** having a pair of discs **168** mounted on its piston rod **170** and straddling a disc **172**, the disc arrangement **168** and **172** operating in an obvious fashion to control the location of the tang shield **164** with respect to the tangs **70**.

FIGURES 10, 11, 12 and 13 illustrate the sequence of operation of the machine of FIGURES 8 and 9 in winding the coil C_1 in slots **4** and **1**. The winding of the coil C_5 by the flier **104** is not illustrated, it being well understood by those skilled in the art that the winding of the coil C_5 would proceed in substantially the same fashion as the winding of the coil C_1 but with the flier **104** rotating in the opposite direction from the flier **102**. In FIGURE 10 the shield **164** is shown abutted against the tangs **70** to prevent hooking of the wire on any of the tangs **70** as the flier **102** rotates. Upon rotation of the flier **102**, the wire used to form coil C_1, with its start end S_1 clamped at **162** is pulled through a conventional wire tensioning device (not shown) at its supply end, through the spindle **96**, and, as shown in FIGURES 10 and 11, is guided by the wire guide wing **92** into slots **1** and **4**. The winding progresses until the appropriate number of turns have been wound by the flier **102** rotating in a clockwise direction as viewed in FIGURE 10 to complete coil C_1. In the FIGURES 12 and 13 position, coil C_1 is fully wound and the flier **102** has come to rest with the length of wire leading from slot **1** to the pulley **106** lying adjacent the tang shield **164**. FIGURES 12 and 13, it will be observed, show the same point in the sequence of operation as that illustrated in the perspective view of FIGURE 8.

In FIGURES 14 and 15 the flier **102** is still arrested in the same position as that shown in FIGURES 12 and 13. However, the armature **60** has now been rotated through the operation of the stepping motor **126** shown in FIGURE 9 by 180°. During this increment of rotation of the armature **60** the shield **164** has remained in place abutted against the tang **70**. The effect of rotating the armature **60** while holding the flier **102** stationary is to draw wire from the flier **102** and partially wrap the wire about the shaft **66** and its insulating sleeve,

designated **66a**, to partially form the wire lead **82**. The 180° rotation of the armature **60** has resulted in the tang a being brought to a position just above the wire leading from the slot **1** to the flier pulley **106**. Accordingly, with the armature **60** now stationary, the shield **164** is withdrawn from the tangs **70**, i.e. moved to the right as illustrated and viewed in FIGURE 16 by the shield air actuator **166** shown in FIGURE 9. The position of the parts is then as illustrated in FIGURE 16. The wire is then looped back over the tang a by rotating the flier **102** in a reverse or counterclockwise direction from that shown in FIGURE 16 through the broken line position shown in FIGURE 17 to the nearly vertical position shown in full lines in FIGURES 17 and 18. Thereafter, the shield **164** is moved back into abutment with the tangs **70**, thus trapping the wire leading to the flier pulley **106** between the tang a and the shield **164**. The armature **60** is then rotated in the same direction as before, that is in a clockwise direction as viewed in FIGURE 20, beyond 360° from its original position wherein slots **1** and **4** were presented for the winding of coil C_1 to appropriately position slots **2** and **5** adjacent the guide wing **92**. Thereafter, the flier **102** is rotated in a clockwise direction from its dotted line position in FIGURE **19** to begin the forming of coil C_2 in slots **2** and **5**. As soon as the wire is pulled into slot **5**, the wire lead **82** is completely wrapped about the shaft **66** as well as looped about the tang a. FIGURE 21 clearly illustrates the single wire lead **82** which is formed between the coils C_1 and C_2 with the flier **102** rotating in a clockwise direction having partially wound the first turn of coil C_2. In the foregoing operation, when the armature **60** is rotated between the winding of the coils C_1 and C_2, the wire guide wings **92** and **94** may be moved slightly away from the armature core **62** so as not to interfere with such rotation.

Referring again to FIGURE 8, it will be understood that the coils C_1 and C_5 are simultaneously wound by the fliers **102** and **104**, respectively. Because the fliers **102** and **104** rotate in opposite directions, the end turns of all the coils as viewed from the commutator end of the armature span the slots in the same direction. The stopped position of the fliers **102** and **104** shown in FIGURE 8 is such that upon subsequent rotation of the armature **60**, the tang e will be positioned immediately below the length of wire from slot **5** to the pulley **108** at the same time the tang a is positioned above the wire leading from coil C_1 to the pulley **106** as previously described in connection with FIGURE 14. The reverse rotation of the flier **102** illustrated by a comparison of FIGURES 14 through 18 is accompanied by a simultaneous reverse rotation of the flier **104** so that wire is hooked about tang e at the same time that wire is hooked about tang a. By the time the winding of coils C_1 and C_2 has progressed to the point illustrated in FIGURE 21, the wire lead **82** between coils C_5 and C_6 will be looped about tang e and completely wrapped or looped about the shaft **66** in the same direction as the illustrated wire lead between coils C_1 and C_2. The winding of the armature **60** will continue in the manner just described until all coils have been wound with wire leads **82** therebetween. The armature shaft **66** is then released by the collet sleeve **136** and the start and finish wires twisted about appropriate commutator tangs as discussed above.

As apparent from the foregoing, the armature **60** is rotated in two increments by the stepping motor **126** between the winding of a pair of coils, first simultaneously to position the selected tangs **70** adjacent the wire leading to the fliers **102** and **104** about which the wire leads are to be hooked, and then rotated through an additional angle in the same direction to position the appropriate pairs of slots for receiving the next pair of coils to be wound by the fliers **102** and **104**. The specific example discussed in FIGURES 7 through 21 involves the "progressive" pattern of wind mentioned above and, accordingly, the total rotation of armatures between the winding of pairs of coils is larger than 360° by the angle between adjacent slots. If the same armature were to be progressively wound with two coils per slot, the total rotation of the armature between the first pair of coils wound in a first pair of slots and the next pair of coils wound in the same pair of slots would be 360°. And after the second coils is wound in each of the first pair of slots, the total rotation of the armature in forming the wire leads **82** would be 360° plus the angle between adjacent slots, whereupon the first pair of coils would be formed in the second pair of slots. The procedure, of course, would be repeated until all sixteen coils are wound.

The retrogressive wind discussed above in connection with FIGURE 3 can easily be accomplished with the same mechanism shown in FIGURES 8 and 9 but with the stepping motor controls so adjusted that the total rotation of the armature between coils to be wound in adjacent slots would be one slot width less than 360°. The wire leads between coils would still, of course, be wrapped around the armature shaft through an angle greater than 360° when the fliers **102** and **104** are subsequently rotated to wind the next pair of coils. Thus, it is seen that by virtue of the winding pattern of this invention and the apparatus of this invention, armatures having opposite polarities can be wound by merely adjusting the sequence control for the stepping motor **126**. Sequential controls for stepping motors are commercially available in which the angle through which the stepping motor rotates upon each operation can be "dialed in " at the stepping motor control housig **160**. In contrast, prior practice in armature winding machines frequently would require a complete revision of the tooling and a change in the direction of rotation of either the fliers or the armature as the winding operation progressed. Naturally, the changes in the armature winding machine would often be drastic and time-consuming.

As obvious, the winding pattern, the method, and the apparatus of this invention can be used when winding armatures having any usual number of slots, whether odd or even, and can be used to wind armatures having either one or two coils per slot. When winding odd slot armatures, the first coil or coils in the first pair of slots would be wound with only one flier operating; the remaining coils would be wound simultaneously in pairs by the two fliers **102** and **104**. Also, the winding process described above could be accomplished by a single flier machine. Thus, in connection with FIGURES 10 through 21, the single flier operation illustrated therein could be used without another flier simultaneously operating therewith, but with repeated indexing or rotating of the armature sufficient to enable the single flier **102** to wind all of the coils. Further, it should be appreciated that the winding pattern is quite flexible and can be varied to meet the needs of the motor manufacturer. For example, the initial increment of rotation of the armature **60** to pick up tang a, as illustrated in FIGURES 14 and 15, could either be greater or less than 180° to pick up a different tang **70** which would be clockwise circumferentially either closer to or further from the commutator slot 1 from which the wire projects, the subsequent increment of rotation of the armature being through either a greater or a lesser angle in order to properly position slots **2** and **5** for receiving a coil as illustrated in FIGURE 20.

Because wire leads are wrapped about the armature shaft rather than hooked about the armature teeth, the only time the fliers are reverse rotated is when the wire is hooked around the tangs **70** and, of course, there will be no tendency for the coils previously wound to unwind. When the fliers are thereafter rotated in the forward direction, that is the direction required to wind a coil, the wires cannot be unhooked from the tangs because they are trapped by the tang shield **164**. Because the fliers rotate through almost the entire winding cycle in only one direction, with only the short reverse rotation used

to hook the wire leads on the tangs, it will be appreciated that the flier drive mechanism, such as the hydraulic drive mechanism previously suggested and the automatic controls, therefor, would be relatively simple. The speed with which an armature can be fully wound may be considerably reduced in view of this invention because there are fewer movements of the fliers and the armature required than in many other winding methods in which the wire leads are placed close to the armature shaft or in which lead loops are formed between coils.

To illustrate the nature of the automatic controls, a hydraulic motor **180** is shown in FIGURE 9 which has an output shaft **182** driving a pulley **184** connected by a timing belt **186** to a driven pulley **188** affixed to the flier spindle **98** to rotate the flier **104**. The same drive shaft **182** could be connected through a suitable reversing mechanism to the spindle **96** so that the fliers **102** and **104** rotate synchronously but in opposite directions. Also shown in FIGURE 9 are a pair of sensing switches **190** and **192** mounted by a bracket **194** on the support stanchion **120** which sense the completion of forward and rearward movements of the discs **168** driven by the air actuator **166** to trigger operations subsequent to the tang shield withdrawal and shielding movements respectively. The rotation of the flier spindles **96** and **98** or the output shaft **182** could be sensed by switches responsive to cams (not shown) thereon. Of course, the described automatic controls are only exemplary of the type of controls commonly used and well known to those skilled in the art.

Although the presently preferred embodiment of the device has been described, it will be understood that within the purview of this invention various changes may be made within the scope of the appended claims.

Having thus described my invention, I claim:

1. In a winding for an armature core on an armature shaft, the winding being of the type including a pair of coils in said armature core and a wire lead between said pair of coils connected to a commutator segment, the improvement wherein said wire lead is looped around the armature shaft, said wire lead extending from the finish of one of said pair of coils in a predetermined direction about the armature shaft to said commutator segment and extending from said commutator segment in the same direction [about] *completely around* said armature shaft to the start of the other of said pair of coils.

2. The improvement of claim **1** wherein said commutator segment is of the type having a commutator tang projecting from [a commutator to] *it toward* said core and wherein an intermediate part of said wire lead is looped [about] *completely around* said commutator tang.

3. In an armature of the type having a shaft, a core on said shaft having a plurality of armature slots for receiving coils, and a commutator on said shaft having a commutator segment for each coil, an armature winding includuing wire wound into a plurality of coils located in a plurality of said armature slots and a plurality of wire leads, one wire lead being between a pair of said coils and formed from said wire, each wire lead extending completely around said shaft and each wire lead having part thereof intermediate its ends connected to one of said commutator segments.

4. The structure of claim **3** wherein all of the coils in said armature are wound from a single wire and the two ends of said wire are connected to a single commutator segment.

5. The structure of claim **3** wherein all of the coils in said armature are wound from two wires, one end of both of said wires being connected to one of said commutator segments and the other end of both of said wires being connected to another one of said commutator segments.

6. The structure of claim **3** wherein each commutator segment has a lead receiving tang and wherein said intermediate part of each said wire lead is looped about one of said tangs.

7. The structure of claim **6** wherein each said wire lead crosses itself under the said tang about which it is looped.

8. The structure of claim **7** wherein all of the coils in said armature are wound from a single wire and the two ends of said wire are connected to a single commutator segment.

9. The structure of claim **7** wherein all of the coils in said armature are wound from two wires, one end of both of said wires being connected to one of said commutator segments and the other end of both of said wires being connected to another one of said commutator segments.

10. In an armature of the type having a shaft, a slotted armature core on said shaft for receiving coils of wire, and a commutator on said shaft having a plurality of commutator segments each provided with a wire lead receiving tang, an armature winding including a plurality of coils wound from a single wire located in a plurality of said slots, a wire lead formed from said single wire between each pair of said coils, each of said wire leads havan intermediate portion looped under, over and back under one of said lead receiving tangs, *each of said wire leads being looped more than 360° around said shaft whereby each of said wire leads crosses over itself two times between said commutator and said core, one crossing over being adjacent the one of said tangs to which it is looped around and the second crossing over being adjacent the one of said armature slots from which it initially extends.*

11. The structure of claim **10** wherein each of said wire leads is looped about said shaft *in a predetermined direction which is the same direction as the wire forming adjacent coil end turns is extended when the coils are being wound.*

12. In an armature of the type having an armature shaft, a slotted armature core mounted on said shaft, a commutator mounted on said shaft adjacent one end of said core, said commutator having a plurality of wire lead receiving portions, and an electric winding comprised of wire wound into coils in pairs of slots in said armature core, said wire having a start end leading to one of said coils, a finish end leading from another of said coils, said start and said finish ends each being connected to the same tang to form a wire lead, and a plurality of other wire leads, each of said other wire leads extending between a pair of coils, the improvement wherein each of said wire leads extends from the finish of the first of said pair of coils between which it extends in a predetermined direction to one of said wire lead receiving portions of said commutator and extends in said predetermined direction from said one of said wire lead receiving portions of said commutator around said armature shaft past said finish of said first of said pair of coils to the start of the second of said pair of coils between which it extends.

13. The structure of claim **12** wherein said wire lead receiving portions of said commutator are tangs, one tang being associated with each of said wire leads and projecting from said commutator toward said armature core and wherein each of said wire leads extends in said predetermined direction from said finish of said first of said pair of coils under a selected one of said tangs, extends in the opposite direction over said selected tang, and extends in said predetermined direction from and under said selected tang to said start of said second of said pair of coils.

14. The structure of claim **13** wherein all of said coils and said wire leads are made from two wire stands, said start end being an end part of one of said wire strands and said finish end being an end part of another of said wire strands, and wherein the other ends of said wire strands are both connected to another one of said tangs.

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DONOVAN F. DUGGAN, Primary Examiner

U.S. Cl. X.R.

310—265

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. Re. 27,893 Dated January 22, 1974

Inventor(s) Jerry E. Miller

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 40, "added" should be ---add---.
Column 2, line 45, "sots" should be ---slots---.
Column 4, line 56, delete the comma after "armature".
Column 5, line 15, "segments 39" should be ---segments 38---.
Column 6, line 24, "cross" should be ---crosses---.
Column 6, line 31, "windding" should be ---winding---.
Column 6, line 49, "throuhg" should be ---through---.
Column 6, lines 53,54, "82, designated L_1 through L_5, are shown progressing out" should be ---82 are directed. Because the wire leads are wrapped or---
Column 7, line 33, "tank" should be ---tang---.
Column 12, line 31, "housig" should be ---housing---.
Column 13, line 57, insert a comma after "slots".
Column 15, line 13, "Dammat" should be ---Dammar---.

Signed and sealed this 19th day of November 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents