FIG. 1.

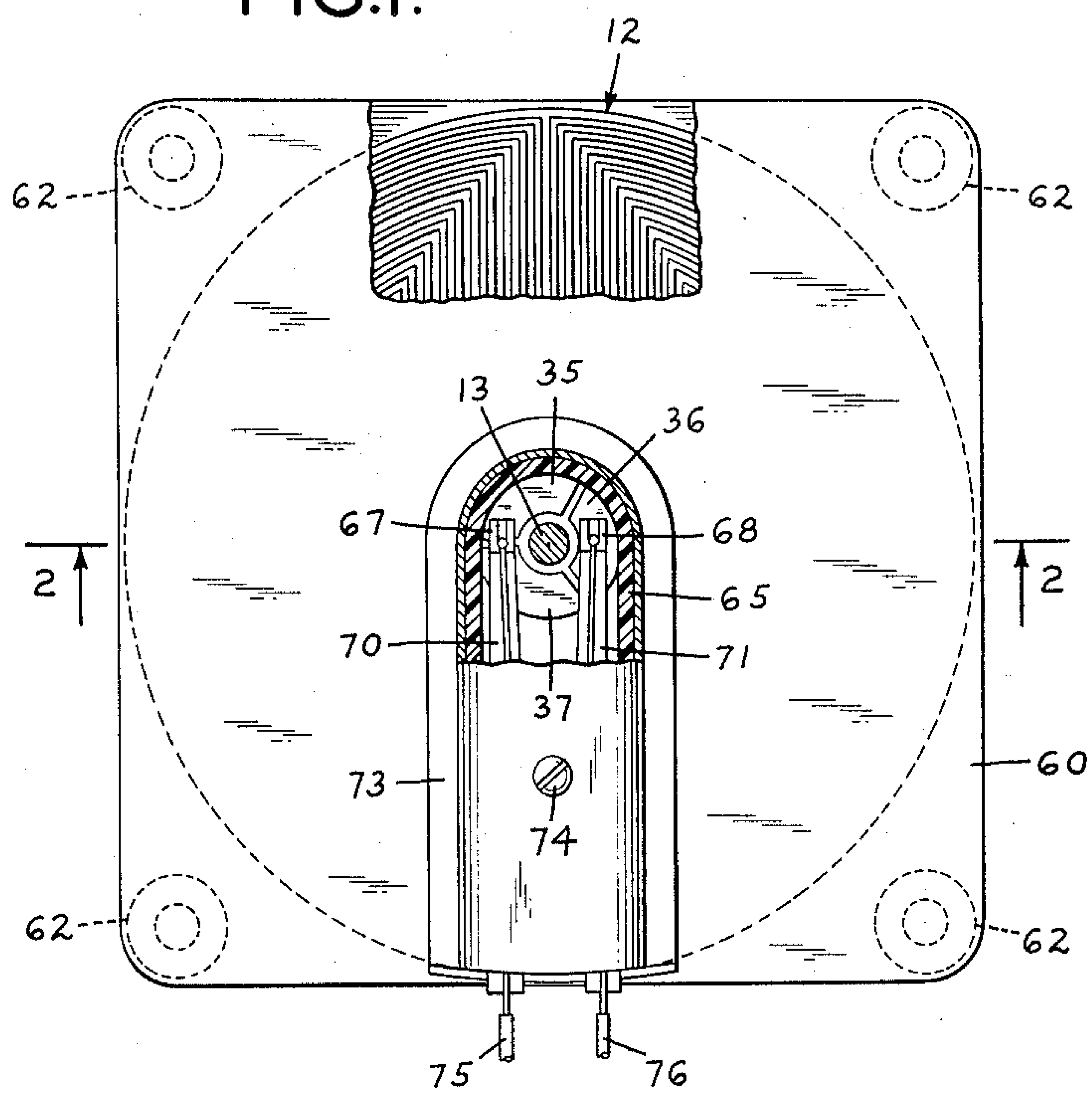
12
62
62
62
62
13
35
36
67
68
65
2
2
70
71
37
73
60
74
75
76

FIG. 2.

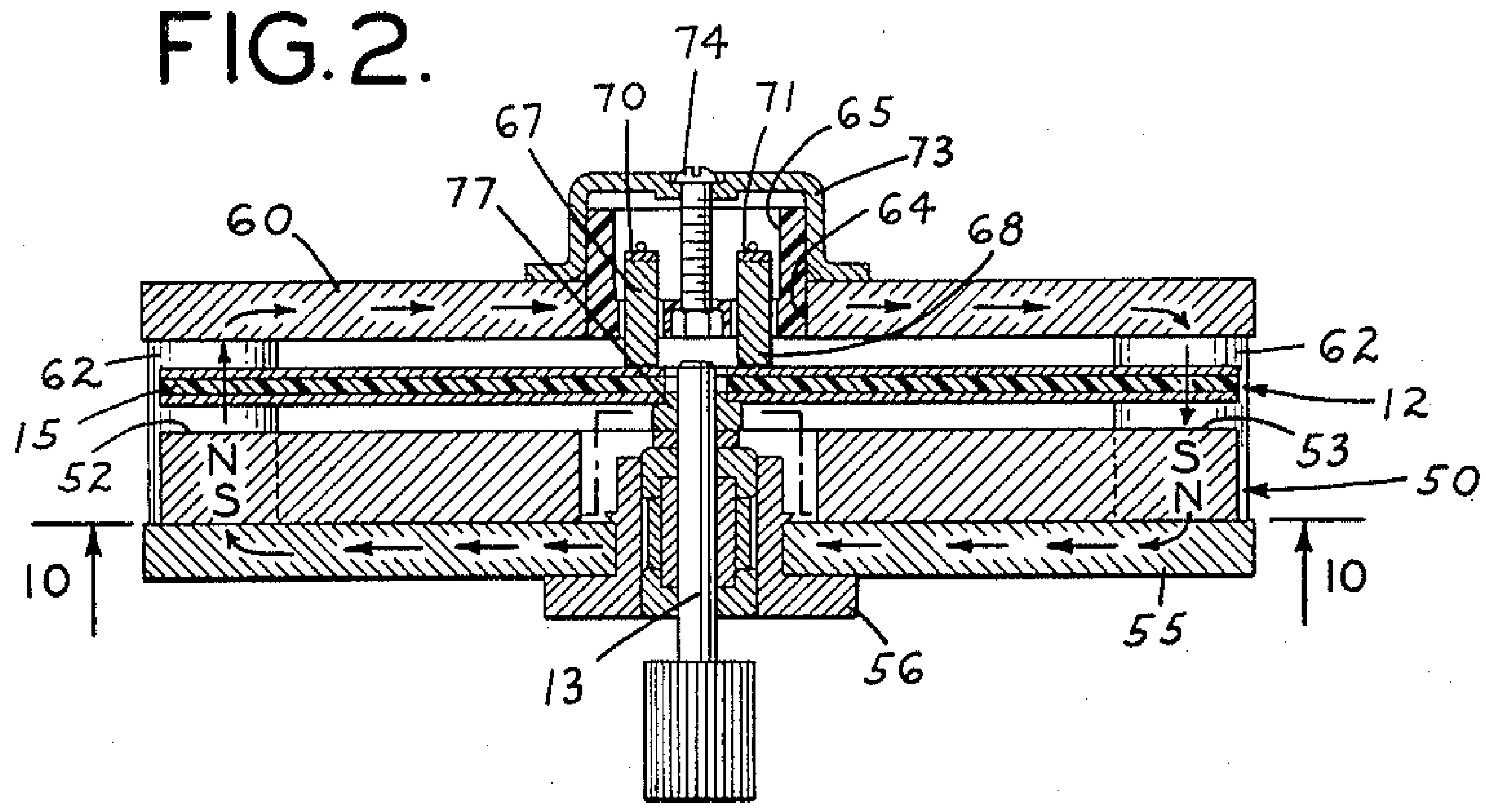
74
67
70
71
65
73
77
64
60
68
62
62
12
15
52
53
50
N
S
S
N
10
10
55
56
13

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FIG. 5.

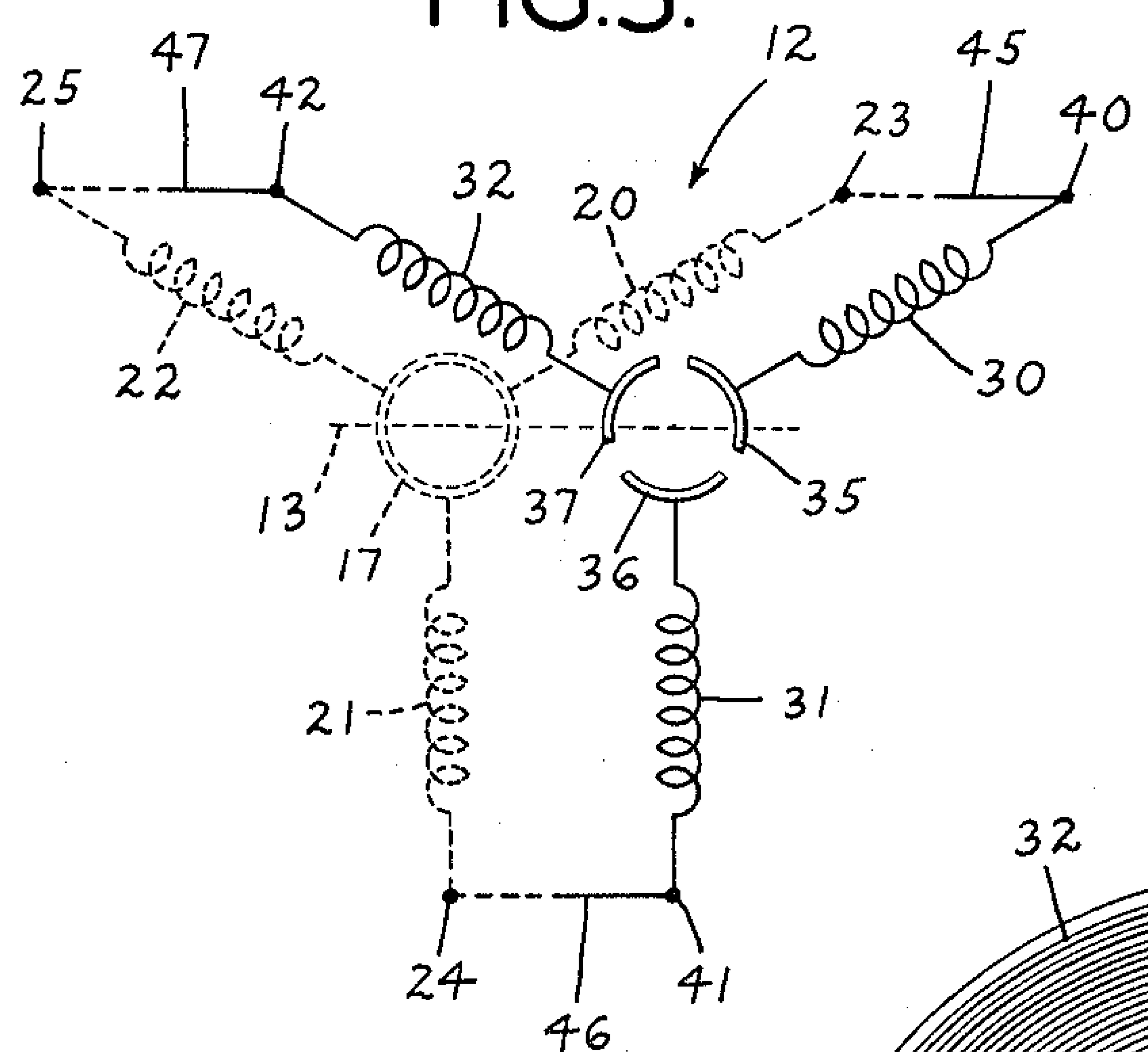
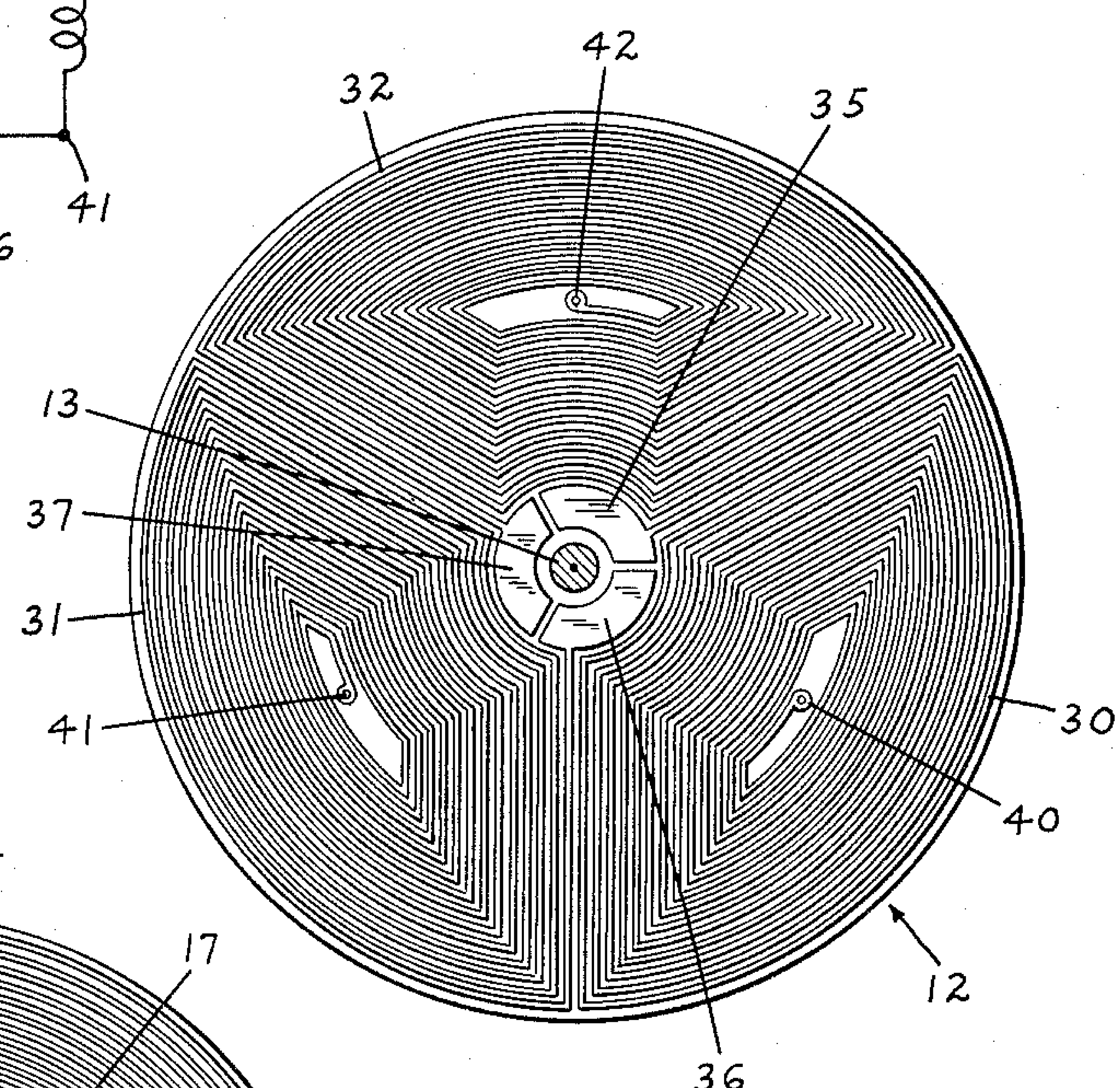


FIG. 3.



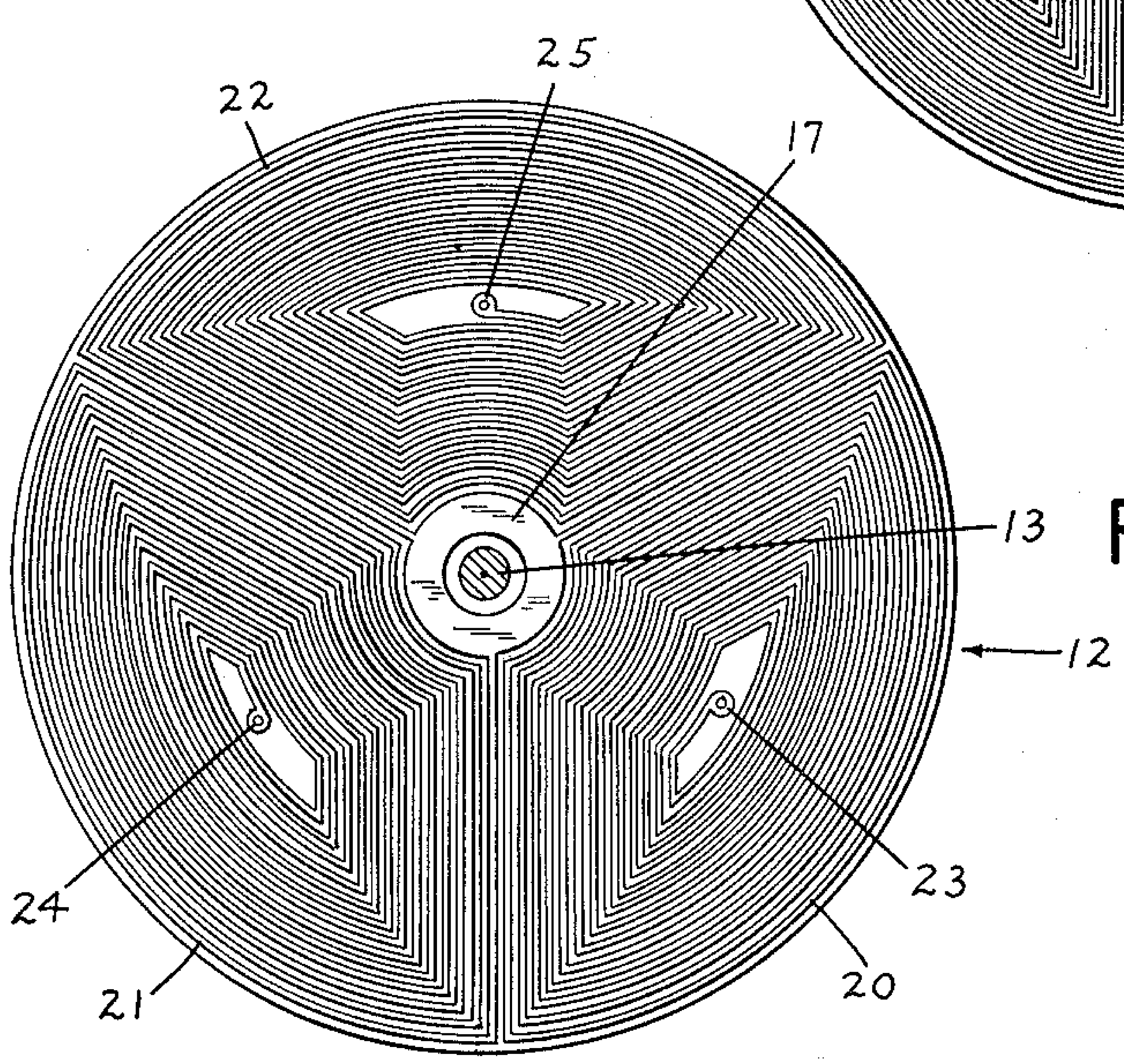


FIG. 4.

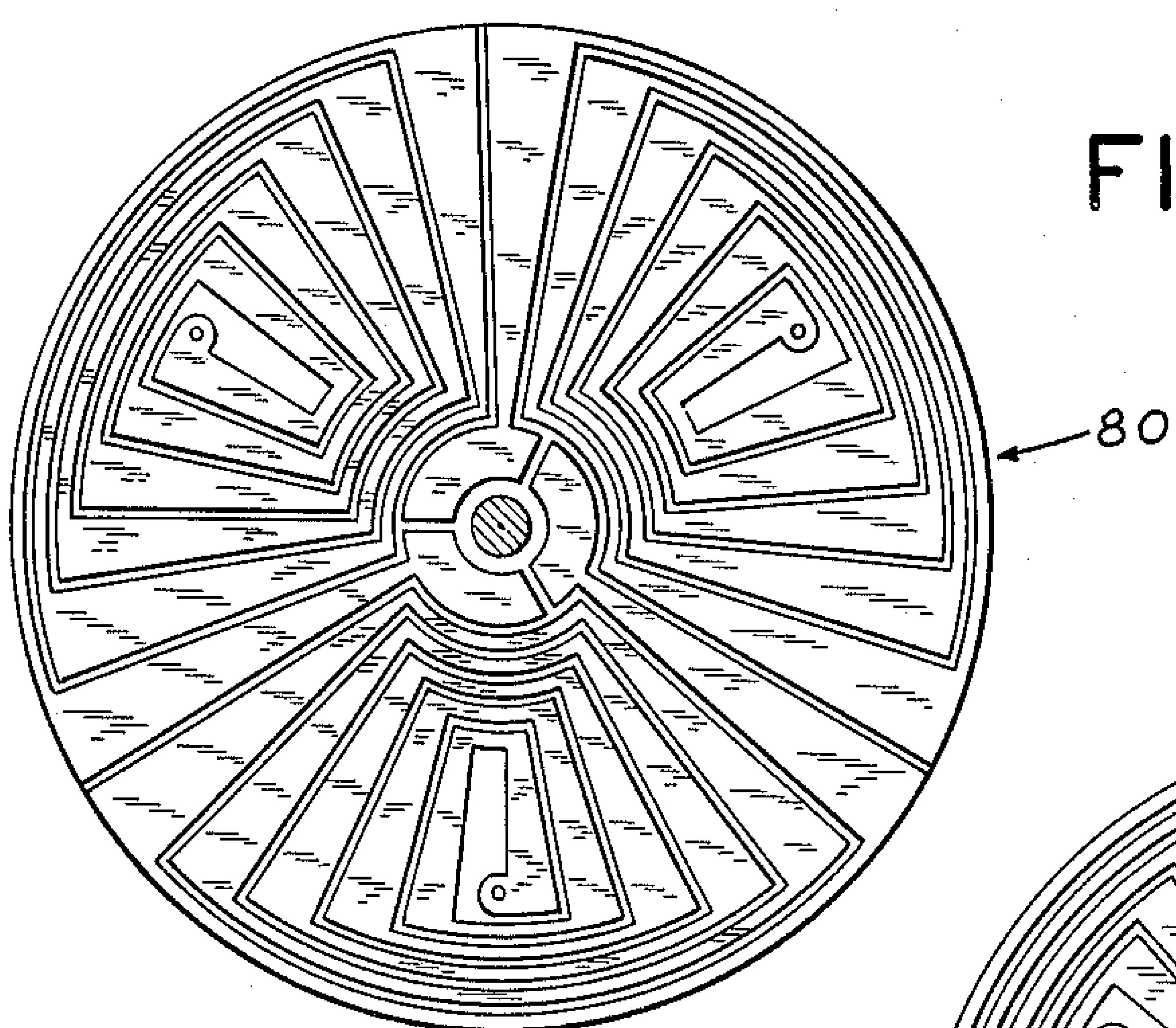


FIG.6.

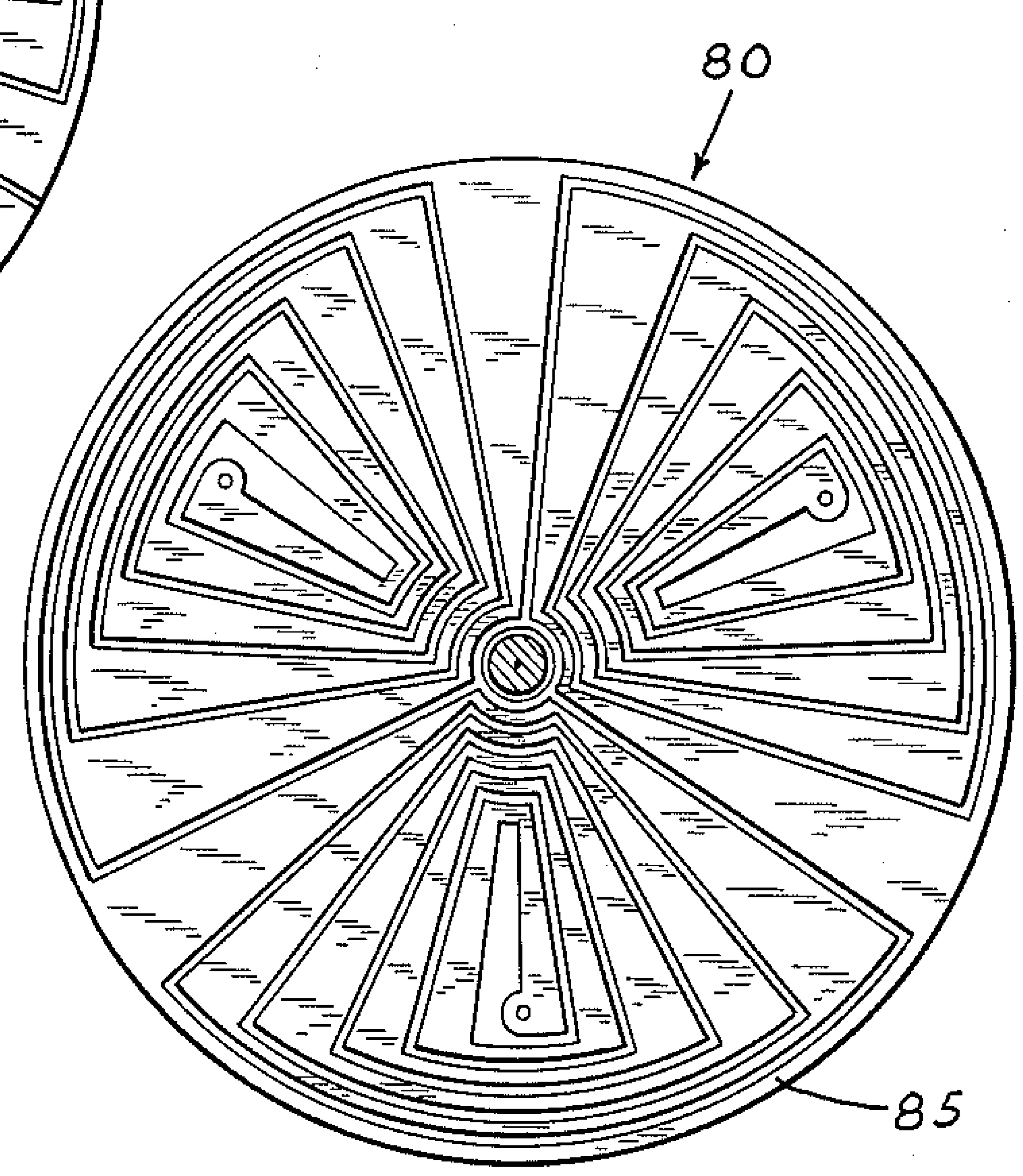


FIG.7.

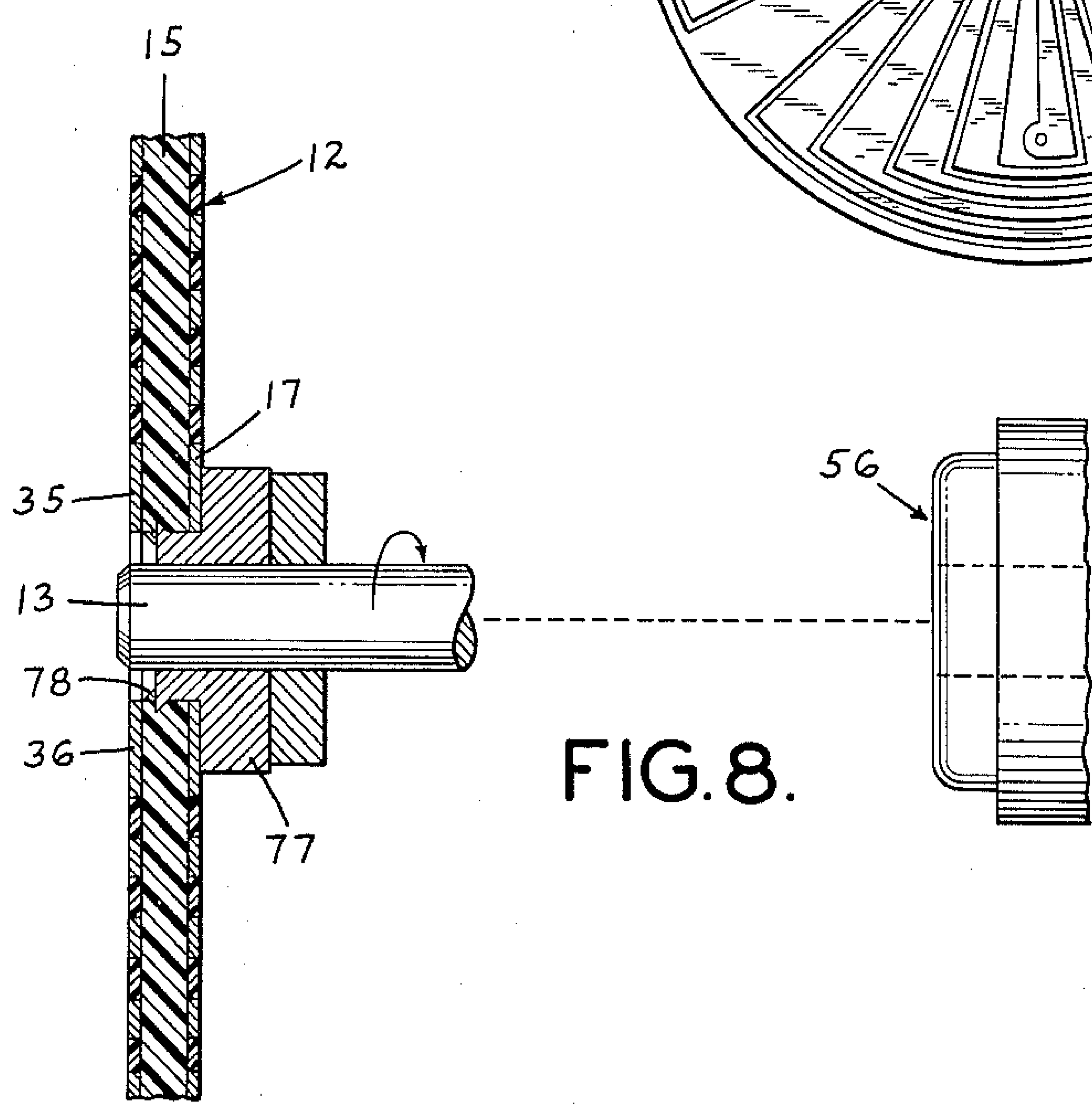


FIG.8.

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FIG. 9.

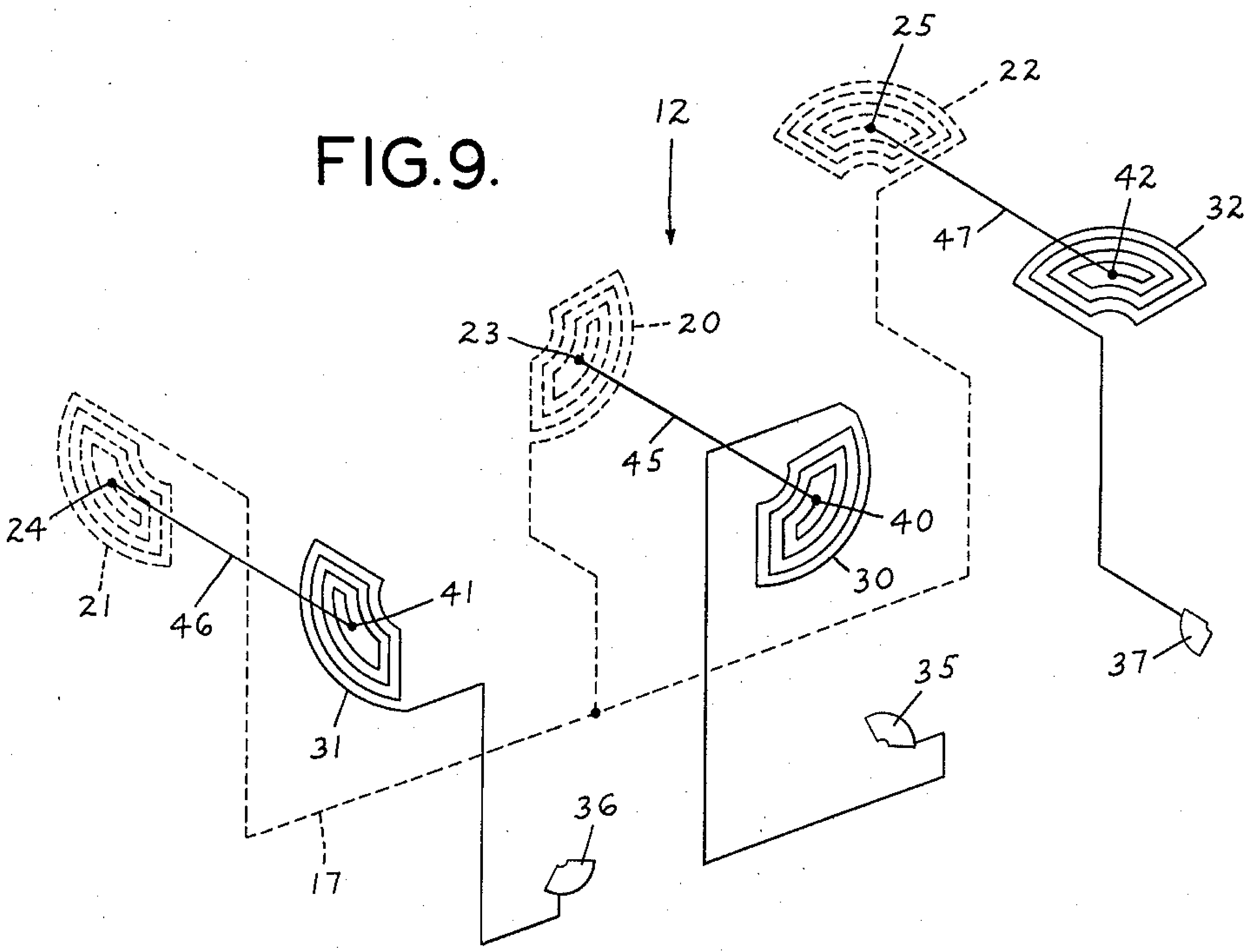
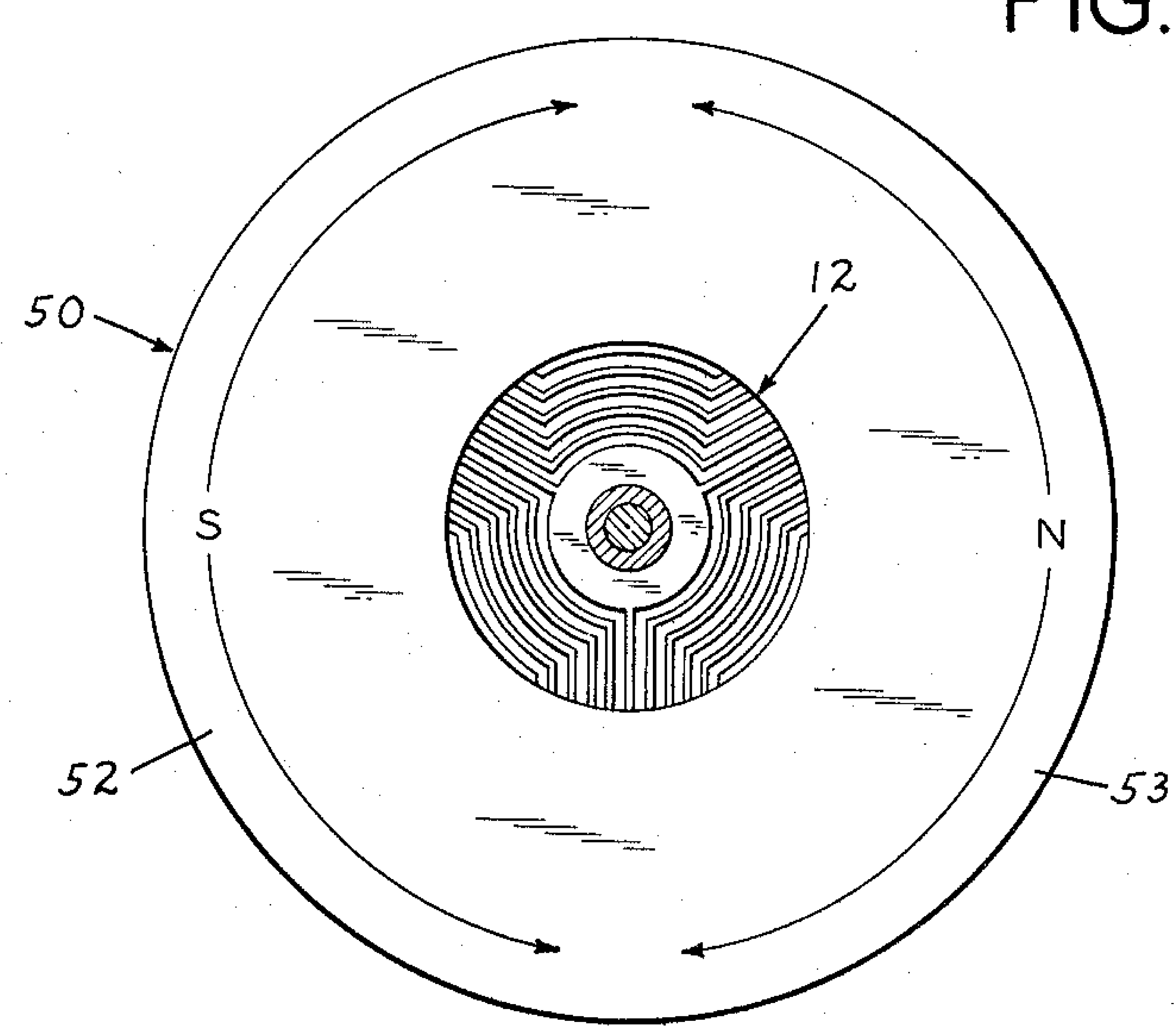


FIG. 10.



3,239,705

ELECTRIC ROTATING MACHINE

Richard J. Kavanaugh, Bristol, Conn., assignor, by mesne assignments, to Tri-Tech, Inc., a corporation of Connecticut

Filed July 13, 1961, Ser. No. 123,780
5 Claims. (Cl. 310—268)

This invention relates to electric rotating machines, and is particularly applicable to D.C. motors having a disc type rotor.

The invention is especially useful in small D.C. motors having a disc-shaped rotor, with conductors formed on each face of the disc, from a layer of conductive material, for example, copper. Such conductors may be formed by several techniques, especially printed circuit techniques. Thus, for example, they may be formed by silk-screen or lithographic techniques, photo-resist or other photographic techniques, in preparation for various forms of etching, plating, or by engraving or stamping.

In certain prior printed circuit rotors, there have been provided a supporting disc of insulating material having on its two surfaces printed circuit conductors, with connections from one surface of the disc to the other, so as to form composite windings distributed on the two surfaces of the disc. In some proposals, there have been a large number of such connections, running into the hundreds. Other proposals have employed several spiral windings on each surface, and, for each such spiral winding, two surface-to-surface interconnections.

Large numbers of such interconnections are undesirable for numerous reasons, including the expense of manufacturing them, and the fact that they tend to reduce the area of the disc available for torque-producing conductors. Also, the greater the number of series-connected interconnections, the more likelihood there is that a given rotor will have a defect; hence the rejection rate and inspection cost tends to be high.

One problem, which is of particular importance in printed circuit motors of the type having the rotor conductors lying substantially in the two planes corresponding to the two surfaces of the disc, is that it is difficult to provide, from a given layer of conductive material, a total length of conductors as great as is desired. This may be better understood when it is realized that, in other types of rotors employing conductors of insulated wire, wound into a coil, many layers of conductors could be superimposed, without difficulties of one turn shorting another turn. In certain embodiments of printed circuit rotors, however, there may be in effect, only two layers of windings, one on each surface of the disc. It may therefore be seen that the limitation to two such layers of windings corresponds to a practical limitation on the total length of the conductors comprising the windings.

In order to gain the advantage of forming the windings from a layer of conductive material by printed circuit techniques and like techniques, one must, as a practical matter, accept a certain limitation on the cross-sectional area of the conductors. In order to produce large torque, it is desirable that the rotor include a large number of turns of its conductors. But practical problems arise when attempts are made to increase the number of turns beyond a certain point, because, the more turns which are obtained from a given sheet of copper, the narrower must be the conductors. And when the width of the conductors is reduced beyond a certain point, it becomes difficult to reduce the width still farther and still form them satisfactorily by such techniques. Moreover, if very narrow conductors are to be formed, by etching, for example, it is not possible to compensate by employing a correspondingly thicker layer of copper. The opposite is

the case. Because the etching tends to have an undercutting action, the usual rule is that, when one reduces the line width, the weight or thickness of the conductive layer must be correspondingly reduced. The resulting reduction in the cross-sectional area of the conductors increases their resistance per unit length and decreases the efficiency of the motor.

Hence, because conductor length is at a premium, it is important to employ designs which use the available area of the disc in the most efficient way.

Another factor is that one important application of printed circuit motors, particularly those of small size, is in portable devices employing relatively low-voltage batteries, in some cases only a single cell. For example, in many of the batteries on the market, the lowest available rated voltage is 1.2 volts. Other common battery voltage ratings are 1.5 volts, 2 volts, 6 volts, 12 volts and 24 volts. It is desirable to provide printed circuit motors having voltage and current requirements which are tailored to the voltage and current provided by commercially available cells or batteries. It is also desirable to provide printed circuit motors which satisfy such voltage and current requirements and which are of small size. A problem heretofore existing in some of the smaller printed circuit motors has been that the voltage required at their input terminals was too low (in some cases lower than even the voltage available from a single cell), and their current requirements were too high, to fit available power supplies.

It is also desirable to provide a printed circuit motor which, for a given input voltage rating, is smaller than those heretofore available.

Another problem is that in prior printed circuit motors there have been certain other factors, related to the commutating action, which have tended to lower the efficiency of the motors. To minimize the tendency for the commutator brushes to produce undesired bridging of one commutator segment to the next, the brushes have been made relatively narrow; but, with typical rotor designs heretofore existing, large currents through the relatively narow brushes have produced high current density in the brushes, causing rapid erosion of the brushes and the commutators, and lowering torque.

In motors having disc type rotors bearing printed circuit commutators as well as the windings on a surface of the disc, the size of the commutators and brushes should be kept to a minimum in order to provide as much usable space as possible for working conductors, as well as to reduce friction. This interrelationship between brush and commutator size and conductor length differs from that existing in motors where conventional cylindrical commutators are used because in the latter case the area of the commutator can be increased by increasing its length without affecting the length of the conductors of the rotor.

An advantageous feature of certain embodiments of the present invention is that it provides a printed circuit rotor, for use in small size D.C. motors, which by a combination of factors is designed for operation with a larger applied voltage at its input terminals, and which is more efficient, than prior printed circuit motors of comparable size. A part of this improvement is obtained by a configuration which enables a larger proportion of the surfaces of the rotor to be employed usefully. Another source of improvement is that, in certain embodiments, the rotor is so designed that, during operation, current, in passing from an input commutator segment through the motor to an output commutator segment, traverses a larger number of windings than in prior such devices. Thus, in certain embodiments, the current may, in some commutator positions, enter a given commutator segment, traverse a winding on one side of the rotor, pass from surface to surface through the rotor to the opposite side, traverse a first winding on the said oposite side, then a second winding on that side, then return to the first side and traverse still another winding on the first side, making a total of four such windings in all, before it leaves the rotor through the second commutator segment.

By providing greater effective length of working conductors in series, the design of the proposed rotor provides a higher back E.M.F., and thus provides a motor capable of operation at a higher operating voltage, other factors being equal, than prior proposals.

In one embodiment of the invention there is provided, in a D.C. motor, a disc-shaped rotor including printed circuit windings on its opposite surfaces, and these windings may be arranged in pairs, members of a pair being disposed on opposite faces of the disc. There is also provided a commutator connected to the winding or windings on one face only of the disc, and it is possible, as described herein, to reduce the number of interconnections between the two surfaces of the disc so that the number of such interconnections equals the number of pairs of oppositely disposed windings.

In a principal embodiment of the invention, the rotor windings employ a form of Y connection. Thus on, or opposed to, one side of the rotor, there may be provided a ring conductor and a plurality, for example, three, windings having one end of each connected to the ring conductor. The windings may each be in the shape of a continuous planar geometric figure having portions extending radially with respect to said rotor, and spiraling toward a connection point, one within each of said figures. Electrically, the connections on this first side of the disc may be regarded as a Y connection. On the second side of the disc, there may be provided printed circuit windings arranged generally similarly to those on the first side of the disc, except that, instead of one end of each of the windings being connected to a ring, one end of each is connected to a segment of a commutator, and there is a surface-to-surface connection between the other end of each of these windings and the connection points of the first-mentioned set of windings. With the three winding portions mentioned previously on each side of the rotor, there need be only a total of three surface-to-surface connections. This is fewer than in any prior printed circuit motor, and the reduction of the number of such connections is an advantage of major signficance. The composite arrangement is such that the windings on the second side correspond electrically to an extension of the Y arrangement portions of the windings on the first side, and they are oriented so that their magnetic fields are cumulative.

Supported in a spaced, face-wise relation to the rotor is a permanently magnetized stator magnet, which may be generally in the shape of a cylinder, the diameter of which is greater than its thickness. This stator may comprise at least a pair of permanently magnetized sectors, magnetized in opposite directions, so as to produce flux extending parallel to the axis of the stator and of the rotor.

When direct current is applied to the commutator, it flows through certain windings of the rotor so as to produce a magnetic interaction between the rotor and the stator, to cause rotation.

The stator magnet may comprise a magnetically hard material, for example a ferrite material or other high-coercive force magnetic material. Another consideration is that it is desirable to employ a stator magnet of high reluctance material, for example a ferrite, and to employ in other portions of the stator structure a low reluctance material, for example, cold rolled steel, the net effect being a high reluctance circuit through the stator as a whole.

The motor of the present invention has many important advantages, including low cost, high-efficiency operation from a practical and readily available power supply, fewer interconnections, and minimum tendency to produce arcing during operation.

The foregoing and other objects, features and advantages of the invention will be understood from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings.

FIGURE 1 is a plan view of a D.C. motor constructed in accordance with one illustrative embodiment of the invention, with certain parts broken away and others in section.

FIGURE 2 is a vertical sectional view taken along the line 2—2 in FIGURE 1.

FIGURE 3 is a plan view of one side of a disc type rotor useful in connection with the embodiment of the invention shown in FIGURE 1.

FIGURE 4 is a plan view of the opposite side of the rotor of FIGURE 3.

FIGURE 5 is a schematic perspective view of the arrangement of the electrical circuitry on the rotor of FIGURE 3, the rotor disc being omitted in FIGURE 5 for purposes of clarity.

FIGURE 6 is a plan view of one side of a disc type rotor constructed in accordance with another illustrative embodiment of the invention.

FIGURE 7 is a plan view of the opposite side of the rotor of FIGURE 6.

FIGURE 8 is a fragmentary exploded view, partially in section, of certain portions of the motor shown in FIGURE 1.

FIGURE 9 is a distorted straight-line perspective view showing the arrangement of commutator segments and windings on the rotor of FIGURE 3, the rotor disc being omitted in FIGURE 9 for purposes of clarity.

FIGURE 10 is a sectional view, with certain parts omitted, taken generally along the lines **10—10** in FIGURE 2.

Referring initially to FIGURES 1–5 of the drawings, there is shown a D.C. motor having a thin, wafer-like rotor **12** mounted at one end of a shaft **13**. The rotor includes a supporting disc **15** which is fabricated from a dielectric material of low permeability, such as epoxy glass, for example.

The disc **15** is provided with electrical circuitry on each side thereof formed by printed circuit techniques. This circuitry includes three pairs of rotor windings connected in Y. Thus, one side of the disc (the side shown in FIGURE 4) includes a printed ring conductor **17**, surrounding and in close proximity to the shaft **13**, and three printed circuit windings **20**, **21** and **22** having one end of each connected to the conductor **17**. These windings spiral inwardly toward connection points **23**, **24** and **25**, respectively.

On the opposite (FIGURE 3) side of the disc **15**, there are provided three printed circuit windings **30**, **31** and **32** which in general are arranged in a manner similar to the windings **20**, **21** and **22**, but are respectively connected to three commutator segments **35**, **36** and **37**. The windings **30**, **31** and **32** are substantially superimposed over the windings **20**, **21** and **22** and spiral inwardly in the same rotational directions toward connection points **40**, **41** and **42**.

The connection points **23** and **40** for the opposed windings **20** and **30** are electrically interconnected by a conductive link **45** (FIGURES 5 and 9) which extends directly through the insulating disc **15** at a point intermediate the center of the disc and the disc periphery. Similarly spaced conductive links **46** and **47** serve to connect the connection points **24** and **41** for the opposed windings **21** and **31** and the connection points **25** and **42** for the opposed windings **22** and **32**, respectively.

With this arrangement, a separate electrically conductive path may be traced from the ring conductor **17** through a pair of windings on the rotor to each of the commutators segments **35**, **36** and **37**. One of these paths extends from the ring conductor through the winding **20** to the connection point **23** on one side of the disc, along the link **45** to the connection point **40** on the opposite side of the disc, and then through the winding **30** to the segment **35**. A second path may be traced from the ring conductor, through the winding **21** to the connection point **24**, along the link **46** to the connection point **41** on the opposite side of the disc and through the winding **31** to the segment **36**. The third path extends from the ring conductor through the winding **22**, the connection point **25**, the link **47**, the connection point **42**, and the winding **32** to the segment **37**.

The windings and surface to surface links on the rotor disc **15** are thus arranged so that a single link is provided for each opposed pair of windings.

Each of the windings is in the form of a continuous, planar geometric figure, the windings **20**, **21** and **22** lying in a single flat plane on one face of the disc **15** and the windings **30**, **31** and **32** lying in a single flat plane on the opposite disc face. The windings are each of substantially triangular configuration, with portions thereof extending radially with respect to the rotor. Thus, the shape of each winding approximates an inwardly spiraling isosceles triangle, with the sides extending in a radial direction from the center portion of the disc and the base extending along an arcuate path parallel to the disc periphery. The arrangement is such that, consistent with proper utilization of the available space on the disc surfaces, a considerable portion of each winding extends radially with respect to the rotor, for purposes that will become more fully apparent hereafter.

The particular winding configuration, together with the use of a single interconnecting link for each pair of windings, enables the provision of a maximum number of turns for a given size rotor.

Coaxially mounted in spaced, juxtaposed relationship with the side of the rotor **12** including the ring conductor **17** is a permanently magnetized stator **50** (FIGURES 2 and 10). The stator is of annular configuration and has an outside diameter that is substantially equal to the diameter of the rotor. The thickness of the stator, while greater than that of the rotor, is considerably less than the stator diameter.

The stator magnet **50** comprises a ferrite material having high coercivity and low permeability. One material which is satisfactory for this purpose is barium ferrite, $BaFe_{12}O_{19}$, available commercially under the trade name "Magnadure" from the Ferroxcube Corporation of America. This material is magnetically "hard" and has a high coercivity which is around 1600 oersteds. The permeability of the material is low and approximates that of air.

As best shown in FIGURE 10, the stator magnet comprises a pair of permanently magnetized sectors or regions **52** and **53** which produce magnetic flux extending in a direction parallel to the common axis of the stator and the rotor. These sectors are magnetized in opposite directions, one being of north (N) polarity and the other of south (S) polarity. The magnet material, having high coercivity, enables the orientation of the oppositely poled regions **52** and **53** in close proximity with each other. In the embodiment illustrated in FIGURE 10, each region advantageously extends through an arc of substantially one hundred eighty degrees of the magnet periphery, as indicated schematically in this figure by the arrows leading from the N and S poles. In other good arrangements, the magnetized regions may be spaced farther apart from each other and may describe a lesser arc, for example, one hundred twenty degrees. Also, in some embodiments the stator magnet need not be ring shaped, but illustratively may be in the form of two spaced-apart, oppositely magnetized sectors, each one hundred and twenty degrees wide, for example.

The stator magnet **50** is supported on a substantially square mounting plate **55** (FIGURE 2), of a magnetically soft material such as cold rolled steel, for example, which is provided with an axially disposed bearing assembly **56** through which extends the rotor shaft **13**. A square cover plate **60**, also of magnetically soft material, is maintained in spaced relationship with the plate **55**, as by corner posts **62**, and is spaced from the rotor **12** on the side thereof opposite that adjacent the stator **50**.

The plate **60** is provided with an elongated opening **64** therein which extends outwardly from immediately adjacent the commutator segments **35**, **36** and **37** on the rotor to one edge of the plate. An insulating member **65** is suitably supported within the opening **64** and accommodates two elongated brushes **67** and **68** which are oriented in directions parallel to the motor shaft **13**. These brushes are carried by leaf springs **70** and **71**, respectively, which serve to bias the brushes into engagement with certain of the commutator segments **35**, **36** and **37**. A housing member **73** partially encloses the brushes and their leaf springs and is secured to the member **65** by a machine screw **74**.

The brushes **67** and **68** are electrically connected to a battery (not shown) or other direct current source by conductors **75** and **76**. In the embodiment illustrated in FIGURE 2, the cross-sectional area of each brush is relatively large, and the brush width is substantially greater than the spacing between adjacent commutator segments. With this arrangement, the current density in the brushes for a given size battery is comparatively small, thereby minimizing the deleterious effects of brush erosion, arcing, etc.

The magnetic flux from the permanently magnetized stator magnet **50** follows a path of relatively high reluctance which may be traced from the stator sector **52**, across the air gap between the magnet **50** and the rotor **12**, through the adjacent portion of the rotor and across the air gap between the rotor and the cover plate **60** to the cover plate **55**. The flux path continues along the cover plate to a position adjacent the oppositely magnetized stator sector **53**, across the gap between the cover and the rotor, through the rotor and then across the gap between the rotor and the sector **53** to this latter sector. The flux returns to the sector **52** through the mounting plate **55**.

The axial spacing between the cover plate **60** and the stator magnet **50** is small in comparison with the magnet thickness. (In FIGURE 2, this axial spacing has been exaggerated for purposes of clarity.) As indicated heretofore, the magnet material has a permeability approximately equal to that of air. The total reluctance of the magnetic circuit is substantially equal to the sum of the reluctance of the magnet **50**, a comparatively large quantity, and the reluctance of the air gap between the magnet and the cover plate, a relatively small quantity. Thus, variations in spacing between the stator and the rotor produce an extremely small percentage variation in the total reluctance.

Upon the application of a D.C. voltage across the insulated conductors **75** and **76**, direct current flows from the brushes **67** and **68** through certain of the commutator segments and windings on the rotor **12**, thus producing magnetic flux which is parallel to the common axis of the rotor disc and the stator **50** and hence parallel to the flux produced by the stator. The interaction between the rotor and the stator fields cause rotation. As the rotor picks up speed, it exhibits a tendency to flatten out, thus further reducing the adverse effects of variations in the air gap between the rotor and the stator.

The D.C. current applied to the motor follows a path from the battery to the conductor **75** and the brush **67**. In some commutator positions, the current flows from this brush to one of the commutator segments **35**, **36** or **37** on the rotor and then flows through four of the rotor windings before returning to the battery through another of the commutator segments, the brush **68** and the conductor 76. Thus, during the time the brushes 67 and 68 are respectively in contact with the commutator segments 35 and 36, for example, the current supplied to the commutator segment 35 flows through the winding 30 (FIGURE 5) to the connection point 40 on one side of the rotor disc, along the conductive link 45 to the connection point 23 on the opposite side of the disc, through the winding 20, the ring conductor 17 and the winding 21 to the connection point 24 on this latter disc side, back through the conductive link 46 to the connection point 41 on the first side of the disc and then through the winding 31 to the commutator segment 36 and the brush 68.

The current flowing through the four series-connected windings 30, 20, 21 and 31 interacts with the magnetic field of the stator 50 to produce a high torque for driving the rotor and thereby increase the overall efficiency of the motor. In addition, the greater effective length of the series-connected windings provides a high back E.M.F. and thus enables operation of the motor at an increased applied voltage across the brushes.

As the rotor revolves, the brushes 67 and 68 alternately bridge adjacent pairs of the commutator segments 35, 36 and 37. The current during this bridging action flows from one of the brushes, through a circuit which includes the bridged segments, the associated parallel pairs of the series-connected rotor windings, the third series-connected winding pair and the segment therefore, and then to the other brush. With this arrangement, the overall efficiency of the motor is further increased.

As indicated heretofore, both the rotor and the stator preferably are fabricated from low permeability materials. The comparatively high reluctance of the magnetic circuit reduces self-induction in the rotor windings and thereby minimizes the deleterious effects of arcing, radio frequency interference, etc. During operation of the motor, the circuit for each successive pair of windings is momentarily opened as the commutator segment for these windings moves out of contact with one of the brushes. However, the reduced inductance in the windings serves to minimize the inductive kick which would otherwise occur during these open-circuit conditions. As a result, the rotor windings may be connected in Y, with all the attendant advantages, without the undesirable effects of a high inductive kick.

The current flowing through the radially extending portions of the rotor windings cuts directly across the stator flux passing through the rotor. By providing a substantial number of these radial winding portions, the effective torque on the rotor is further increased.

In certain advantageous embodiments, the rotor 12 is mounted on the shaft 13 in a manner such that the rotor at all times is in accurate dynamic balance. Thus, as best shown in FIGURE 8, a bushing 77 is suitably affixed to the shaft, and the rotor is cemented to a face of this bushing, as at 78. Before the cement hardens, the shaft is rotated at high speed. The centrifugal forces on the rotor serve to orient it perpendicular to the shaft, with the result that, upon operation of the motor, the forces acting on the rotor are uniform and in proper balance.

FIGURES 6 and 7 are illustrative of an alternative rotor 80 useful in connection with the invention. The rotor 80 is in general similar to the rotor 12 described above and includes a supporting disc which is provided with Y connected printed circuit windings arranged in two parallel planes on opposite disc faces. The conductors forming the various windings of the rotor 80, however, are substantially wider than those of the rotor 12. In addition, the windings on the side of rotor 80 opposite that including the commutator segments are interconnected by a ring conductor 85 which extends around the periphery of the disc, rather than adjacent the center portion of the disc. One advantage of the arrangement of FIGURES 4 and 5 is that more space is available adjacent the center of the ring side of the disc for the windings. Hence, for a given size motor, the number of turns for each winding may be reduced.

In the manufacture of the rotors 12 and 80 shown in the drawings, the conductive portions on the two sides of the rotor disc may be formed from a pair of sheets of copper, arranged with one on each side of the disc, separated by insulating material. Thus, the commutators and windings and interconnections on one side are formed from one sheet of copper, and the windings and interconnections on the other side are formed from another sheet of copper.

As has been explained, there are advantages in providing rotor designs which reduce the number of series-connected surface-to-surface interconnections. The rotors described herein make it possible to employ surface-to-surface interconnections in a small number of areas of the rotor. For example, referring to FIGURES 3 and 5, it may be seen that surface-to-surface interconnections are provided in only three small areas in this particular illustrative rotor: namely, the regions of the connection points 40, 41 and 42. Hence, the number of interconnection areas, three, is equal to the number of pairs of opposed windings, three. In some cases there may be advantages in providing, in each of these interconnection areas, more than a single surface-to-surface connecting link. As an illustration, there may be provided, between the connection points 41 and 24, not just a single connecting link 46, but a plurality of such links, for example, three, connected in parallel.

Thus, within the small area enclosed by the generally closed geometric pattern or planar geometric figure of a given winding, there is a single interconnection area which encompasses the only surface-to-surface interconnection or interconnections between the given winding and its opposed winding.

It will be understood that the use of a plurality of parallel connecting links in a given interconnection area is different from the undesirable arrangements referred to previously in which a large number of series-connected interconnections were provided; in the last-mentioned arrangements, a single incomplete connection produces an effective open circuit, because they are all connected in series. On the other hand, if one of several parallel connections is accidentally incomplete, the others serve to maintain a conduction path.

The connecting links may be formed by a variety of techniques. For example, in one satisfactory technique, the rotor disc is provided with a surface-to-surface hole at each point where a link is to be formed, and the hole is plated with copper or other electrically conductive material. The various windings are then formed in the manner outlined heretofore, with the appropriate connection points in contact with the plated holes. In another illustrative technique, each hole in the disc is provided with a copper eyelet, slug, etc., which is soldered at opposite ends to the corresponding connection points on the windings.

Whereas various illustrative embodiments of electric rotating machines constructed and arranged in accordance with the invention have been described with reference to their use as D.C. motors, these and other embodiments may be satisfactorily utilized as generators of electrical potential by mechanically driving the rotor with a prime mover and deriving voltage and current from the conductive leads of the brushes.

The terms and expressions which have been employed are used as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding any equivalents of the features shown and described, or portions thereof, it being recognized that various modifications are possible within the scope of the invention claimed.

What is claimed is:

1. In a D.C. motor, a printed circuit rotor comprising

a disc bearing printed circuit windings conected in Y, including, on a first surface of said disc, at least three printed circuit windings, printed circuit means connecting together one end of each of said windings, and means connecting the other ends of each of said windings to connection points on the second surface of said disc, and including, on said second surface of said disc, at least three windings, one end of each of the windings on said second surface being connected to one of said connection points, a printed circuit commutator, and means connecting the other end of each of said last-mentioned windings to said commutator, the number of the connections through said disc from its two surfaces being equal to the number of windings on each of its surfaces.

2. In a D.C. printed circuit motor, a disc-shaped rotor comprising, on each face of the disc, printed circuit conductors arranged in a plurality of continuous geometric figures, there being one end portion for said conductors within each of said figures, means interconnecting pairs of the said end portions on opposite faces of said disc, the conductors forming each of the said continuous geometric figures having a second end portion, a commutator including segments, said segments being connected respectively to the said second end portions on one face only of said disc, and printed circuit means interconnecting the said second end portions of the conductors on the opposite face of said disc with one another, whereby to form a Y-connected printed circuit rotor having windings distributed on opposite surfaces of said disc.

3. In a D.C. electric rotating machine, a disc-shaped rotor comprising printed circuit cnoductors arranged to form composite winding means distributed on opposite faces of the disc, each of said printed circuit conductors having a first and a second end portion, means intermediate the center and the periphery of said disc for interconnecting pairs of the said first end portions on said opposite disc faces, a commutator connected to the said second end portions of the conductors on one face of said disc, and means including a ring-shaped member interconnecting the said second end portions of the conductors on the opposite face of said disc with one another.

4. In a D.C. printed circuit motor, a disc-shaped rotor comprising, on each face of the disc, printed circuit conductors arranged in a plurality of continuous geometric figures, there being one end portion for said conductors within each of said figures, means interconnecting pairs of the said end portions on opposite faces of said disc, the conductors forming each of the said continuous geometric figures having a second end portion, a commutator including segments, said segments being connected respectively to the said second end portions on one face only of said disc, and means including a printed circuit ring near the center of said disc for interconnecting the said second end portions of the conductors on the opposite face of said disc with one another, whereby to form a Y-connected printed circuit rotor having windings distributed on opposite surfaces of said disc.

5. In a D.C. printed circuit motor, a disc-shaped rotor comprising, on each face of the disc, printed circuit conductors arranged in a plurality of continuous geometric figures, there being one end portion for said conductors within each of said figures, means interconnecting pairs of the said end portions on opposite faces of said disc, the conductors forming each of the said continuous geometric figures having a second end portion, a commutator including segments, said segments being connected respectively to the said second end portions on one face only of said disc, and means including a printed circuit ring near the outer edge of said disc for interconnecting the said second end portions of the conductors on the opposite face of said disc with one another, whereby to form a Y-connected printed circuit rotor having windings distributed on opposite surfaces of said disc.

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