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Donahoo

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[54] **CONCENTRATED WINDING SALIENT-POLE SHADED POLE MOTORS HAVING MULTIPLE SHORT CIRCUITED SHADING COILS FOR EACH POLE**

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[22] Filed: **May 17, 1978**

Related U.S. Patent Documents

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[64] Patent No.: **3,959,678**
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Appl. No.: **293,802**
Filed: **Oct. 2, 1972**

[51] **Int. Cl.**[3] **H02K 17/10**
[52] **U.S. Cl.** **310/172**
[58] **Field of Search** 310/179, 180, 172, 42, 310/51, 211, 214, 216, 218, 166, 184, 40, 187, 186, 254, 259, 258; 318/776

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Attorney, Agent, or Firm—Ralph E. Krisher, Jr.

[57] **ABSTRACT**

Salient-pole shaded pole motors with multiple short circuited shading coils on each pole piece; the pole pieces extending generally radially from the geometric center of the magnetizeable yoke. Pole pieces are interconnected by a magnetic yoke that encompasses the pole pieces as well as rotor. Adjacent pole tips of pole pieces are displaced in space from one another to, among other things, facilitate placement of concentrated winding means about the pole pieces. The leading edges or pole tips of the pole pieces exhibit a relatively high reluctance as compared to the center portion or region of the pole pieces.

18 Claims, 11 Drawing Figures

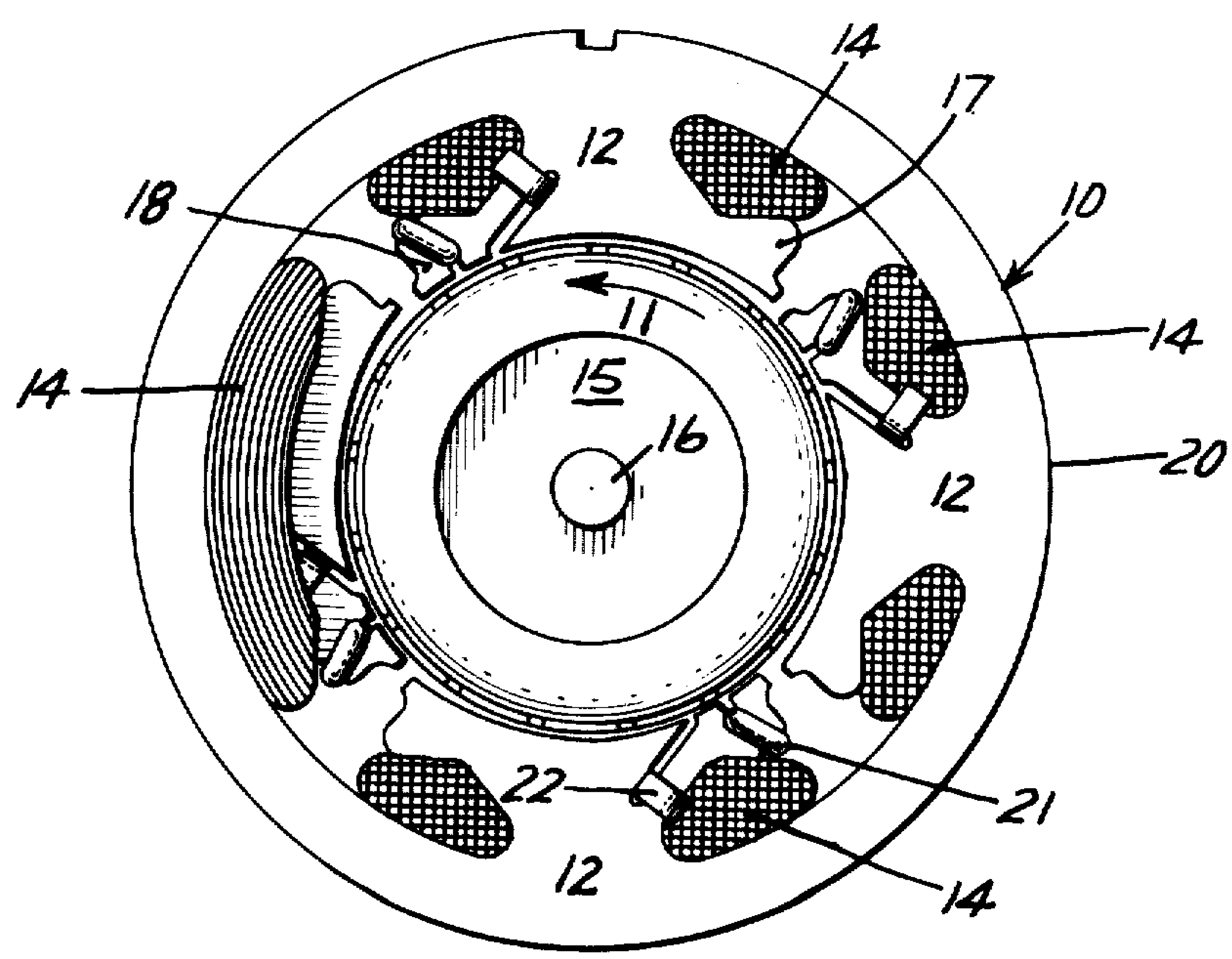


FIG.1

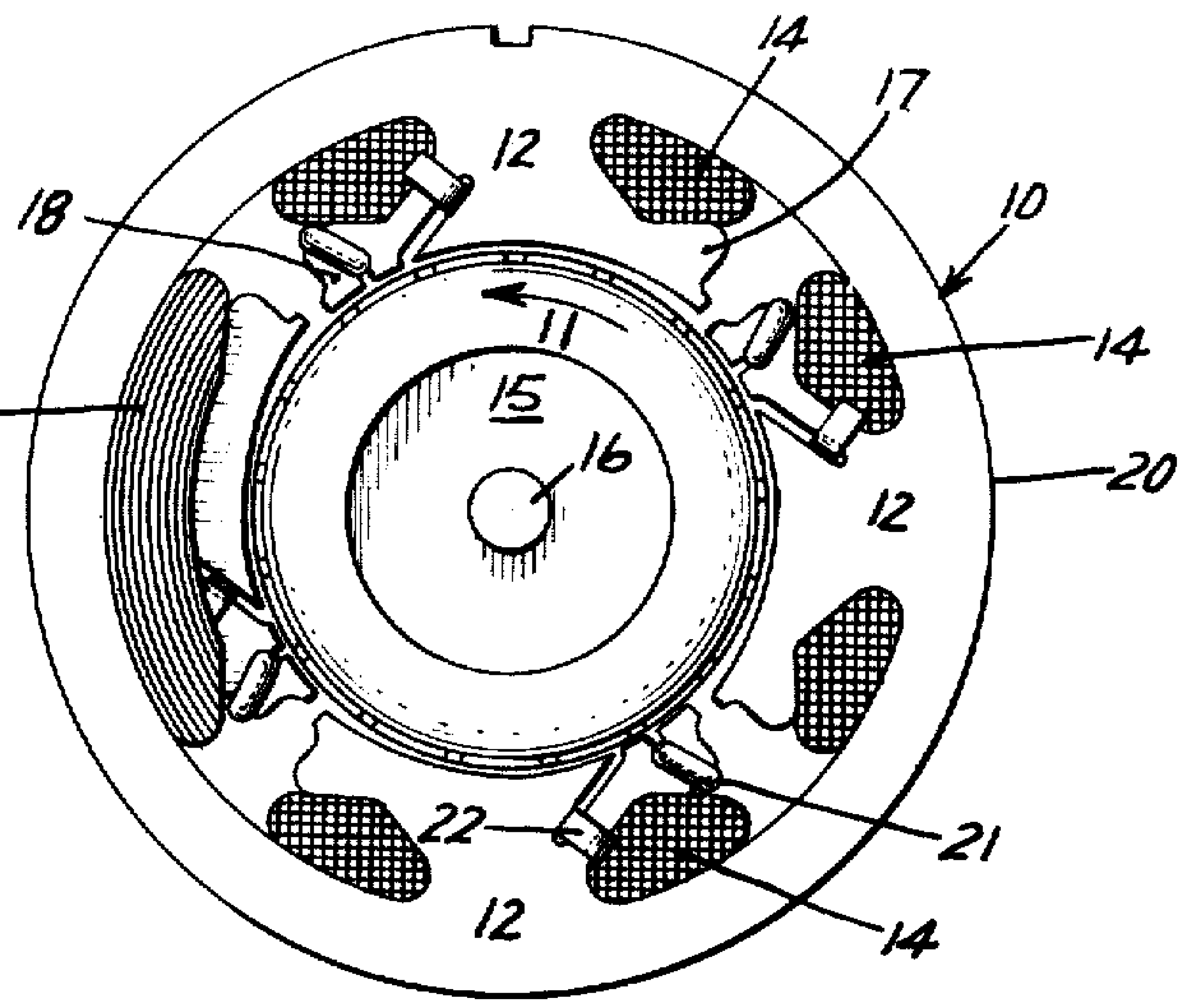
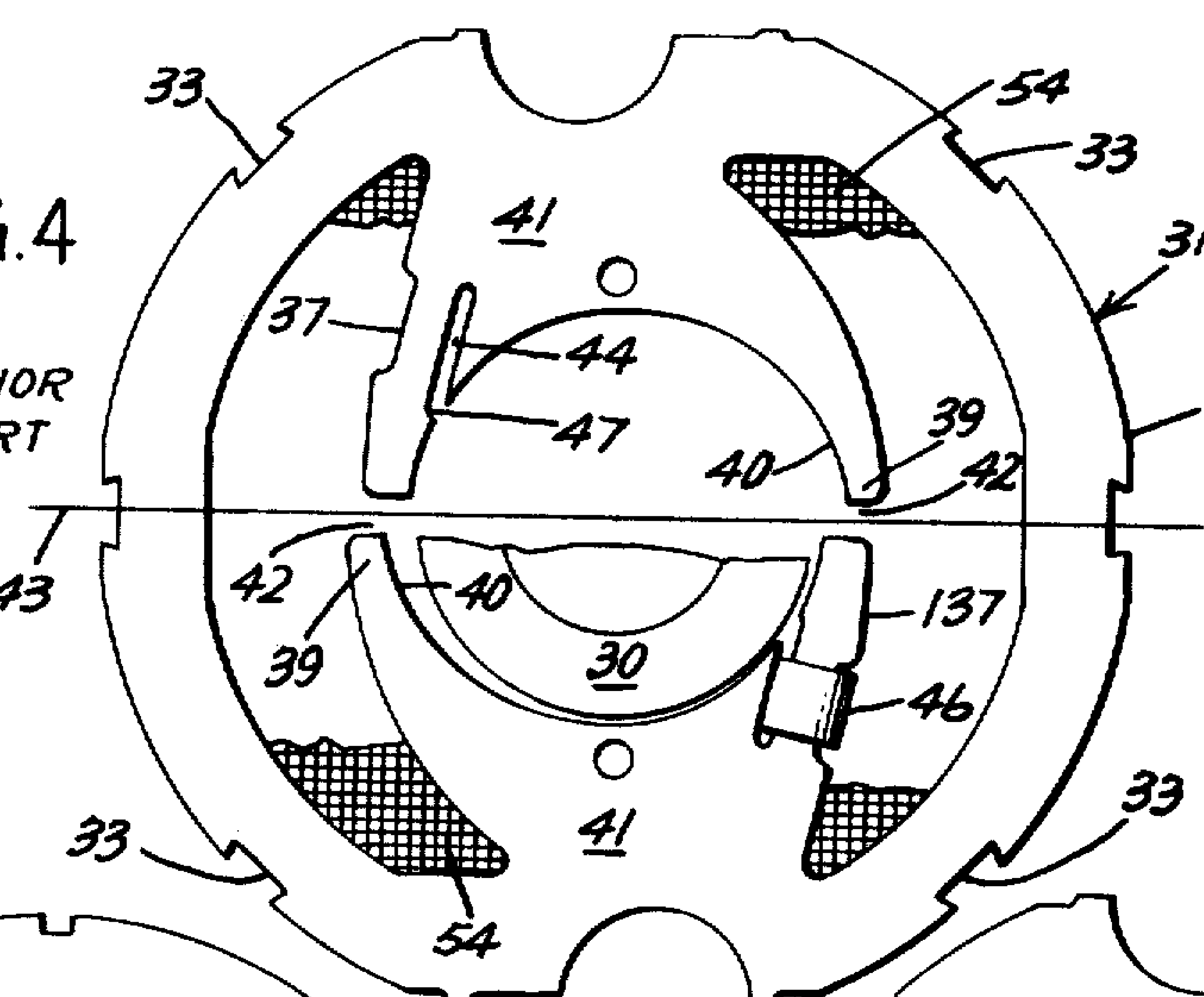


FIG.4



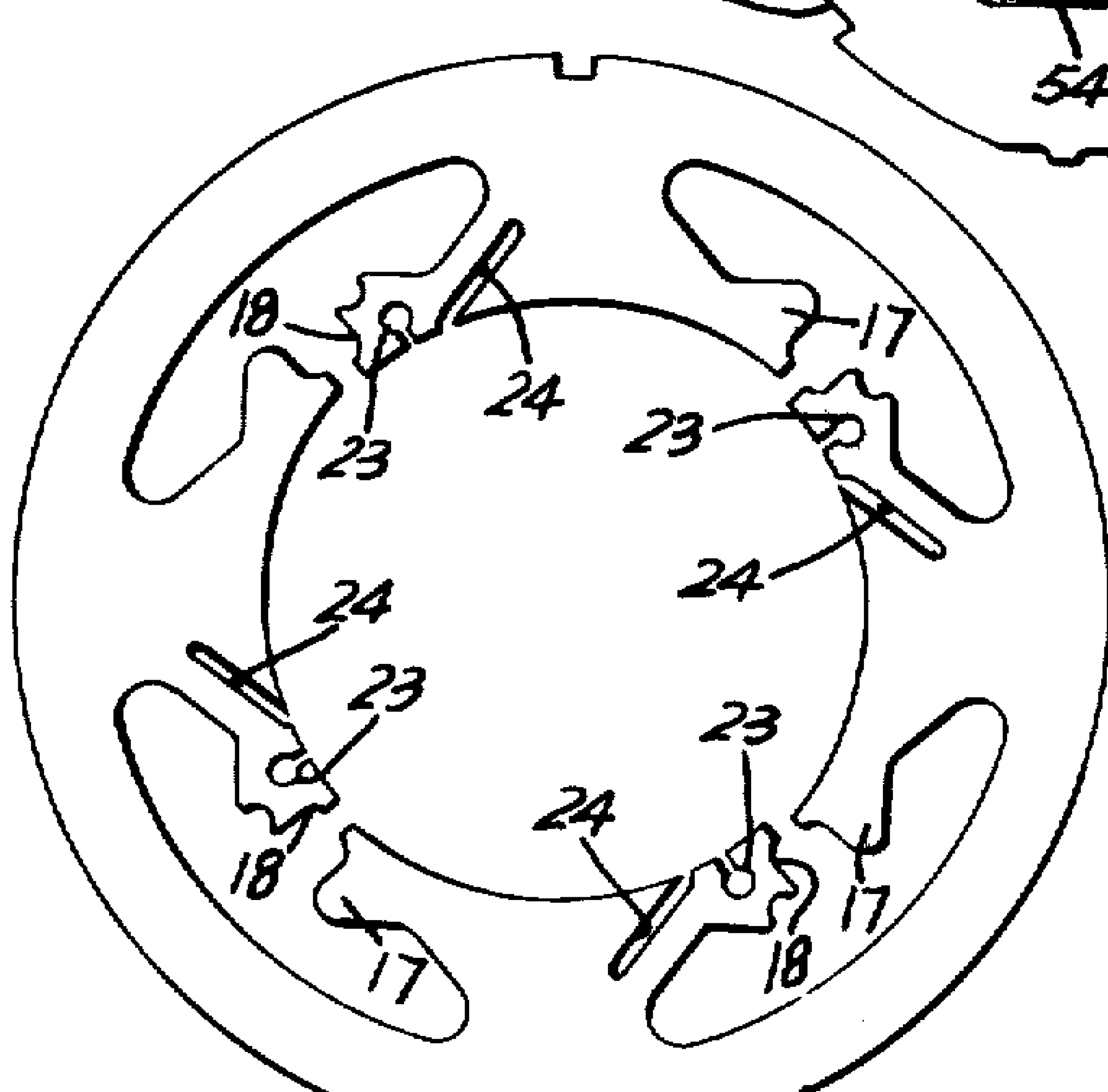


FIG.2

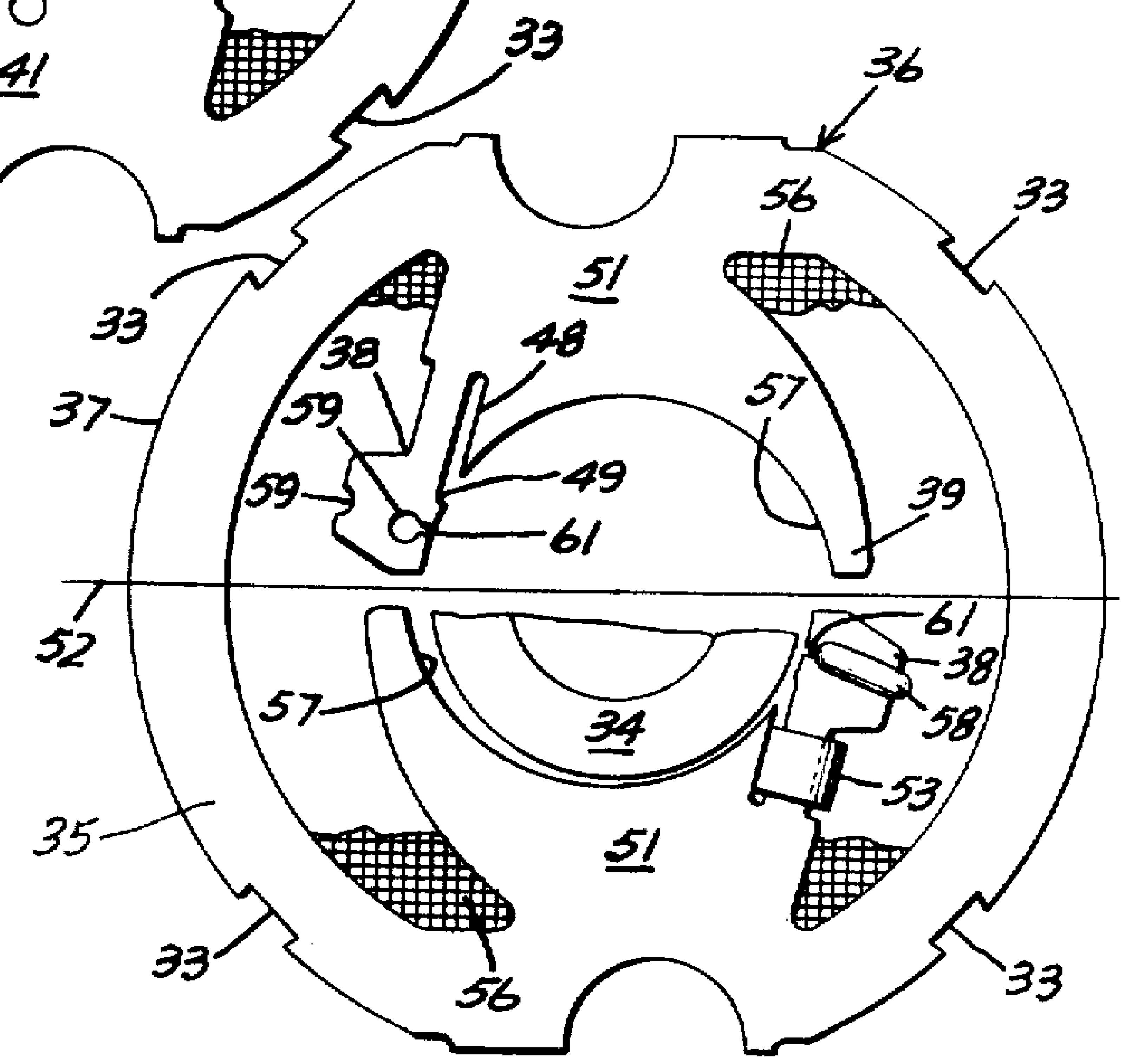


FIG.3

FIG.5

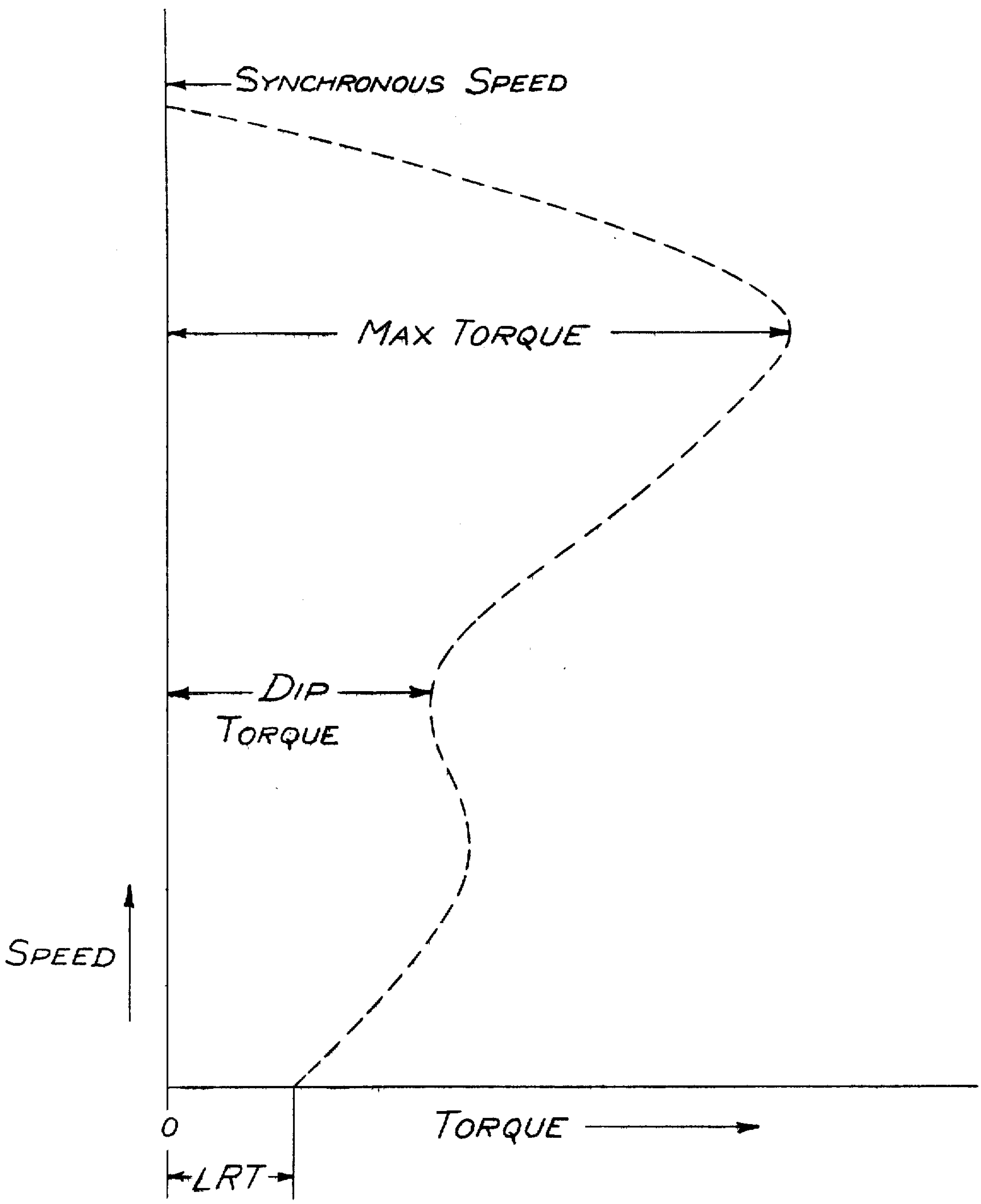


FIG. 6

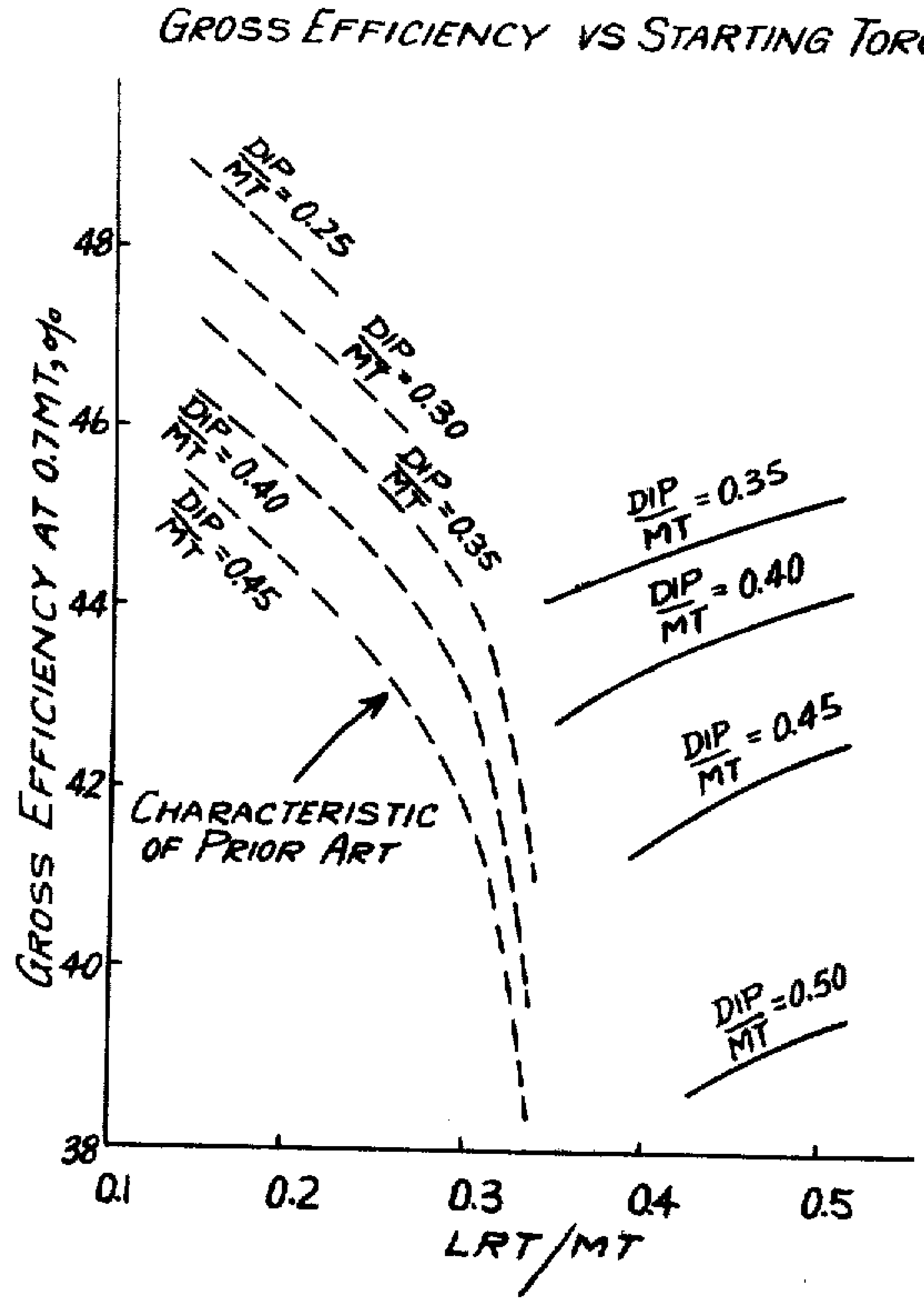


FIG. 7

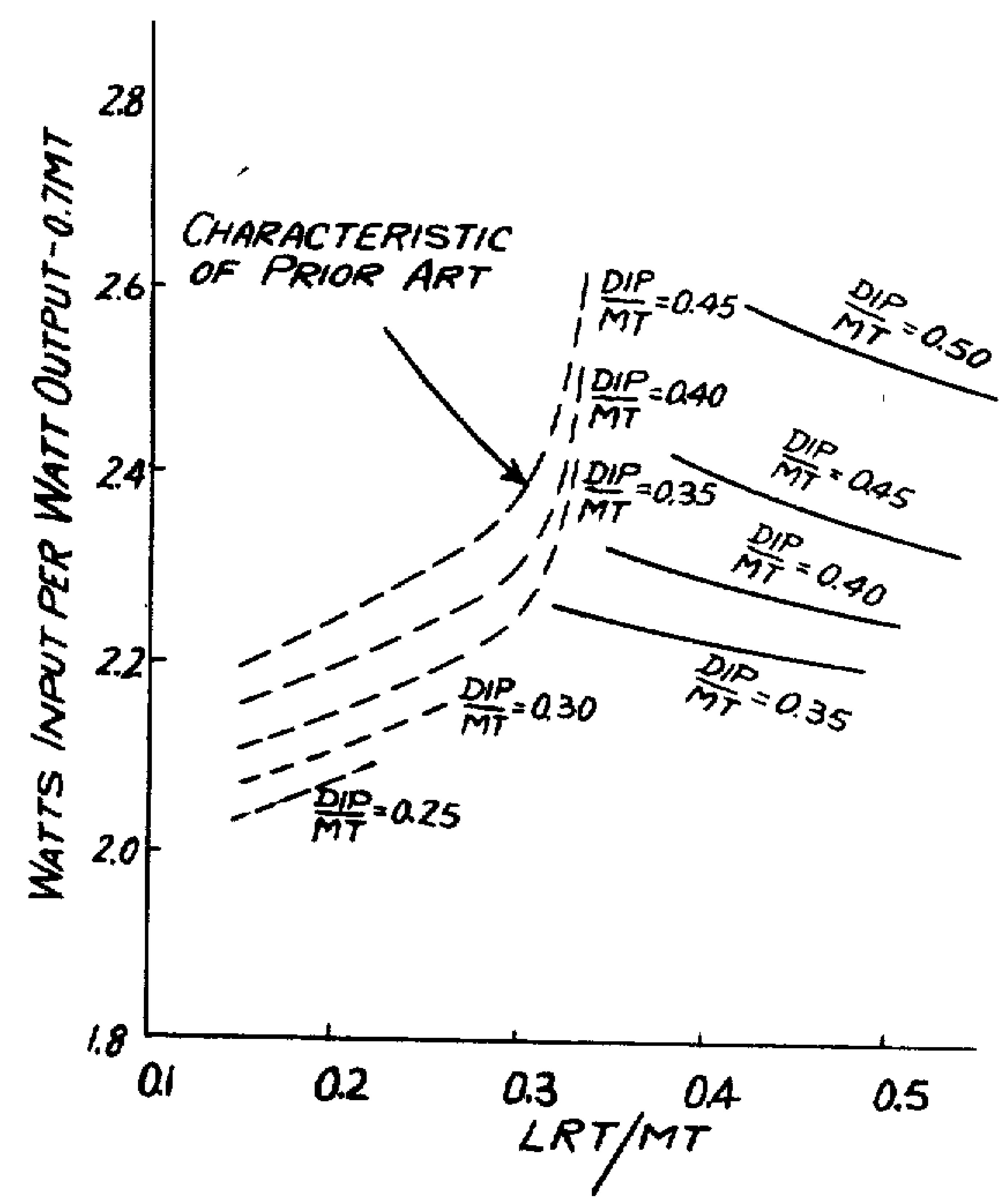


FIG. 8

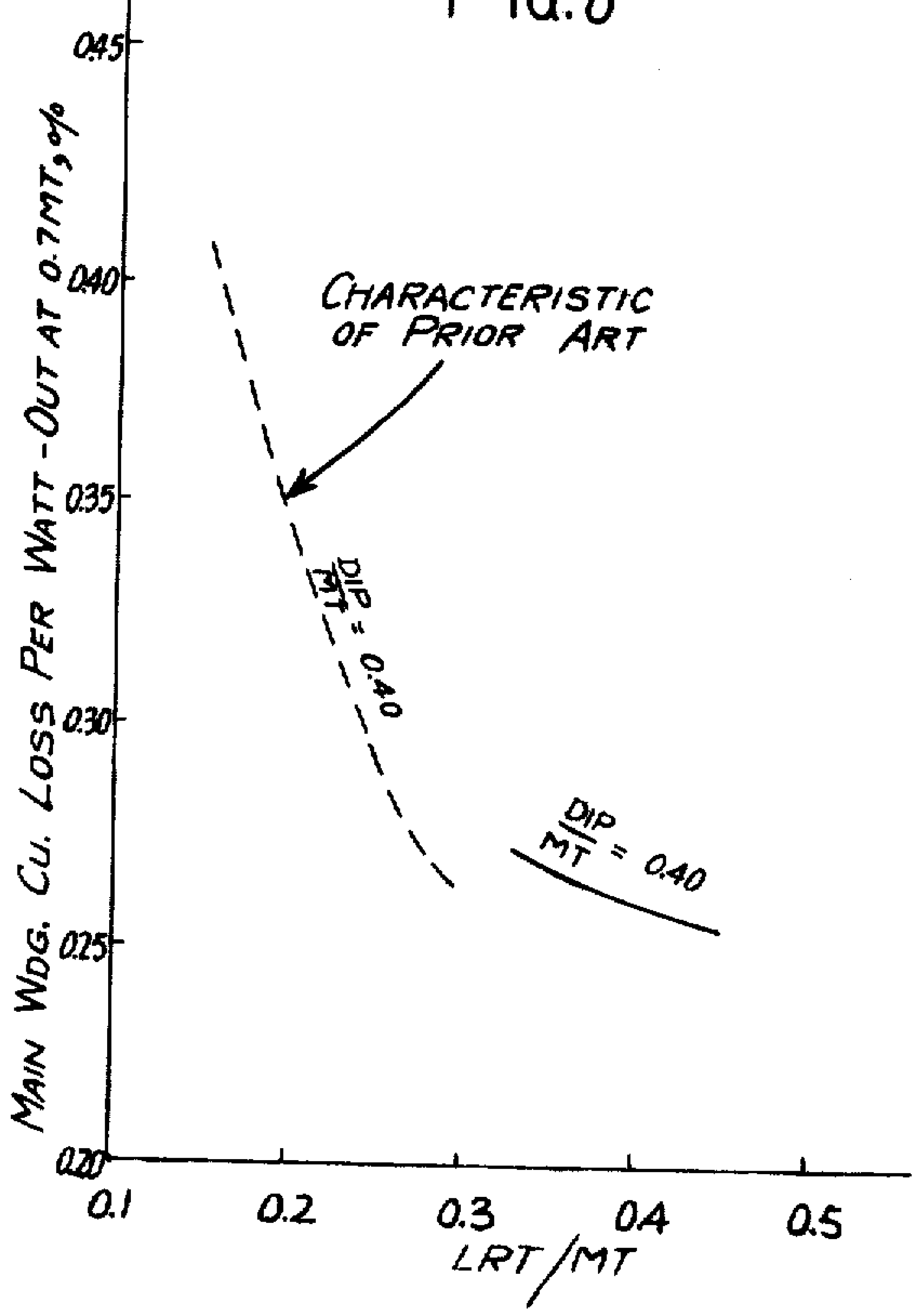


FIG. 9

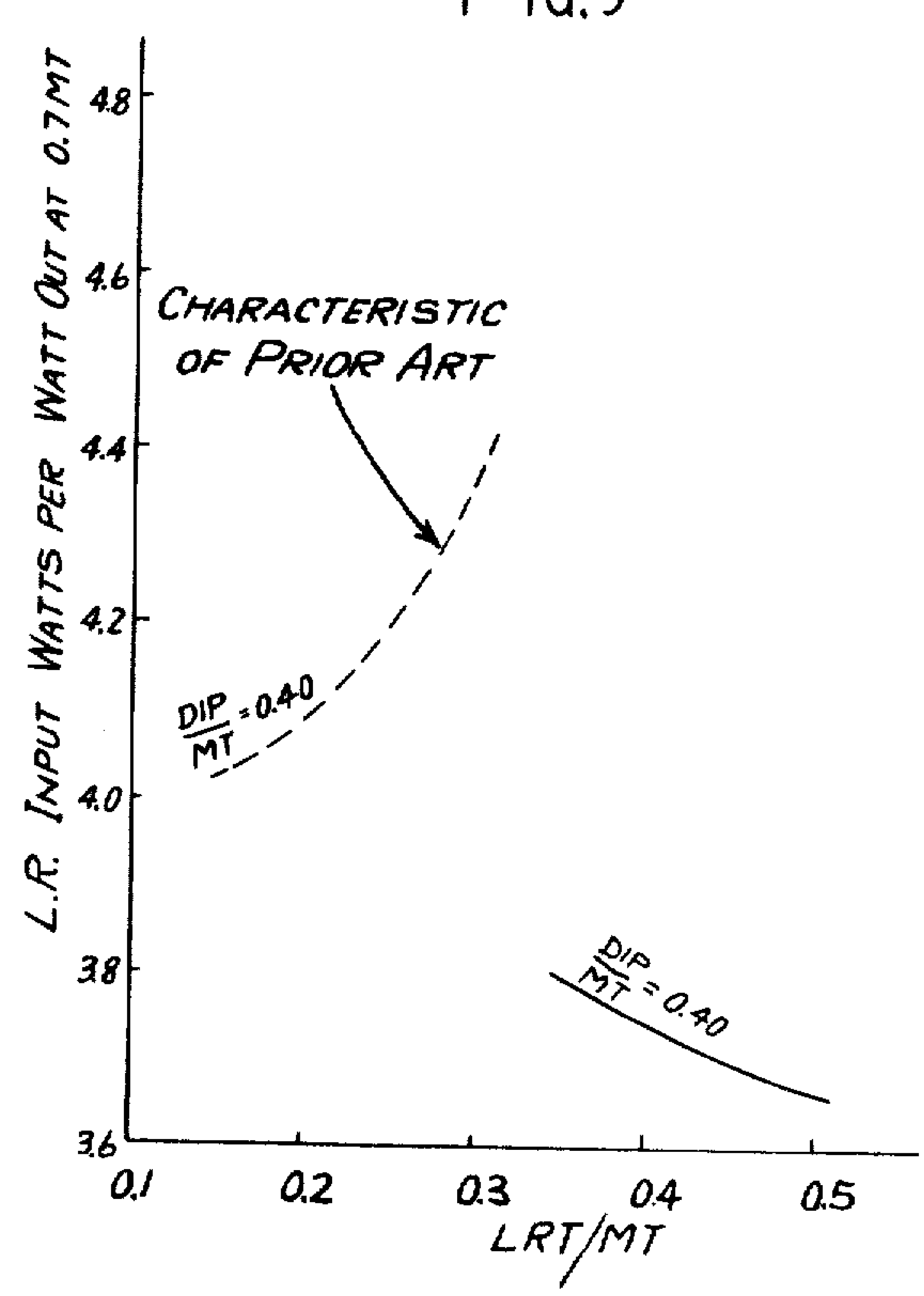


FIG. 10

PRIOR ART

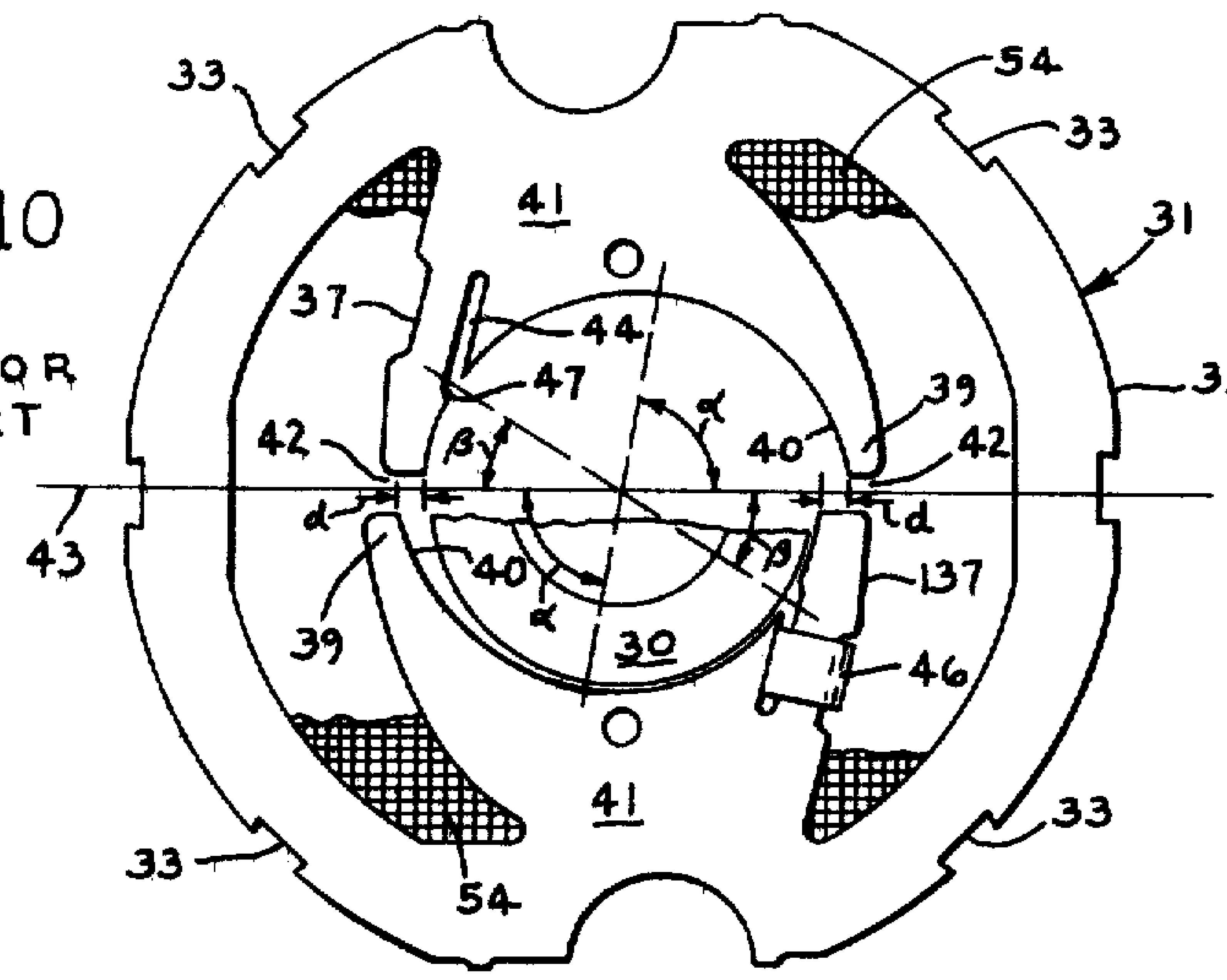
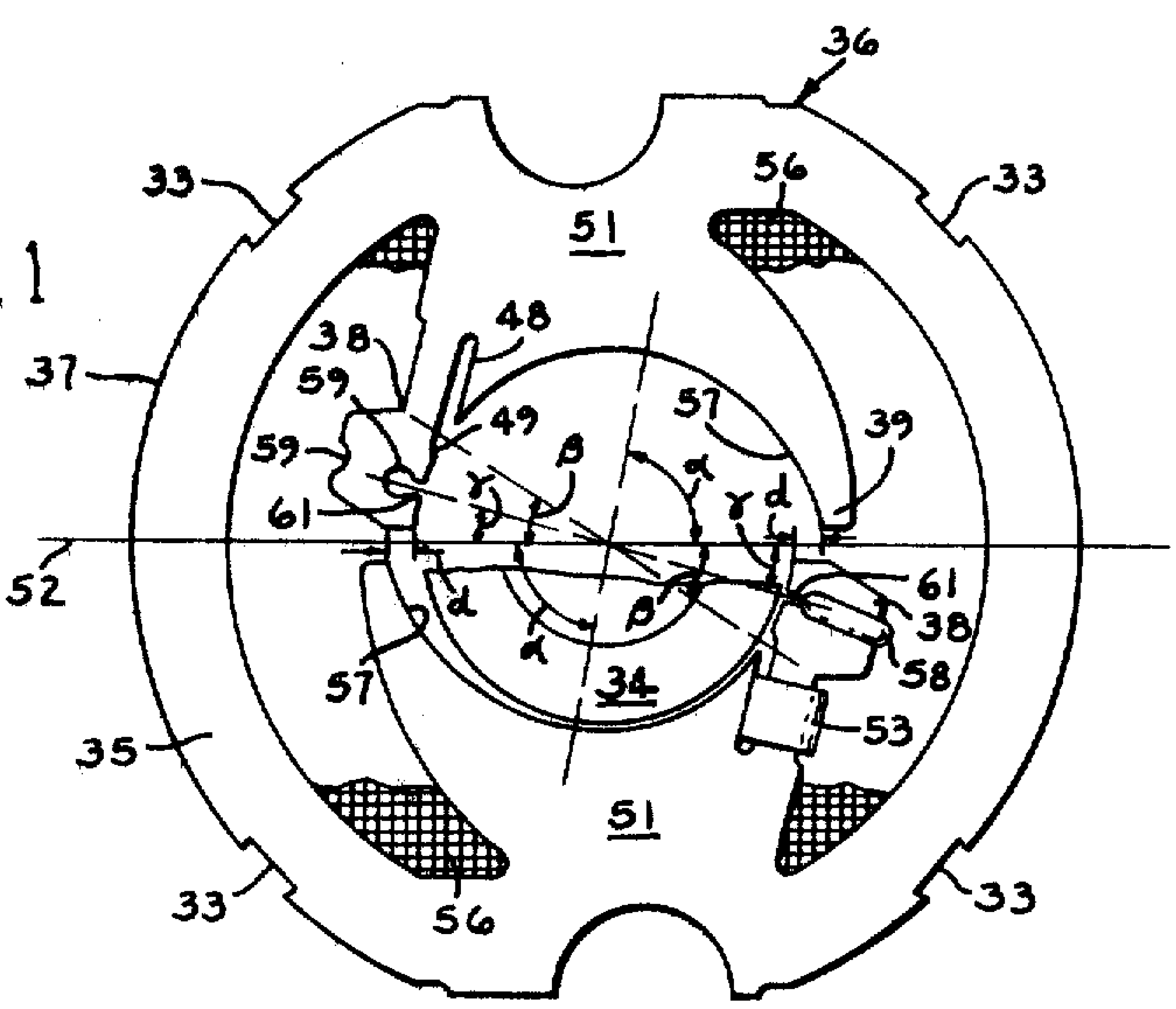


FIG. 11



CONCENTRATED WINDING SALIENT-POLE SHADED POLE MOTORS HAVING MULTIPLE SHORT CIRCUITED SHADING COILS FOR EACH POLE

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.

BACKGROUND OF THE INVENTION

This invention relates to dynamoelectric machines and, more particularly, to salient-pole, shaded pole motors having concentrated windings disposed around circumferentially spaced apart pole pieces that each have a leading pole tip separated by an air gap from the trailing pole tip of the pole piece adjacent thereto.

Shaded pole motors of the concentrated winding, salient-pole variety, are one of the less expensive types of motors to manufacture. Accordingly, this type of motor is usually selected for alternating voltage applications whenever the heretofore known operating characteristics (in terms of starting torque, maximum or break down torque, running torque, dip torque, efficiency, etc.) of this type of motor will meet the needs of an intended application.

If one or more operating characteristics of this type of motor is not satisfactory for a given application, however, distributed wound motors will normally be used. Generally speaking, distributed wound motors are more expensive to manufacture than shaded pole motors. In addition, mechanical duty distributed wound motors utilize approaches such as selectively energizeable auxiliary winding arrangements so that desired operating characteristics can be achieved. For example, increased starting or locked rotor torque, efficiency, and so forth can be realized with these more expensive motors as compared to prior salient-pole shaded pole motors of similar overall physical size.

Shaded pole motors of the concentrated winding salient-pole variety, when designed to be relatively efficient during operation (e.g., those having efficiencies of 35% to 40% and greater) have relatively low starting torques. For example, when motors of this type have an operating efficiency in the neighborhood of 40% or more, the ratio of starting or locked rotor torque to maximum torque seems invariably to be about 0.33 or less. This is one of the primary reasons why the use of shaded pole motors has been generally limited to applications for driving fans and other fluid moving devices such as pumps. In many of these applications, the needed locked rotor torque is a relatively small fraction of the desired maximum torque or running torque (expressed as a percentage of maximum torque).

In the more efficiently designed concentrated winding salient-pole shaded pole motors of which I am aware, pole pieces project radially from a magnetizeable yoke. In addition, the pole tips of adjacent ones of such pole pieces are spaced apart by air gaps (as shown, for example, [for example] in the Arnold U.S. Pat. No. 3,313,965) *and thus are noted interconnected with magnetic material*. With designs of this general type, changes that increase efficiency (for a given dip to maximum torque ratio) will decrease the ratio of locked rotor torque to maximum torque. On the other hand, for a given locked rotor torque and maximum torque, any further improvement in efficiencies causes, expectedly, a decrease in dip torque (DT).

While a reduction in dip torque may be generally undesirable, it may become intolerable (because of loss of motor stability) in motors designed with tapped windings and intended for multispeed operation. For example, while a multispeed salient-pole shaped pole motor may be stable for high speed fan operation; when the motor is energized for low speed operation, it will not come up to speed if the dip torque is less than the amount of torque needed to accelerate the fan or other load past the speed associated with the dip torque of the motor. However, for a given locked rotor torque and maximum torque, any increase in stability associated with increased dip torque causes a reduction in operating efficiency with prior art approaches.

It therefore should *now* be understood that it would be advantageous and desirable to provide new and improved salient-pole shaded pole motors having winding coils concentrated about radially disposed pole pieces; such motors having characteristics that would *not* make it necessary (among other things) to sacrifice efficiency for increased locked rotor torque to maximum torque ratios for a given dip torque to maximum torque ratio. It would also be of importance to provide new and improved salient-pole shaded pole motors with characteristics that would permit the use of this type motor in so-called mechanical duty applications where the more expensive types of induction motors (with auxiliary starting devices) have been used heretofore. Two general examples of this type of application is the business machine field and electric motor driven gear reducer fields.

Accordingly, it is an object of the present *invention* to provide new and improved concentrated winding salient-pole shaded pole motors that have high efficiency and that have greatly improved locked rotor torque characteristics.

It is another object of the present invention to provide new and improved motors of the just mentioned type wherein the interrelationships between various characteristics such as dip torque, locked rotor torque, maximum torque, and current or power requirements are basically different as compared to motors of the same type known heretofore.

Still another object of the invention is to provide new and improved salient-pole shaded pole motors wherein the above and other objects may be fulfilled without necessarily making drastic increases in the physical size of motors of a given power rating.

SUMMARY OF THE INVENTION

The above and other objects are carried out, in one preferred form, in motors having rotor and stator assemblies. The stator assemblies include laminated cores that have a magnetic yoke and pole pieces, *the tips of which are separated by non-magnetic gaps*. Multiple short circuited shading coils are provided on the trailing pole tip of each pole piece that in turn extends generally radially from the geometric center of the magnetizeable yoke. This yoke magnetically interconnects the pole pieces.

In exemplifications of the invention illustrated herein, the leading pole tip of each pole piece is separated by an air gap from the trailing pole tip of the pole piece adjacent thereto. Among other things, these air gaps facilitate the placement of windings about the pole pieces. In addition, there is less iron in the magnetic circuit (from the rotor to the pole piece) relative to the amount of air in such circuit along the leading pole tip of each pole piece, as compared to the relative amounts of iron and air along the center portion of the pole pieces. In other words, the leading edges or pole tips of the salient-pole pieces exhibit a relatively higher reluctance as compared to the center portion or trailing tips of the pole pieces. This is accomplished in illustrated embodiments with chamfered bore defining surfaces—an approach that, by itself, is known in the art. The trailing tip of each pole piece is arranged to accommodate at least two short circuited shading coils and each trailing tip is spaced from the leading pole tip of an adjacent pole piece so that there will be substantially no magneticaly permeable material forming a bridge between such adjacent pole tips.

A plurality of turns of conducting material are concentrated adjacent to each of the pole pieces. The concentrated winding turns, stator core, shading coils and other necessary parts such as a housing, bearing support, and so forth, together comprise the stator assembly. The rotor assembly, which includes a shaft, is supported for rotation relative to the stator assembly.

Numerous advantages can accrue from practicing the present invention. For example, it is now possible to construct motors of the above referred to type having locked rotor torque to maximum torque ratios in excess of values that were previously throught to be limiting values for motors with efficiencies in excess of 40%. Moreover, motors embodying the invention are relatively stable, i.e. they can be selected to have satisfactory dip torque to maximum torque ratios. Alternatively, my teachings may be followed to provide motors having greater locked rotor torque (for a stated maximum torque) without necessarily being penalized in terms of reduced efficiency. Accordingly, salient-pole, shaded pole motors may now be designed for various mechanical duty applications where more expensive induction motors have been used heretofore.

The subject matter which I regard as my invention is particularly pointed out and distinctly claimed in the concluding portion of this specification. The invention itself, however, together with further objects and advantages thereof may be better understood by reference to the following description taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an end elevation of a salient-pole shaded pole motor, with parts removed and parts in section, embodying the invention in one form;

FIG. **2** is a plan view of one of the stator laminations of the motor shown in FIG. **1**;

FIG. **4** is an end elevation, with parts removed, broken away, and in section, of a prior art motor;

FIG. **3** is a view, with parts in section, parts broken away, and parts removed, of another motor embodying the present invention;

FIG. **5** is a plot of speed versus torque for motors of the general type described herein;

FIGS. **6** through **9** are plots of various performance or operational characteristics for motors of the type described herein as prior art and for motors embodying the invention, and of these:

FIG. **6** is a plot of gross efficiency at 70% of maximum torque versus the ratio of locked rotor torque to maximum torque;

FIG. **7** is a plot of watts input per watt output at 70% of maximum torque load versus the ratio of locked rotor torque to maximum torque (LRT/MT);

FIG. **8** is a plot of main winding copper loss per watt output at 70% of maximum torque versus LRT/MT; **[**and**]**

FIG. **9** is a plot of locked rotor input watts per watt output at 70% of maximum torque versus LRT/MT**[**.**]**;

FIG. 10 is identical to FIG. 4, except that reference characters denoting chamfer and shading coil dimensions are applied thereto; and

FIG. 11 is identical to FIG. 3, except that reference characters denoting chamfer and shading coil dimensions are applied thereto.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, and particularly to FIG. **1**, I have illustrated a salient-pole shaded pole motor **10** that includes a stator assembly, rotor assembly, and not shown bearing means as well as associated supporting structure.

The stator assembly includes a magnetic core formed of a plurality of magnetizeable laminations that define a magnetizeable yoke and a plurality of spaced apart pole pieces. The stator assembly also includes a plurality of turns of conductor wire disposed about a portion **11** of each of a plurality of substantially identical pole pieces **12**. The portions **11** extend generally radially from the geometric center of the stator core which, for the motor of FIG. **1**, also lies along the center or axis of rotation of the rotor.

The winding coils **14** about each pole piece are substantially identical in terms of conductor size and number of turns. These coils are interconnected in conventional manner so that when not shown external power leads (connected to the ends of the winding comprised of the coils **14**) are connected to a suitable source of excitation voltage, the rotor **15** will turn in a direction indicated by the arrow **11**, i.e., from the leading pole tips **17** toward the lagging or trailing pole tips **18**.

For simplicity of description and clarification of illustration, parts of the complete motor **10** have not been illustrated and will not be further described except to note that the motor **10** also includes stationary structure for supporting the stator core **20**. There also is included one or more bearing supports by means by which one or more bearings are positioned to journal the shaft **16** for rotation. It is also noted that the motor **10** may be of either the unit bearing or dual bearing type.

The body of rotor assembly **15** may be formed in any conventional manner and, preferably, is comprised of a stack of laminations formed from the same type of magnetizeable low carbon iron or steel as the laminations of the stator core **20**. All of the motors illustrated herein were constructed from laminations that were about 0.025 inches thick. The rotor laminations have slots formed therein for accommodating the bars of a short circuited squirrel cage winding. These bars and associated end rings **17** may readily be formed of aluminum in a die casting process.

The leading pole tips **17** of each of the pole pieces **12** is chamfered so that the air gap flux density under the leading pole tips, as compared to the air gap flux density at the center of each of the pole pieces **12**, is reduced. With the illustrated structure, the relatively less iron in the magnetic circuit in the vicinity of the leading pole tips, as compared with the amount of air, provides the desired differential air gap flux density. Other approaches may also be used to accomplish this result. For example, other approaches would be to provide a stepped bore, or reluctance slots in the leading pole tips so as to establish high reluctance leading pole tips.

Pairs of shading coils **21**, **22** are accommodated on the trailing pole tip **18** of each pole piece **12**. These coils **21**, **22** are disposed in slots **23**, **24** formed in each of the salient-pole pieces. The relationship, shape, and configuration of the slots **23** and **24** most clearly revealed in FIG. **2** which shows the core **20** with all windings and shading coils removed therefrom.

It will be noted that the slots **21** in the trailing pole tips **18** have been configured to accommodate a round shading coil whereas the slots **22** are formed to accommodate a rectangular shaped shading coil. The shapes of these coils have been selected on the basis of convenience and manufacturability. The actual cross-sectional area of the coils for slots **21**, **22** are selected so that the shading coils will have an electrical resistance that is preselected for a given application. The material out of which the shading coils will be constructed may also be chosen on the basis of economics, ease of manufacture, and efficient utilization of the space available on a given core for accommodating the shading coils.

A four-pole salient-pole construction is illustrated by FIGS. **1** and **2**. However, advantages of the present invention may also be realized with two-pole, six-pole and other multiple-pole constructions.

The advantages that may be obtained by use of the present invention will be best appreciated from the description now to be presented of the motors depicted by FIGS. **3** and **4**, it being noted that portions of each of these motors have been removed, broken away, or shown in section for purposes of description. It is to be understood however, that motors depicted by FIGS. **3** and **4** have been constructed and tested for purposes of comparison.

The prior art motor depicted by FIG. **4** has been available commercially from the assignee of this application for more than a year prior to **[**the filing date of this application**]** *October 2, 1972*. This motor, designated by reference numeral **31**, includes a rotor assembly formed of a two inch stack of laminations. The rotor body was constructed with **[18]** *eighteen* uniformly spaced apart die cast aluminum conductor bars and end rings. The fundamental calculated resistance of the rotor **[32]** *30*, referred or reflected to the main winding was about 4.75 ohms.

The stator core **32** was also a two inch stack of laminations that were held together by keys that were retained in keyways **33** which are formed in the magnetizeable yoke portion of the laminations.

The rotor **34** of motor **36** shown in FIG. **3** was substantially identical to rotor **30** and core **37** of motor **36** was substantially identical to core **32** with the exception that two keyways and two windings pin accommodating holes in the magnetizeable yoke portion **35** of the stator laminations were omitted. Essentially the only other structural difference between motors **31** and **36** were those differences observed when the trailing pole tips **37**, **38** are compared in FIGS. **3** and **4**.

Essentially all other construction details of motors **31** and **36** were the same. For example, available bearing supports and bearing structures of the same size and type were used to support the rotors **30**, **34** for rotation relative to the respective stator cores **32** and **37**. All of this is here pointed out so that the totally unexpected differences in performance and characteristic relationships that became apparent after testing motors embodying the invention will be better appreciated.

The outline of the *two pole* cores shown at **32** and **37** were each drawn to substantially full scale in the accompanying drawings so as to correspond in size and geometric configuration to the size and configuration of the stator laminations in *two pole* motors that were actually constructed and tested, all as will be pointed out in a discussion of data presented in Table I hereinbelow.

Considering FIGS. **3** and **4** now in detail, and with initial reference to FIG. **4**, the leading pole tip **39** of each of the *two* pole pieces **41** were chamfered at **40** for a span of **[80]** *eighty* electrical degrees as illustrated *(it being noted that, as is well-known, electrical degrees are equal to mechanical degrees for two-pole motors, or cores for such motors)*. The radial depth of the chamfer was about 0.08 inches, measured on the centerline of wire admitting slots **42**. This centerline is represented in FIG. **4** by reference line **43**.

Pole pieces **41** were also provided with slots or notches **44** in each of which a copper shading coil **46** was accommodated.

The center of opening **47** for shading coil slot **44** was **[30]** *thirty* electrical degrees measured from reference line **43** and thus each coil **46** shaded **[30]** *thirty* degrees of the total span of the magnetic pole established by pole piece **41**. The size and position of slots **48** (and openings **49** in pole pieces **51** of core **37**) relative to center reference line **52** were the same as the relations just discussed for core **32**. *Thus, the center of openings 49 were thirty electrical degrees measured from the reference line 52; and each coil 53 shaded thirty degrees of the total magnetic pole span of the pole pieces 51.* Moreover, the two coils **46** and two coils **53** were all formed of uninsulated copper conductor that was 0.281 inches wide and 0.05 inches thick.

FIG. 10 is identical to FIG. 4 except that the previously mentioned chamfer span, chamfer depth, and shading coil span are represented by the reference characters α, d, and β, respectively. More specifically, the above-mentioned span of eighty electrical degrees has been depicted as the angle α measured from the reference line 43; the chamfer depth of about 0.08 inches is depicted by the dimension d, and the thirty electrical degree shading coil span is denoted by the angle β.

FIG. 11 is identical to FIG. 3 except that the reference characters α, β, and d (as in FIG. 10) have been used to denote the span of chamfers 57, span of shading coils 53, and the 0.08 inch depth of the chamfers 57.

Disposed about each of the pole pieces **41** and **51** was a coil of winding turns. Each of the coils **54** and each of coils **56** comprised 125 turns of 0.0359 inch (conductor diameter) insulated copper wire. Substantially the only difference between the windings for motors **31** and **36** was that the winding resistance of motor **31** was about 1.6 ohms whereas the winding resistance of motor **36** was about 1.7 ohms. This however, was caused by the need to have slightly increased lengths of wire for those turns in the vicinity of pole tips **38** of motor **36** as compared to the lengths of wire in the turns adjacent to pole tips **37** of motor **31**.

Since the chamfer *57 was substantially the same, both in span and depth, as chamfer* **40**, the only other difference between motors **31** and **36** was that motor **36** included additional shading coils **58**, each of which were carried on an enlarged pole tip **38** in a slot pair **59**. The coils **58** were formed of No. 9AWG uninsulated copper conductor, the wire diameter being about 0.1144 inches. The tips **38** were enlarged (relative to tips **137** of motor **31**) an amount sufficient to prevent magnetic saturation of the laminations under coils **58** due to the shading coil flux. The span of shading coils **58**, i.e., the arcuate measure *(denoted by the angle γ in FIG. 11)* from reference line **52** to the center of opening **61** was **[18]** *eighteen* electrical degrees, it *again* being noted that (as is well-known) electrical degrees are equal to mechanical degrees for two-pole motors. *It thus is quite apparent that the first and second shading coils 53, 58 had first and second spans that were both less than the span of eighty electrical degrees preselected for the chamfers 57 which established the high magnetic reluctance regions of the pole pieces 51.*

A motor **36** was then tested, and the test data was recorded and then compared with test data for motors like motor **31**. The tests were performed with a reaction dynamometer while the shaft of the motor being tested was coupled to the shaft of a direct current motor. The speed of motor **36** was very precisely controlled by varying the speed of the d.c. motor which, in effect, acted as a fixed speed driven device. A tachometer on the d.c. motor provided a speed signal while strain gauges provided a signal that was indicative of test motor torque for various speeds. Sensors were also used to determine current (in amperes) and power (in watts) drawn or used by the test motor under various load conditions.

Three motors were constructed as exemplified by motor **36** and the average data for these three motors, after testing, is reported in column B of Table I, while column A reports data obtained by corresponding tests of a motor constructed as described for motor **31**. In Table I, the load condition and characteristic investigated is listed on the left-hand side of the table while recorded, observed, and calculated quantities appear in column A and B.

TABLE I

	A	B
Winding Resistance, ohms	1.552	1.674
Test Voltage, 60 Hz	115	115
Main Winding I^2R (heating) loss, watts	41.64	43.13
No Load Condition		
Speed, rpm	3516	3531
amps	5.18	5.08
watts	233	249
Max Torque Condition		
Speed, rpm	2720	2793
(MT) Torque, oz-ft	8.25	8.47
Current, amps	7.20	6.71
Power Input, watts	534	540
.7 Max Torque Condition		
(EFF) Gross Efficiency, %	41.8	43.5
Speed, rpm	3188	3234
(.7MT) Torque, oz-ft	5.78	5.93
Current, amps	5.80	5.47
Power Input, watts	391	391
Dip Torque Condition		
(DIP) Minimum torque, oz-ft	3.66	3.47
Locked Rotor Condition		
(LRT) Torque, oz-ft	2.52	3.38
Current, amps	9.68	8.92
Power Input, watts	667.5	669
Calculated Ratios		
DIP/MT	.444	.409
LRT/MT	.305	.399
.7MT Eff., %	41.8	43.5

It is believed that much of the data in Table I is self-explanatory. However, FIG. **5** of the drawings is a typical speed-torque curve for salient-pole shaded pole motors, and is presented as an aid to understanding the data of Table I. The subheading "No Load" refers to a test condition when the motor being tested was operating at no load or maximum speed conditions. "Max Torque" refers to the maximum torque (also referred to as breakdown torque) point on the curve of FIG. **5**; "Dip Torque" refers to the similarly labeled minimum torque region of the FIG. **5** curve; "0.7 Max Torque" would represent a condition where a load was applied to a test motor so that it operated at a speed between maximum speed and maximum torque speed and on a point on the FIG. **5** curve corresponding to 70% of maximum torque. As a final point of explanatin, "Gross Efficiency" as used herein is calculated or measured to include output power used to overcome bearing friction as part of the useful output power of the motor, and is defined as watts output per watts input × 100.

The data of Table I indicates that the motors embodying the invention had several surprising and significantly improved operational characteristics as compared to the prior art. For example, the no-load speed is higher than for the prior art motor **31**. Even more significantly however, the max. torque speed and max. torque were both increased while max. torque current decreased. The fact that max. torque power input was greater in column B than in column A indicates that the power factor of motors like motor **36** are closer to unity than was the case for motor **31**—and this is also a desirable feature.

Of even more significance, although column B dip torque is about 5% less than that of column A, the starting or locked rotor torque recorded in column B is at least ⅓ or 33% greater than the torque recorded in column A.

A comparison of the calculated ratios in Table I even further emphasizes the significant and surprising differences between motors **31** and **36**. Motors like motor **36** had an LRT/MT (locked rotor torque to maximum torque) ratio above 0.33 while being 43.5% efficient and also while being relatively stable as evidenced by the calculated value of the ratio "DIP/MT".

Heretofore it has appeared that compromise must be made, in shaded pole motor designs, between any need for efficiencies greater than 35% and any need for LRT/MT ratios in excess of 0.33. For example, skeleton type motors (as shown for example in the Ballentine U.S. Pat. No. 2,454,589) may be optimized (by using multiple shading coils and chamfered pole faces) to have LRT/MT ratios in excess of ⅓; but the efficiency of such motors would be only about 35% at best.

Motors as shown in FIG. **4** herein on the other hand may be optimized in design to have efficiencies in the neighborhood of 50%, but only at the expense of ever reducing LRT/MT ratios from an upper limit of about ⅓.

Because of the improvement in performance of motors like motor **36**, which was surprising to an unexpected degree, a quantity of other motors embodying the invention were constructed and tested in the manner described above. All of these additional motors were of salient-pole shaded pole type. Moreover, to limit the number of variables, each had: a double shading coil trailing pole tip design; the same winding in terms of conductor size and number of turns; the same core stack height; a high reluctance leading pole tip that was stepped rather than chamfered; the same rotor stack height; the same rotor end ring; and the same basic stator core lamination design. The stator core laminations were varied, one from another, by providing variations in the: spans for the step in the leading pole tips; depths for the steps in the leading pole tips; span of the larger shading coils; span of the smaller shading coils; conductor size of the larger shading coils; and conductor size of the smaller shading coils. In addition, the size of the rotor conductors (and therefore rotor resistance) was varied.

The data obtained from testing these motors was then used to establish a mathematical model and the model employed, in turn, to establish points for various curves which are presented in FIGS. **6**, **7**, **8** and **9**. The data obtained from the motors actually constructed of course verified the solid line curves in these figures. Before describing the significance of these curves, it should be noted that further variations could be made in salient-pole, shaded pole motors embodying the invention that would result in motor efficiencies in the neighborhood of 50% or locked rotor torque to maximum torque ratios in excess of 0.6 with efficiencies of 40% or more, all as will be explained hereinafter. For example, salient-pole, shaded pole motors have now been constructed with an efficiency of 39% and an LRT/MT ratio of 0.6

Turning now to FIGS. **6**, **7**, **8** and **9**; the broken line curves represent characteristic relationships associated with prior art salient-pole shaded pole motors typified, for example, by motor **31** of FIG. **4**. The solid line curves in FIGS. **6–9** are plots that represent characteristic relationships associated with motors embodying my invention as discussed above.

A brief review of these curves quickly indicates that motors embodying the invention will have operating characteristics or properties that provide significant advantages. For example (refer to FIG. **6**), salient-pole shaded pole motors now can have LRT/MT ratios well in excess of ⅓ with efficiencies of 40% and more when providing 70% of maximum torque.

FIG. 7, being a plot of watts input per watts output at 70% of maximum torque, is in effect an inverse plot of the curves of FIG. **6** and emphasizes that, for a given DIP/MT ratio, an increase of locked rotor torque to maximum torque can be obtained with motors that will operate at 70% of maximum torque with reduced input to output power ratios.

The curves of FIGS. **8** and **9** have been presented to further emphasize the differences in other characteristic ratios of motors embodying the invention as compared with the prior art motors that might be argued to be the most closely related thereto. For example, FIG. **8** shows that for applications requiring increased LRT/MT ratios (in excess of ⅓); motors embodying the invention will exhibit the desired relationships of decreasing amounts of power loss due to I^2R losses in the stator winding at operating conditions. FIG. **9** on the other hand reveals that, for LRT/MT ratios greater than 0.33, motors embodying the invention will require relatively low amounts of power (expressed as a multiple of the power required for operation at 70% of maximum torque) under locked rotor conditions.

With reference once again to FIG. **6**, it should be noted that, in general, if the leading pole tips of salient-pole shaded pole motors embodying the invention are not designed to reduce the air gap flux density along the leading pole tip, the motor efficiency at 70% MT would be expected to be about ten points less than that indicated in FIG. **6**.

Still having reference to FIG. **6**, I have found that, for a given DIP/MT ratio, the ratio of LRT/MT (and therefore operating efficiency) for a given motor design embodying the invention may be increased by decreasing the span of the shading coils along the trailing pole tips. However, it then also is desirable to reduce the span of any chamfer or step along the leading pole tip and to make such chamfer or step deeper, so as to increase the reluctance along the leading pole tip (i.e., further reduce the air gap flux density along the leading pole tip).

It may also be desired, given a motor having an LRT/MT ratio above ⅓, to increase the DIP/MT **[**ratio**]** *ratio* of such motor without causing a reduction in the LRT/MT ratio. To accomplish this change, one would increase the rotor resistance; reduce the small shading coil span relative to the large shading coil span; increase the conductor size of the larger shading coil; reduce the size of the smaller shading coil conductor; and change the reluctance characteristic of the leading pole tip, e.g., by increasing the depth of the step or chamfer. It should also be recognized that, with larger motors (e.g. 1/6 or ¼ hp), it will be relatively easier to manufacture optimized multi-shading coil designs as compared to 1/20 hp and smaller size motors. The reduced physical size of the smaller motors would make it more difficult to use more than two shading coils or to reduce the span of the smaller shading coils beyond practical manufacturable limits.

It should now be apparent to those skilled in the art, that I have shown and described what at present are believed to be preferred embodiments of the invention. However, numerous other salient-pole shaded pole motors embodying the invention and having desired characteristics may also be provided by following the teachings herein. Accordingly, I intend to cover in the following claims all equivalent variations as fall within the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A shaded pole motor comprising a stator assembly having at least one excitable winding, a rotor assembly, and means for supporting the rotor assembly in spaced apart air gap defining relation with the stator assembly and for permitting rotation of the rotor assembly relative to the stator assembly during excitation of said winding; said stator assembly including a magnetizeable core having circumferentially spaced apart pole pieces; at least one of the pole pieces having a leading pole tip configured to establish a relatively high magnetic reluctance therealong, as compared to another region of such pole piece; said at least one of the pole pieces also having at least two short circuited shading coils disposed along the trailing pole tip thereof; and said pole pieces being spaced apart so that the leading pole tip of each pole piece is spaced from the trailing pole tip of the pole piece adjacent thereto; said rotor assembly including a short circuited squirrel cage winding, and the locked rotor torque to maximum torque ratio for the motor being greater than about thirty-three one hundredths.

2. A motor as set out in claim **1** wherein the excitable winding comprises a first concentrated group of conductor turns accommodated closely adjacent to a first pole piece, and at least one other group of conductor turns accommodated closely adjacent to another pole piece.

3. A salient-pole shaded pole motor including a stator assembly and rotor assembly; the stator assembly comprising a magnetizeable core having a magnetizeable yoke and a plurality of spaced apart pole pieces each having a leading and trailing pole tip, with the leading tip of each pole piece spaced from the trailing pole tip of a pole piece next adjacent thereto; said stator assembly further including a plurality of electrically short circuited shading coils disposed on and thereby identifying each of the trailing pole tips, and a winding comprising at least one concentrated group of conductor turns accommodated closely adjacent to at least one of the pole pieces; the motor exhibiting, during excitation of the winding by a given voltage, a locked rotor torque to maximum torque ratio of at least about 0.33 and a gross operating efficiency in excess of thirty-five percent for an operating condition corresponding to about seventy percent of the maximum torque producible by the motor during excitation of the winding; said rotor assembly including a short circuited squirrel cage rotor spaced by an air gap from bore defining faces of the pole pieces, and the leading pole tip of each pole piece being configured to establish a higher reluctance to magnetic flux in the air gap along the leading pole tips as compared to the reluctance to magnetic flux in the air gap along the pole piece faces in the vicinity of the center of the pole pieces.

4. A salient-pole shaded pole motor as set forth in claim **3** wherein the rotor assembly includes a plurality of conductors and a shaft, the pole pieces each include a portion extending generally radially outwardly from the shaft, and the magnetizeable yoke substantially encompasses the pole pieces and the plurality of conductors.

5. A shaded pole motor comprising a rotor, at least two pole pieces spaced radially outwardly from the rotor and each having a face at one end thereof defining an air gap with the rotor, a magnetizeable yoke extending between adjacent pole pieces and encompassing the rotor, conductor turns of a concentrated winding adjacent to at least one of the pole pieces, and at least first and second separate shading coils on a first portion of each pole piece; a second portion of each pole piece being constructed to have a relatively high reluctance as compared to another portion of the same pole piece; and wherein the first portion of each pole piece comprises the trailing pole end thereof, the second portion of each pole piece comprises the leading pole end thereof and wherein the trailing pole end of each pole piece is displaced in space from the leading pole end of the pole piece adjacent thereto.

6. A stator assembly for a shaded pole motor, the stator assembly comprising a core having a magnetizeable yoke and a plurality of spaced apart magnetizeable pole pieces each having a leading and trailing pole tip, with the leading tip of each pole piece displaced in space from the trailing pole tip of a pole piece next adjacent thereto; said stator assembly further including at least first and second shading coil means disposed along one of the pole tips of each of the pole pieces, and a winding comprising at least one concentrated group of conductor turns accommodated closely adjacent to a least one of the pole pieces; the stator assembly being of particular utility in motors having, during excitation of said winding by a given voltage, a locked rotor torque to maximum torque ratio of at least about 0.33 and a gross operating efficiency in excess of thirty-five percent for an operating condition corresponding to about seventy percent of the maximum torque producible by the motor during excitation of said winding; the other pole tip of each of the pole pieces being configured to establish a higher reluctance to air gap magnetic flux as compared to the reluctance to air gap magnetic flux along the face of each pole piece in *the* vicinity of the center of the pole pieces.

7. A stator assembly as set forth in claim **6** wherein the winding comprises at least one other concentrated group of conductor turns accommodated closely adjacent to a pole piece other than said at least one of the pole pieces.

8. A shaded pole motor comprising a first assembly having an excitable winding, and a second assembly supported in spaced apart air gap defining relation with the first assembly; said first assembly including a core formed from magnetizeable material and including pole pieces displaced in space, one from another; each of the pole pieces having a first region along the air gap configured to establish a relatively high magnetic reluctance therealong, as compared to another region of each pole piece; and each of the pole pieces also having at least first and second shading coil means disposed along a second region thereof; said pole pieces being displaced in space so that extremities of adjacent pole pieces are spaced from one another; said motor having a gross operating efficiency, when providing an output torque of about seventy percent of the maximum torque of the motor, of at least 35 percent and having a locked rotor torque to maximum torque ratio greater than one-third.

9. A stator assembly for a shaded pole motor having stator and rotor assemblies disposed about a central axis; said stator assembly including a magnetizeable core having at least two spaced apart pole structures each comprising a portion extending generally radially relative to the central axis for accomodating an excitation winding and further comprising a portion for accommodating shading coil means, said shading coil means comprising, for each of the at least two spaced apart pole structures, a first short circuited shading coil and at least one other short circuited shading coil accommodated along the trailing portion of the pole structure; each of the at least two spaced apart pole structures being configured along the leading portion thereof so as to establish a relatively high magnetic reluctance therealong as compared to the magnetic reluctance along the trailing portion thereof, the locked rotor torque to maximum torque ratio of a motor including said stator assembly being greater than one-third.

10. A motor as set forth in claim 3 wherein the leading pole tip of each pole piece is configured to establish a higher reluctance along a selected span of the magnetic pole associated with each pole piece, and wherein such selected span is greater than the total span of the magnetic pole associated with each pole piece that is shaded by the shading coils.

11. A stator assembly as set out in claim 6 wherein the shading coil means of each pole piece shades a selected span of the magnetic pole associated with such pole piece; and wherein the pole pieces are each configured to establish a higher reluctance along a span of the magnetic poles associated therewith that is greater than said selected span.

12. The shaded pole motor of claim 8 wherein said first region of each pole piece is of a first selected span of the magnetic pole associated with each pole piece; and wherein the shading coil means of each pole piece shade a span of the magnetic pole associated with each pole piece that is less than the selected span.

13. A motor as set out in claim 1 wherein said at least two short circuited shading coils comprise first and second shading coils that shade first and second spans respectfully of the pole established by said at least one of the pole pieces; wherein the same at least one of the pole pieces has a relatively high magnetic reluctance region therealong of a selected span of the pole established by the pole piece; and wherein said first and said second spans shaded by the first and second shading coils are both less than said selected span.

14. A stator assembly as set forth in claim 9 wherein the first and second short circuited shading coils of each of the at least two pole structures shade first and second spans respectively of the respective poles established by respective ones of the at least two pole structures; wherein a relatively high magnetic reluctance region is established, along each of the at least two pole structures of a selected span of the respective poles, by respective ones of the at least two pole structures; and wherein said first and second spans shaded by the first and second shading coils are both less than the selected span.

15. A shaded pole motor comprising a rotor, a magnetizable stator core including at least two circumferentially and magnetically spaced apart pole pieces having first and second portions spaced radially outwardly from the rotor and each having a face at one end thereof defining an air gap with the rotor, a magnetizable yoke extending between adjacent pole pieces and encompassing the rotor, conductor turns of a concentrated winding adjacent to at least one of the pole pieces, and at least first and second separate shading coils on a first portion of each pole piece wherein the first and second shading coils have first and second spans respectively across a magnetic pole associated with a pole face; a second portion of each pole piece being constructed to have a relatively high reluctance as compared to another portion of the same pole piece, wherein the relatively high reluctance region has a span across the magnetic pole greater than said first and second spans.

16. The shaded pole motor of claim 15 wherein the locked rotor torque to maximum torque for the motor is greater than about thirty-three one hundredths.

17. A salient pole shaded pole motor comprising a stator assembly having at least one excitable winding, a rotor assembly, and means for supporting the rotor assembly in spaced apart air gap defining relation with the stator assembly and for permitting rotation of the rotor assembly relative to the stator assembly during excitation of said winding; said stator assembly including a magnetizable core having pole pieces spaced apart circumferentially by air gaps; at least one of the pole pieces having a leading pole tip configured to establish a relatively high magnetic reluctance region along a given span of the magnetic pole associated with said at least one of the pole pieces, as compared to another region of such magnetic pole; said at least one of the pole pieces also having at least two short circuited shading coils disposed along the trailing pole tip thereof shading the magnetic pole associated with said at least one of the pole pieces for a span less than said given span, and said pole pieces being spaced apart so that the leading pole tip of each pole piece is spaced from the trailing pole tip of the pole piece adjacent thereto by an air gap; and said rotor assembly including a short circuited squirrel cage winding.

18. The motor of claim 17 wherein the locked rotor torque to maximum torque ratio for the motor is greater than about thirty-three one hundredths.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : Reissue 30,585

DATED : April 21, 1981

INVENTOR(S) : Joe T. Donahoo

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

Col. 1, line 59, change "magnetizeable" to --magnetizable--;
line 63, change "noted" to --not--.
Col. 2, line 7, change "shaped" to --shaded--;
line 60, change "magnetizeable" to --magnetizable--.
Col. 3, line 14, change "magneticaly" to --magnetically--.
Col. 4, line 25, change "magnetizeable" to --magnetizable--;
line 26, change "magnetizeable" to --magnetizable--.
Col. 5, line 58, change "windings" to --winding--;
line 59, change "magnetizeable" to --magnetizable--.
Col. 8, line 13, change "explanatin" to --explanation--.
Col. 11, line 1, change "magnetizeable" (both occurrences) to --magnetizable--;
line 30, change "magnetizeable" to --magnetizable--;
line 36, change "magnetizeable" to --magnetizable--;
line 51, change "magnetizeable" to --magnetizable--;
line 52, change "magnetizeable" to --magnetizable--;
line 60, change "a" to --at--.
Col. 12, line 15, change "magnetizeable" to --magnetizable--;
line 32, change "magnetizeable" to --magnetizable--;
line 35, change "accomodating" to --accommodating--.

Signed and Sealed this

Twentieth Day of *October 1981*

[SEAL]

Attest:

GERALD J. MOSSINGHOFF

Attesting Officer *Commissioner of Patents and Trademarks*