United States Patent

Laing

[15] **3,645,650**

[45] **Feb. 29, 1972**

[54] **MAGNETIC TRANSMISSION**

[72] Inventor: **Nikolaus Laing,** Hofener Weg 35-37, 7141 Aldinger, near Stuttgart, Germany

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[30] **Foreign Application Priority Data**

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Dec. 30, 1969 Austria ....A 12101/69

[52] **U.S. Cl.** **417/420,** 310/104
[51] **Int. Cl.** **F04d 25/06,** H02k 49/06
[58] **Field of Search** 310/103, 104; 417/420

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Primary Examiner—D. X. Sliney
Attorney—Pennie, Edmonds, Morton, Taylor and Adams

[57] **ABSTRACT**

A magnetic transmission with two pole rings separated by a conductor pole ring comprising a plurality of conductors with the two pole rings being independently arranged for rotation with respect to one another where the two pole rings each have a plurality of pole faces of alternating polarity with one of the pole rings having more pole faces than the other whereby rotation of one of the pole rings with respect to the other pole ring will be at a predetermined ratio.

42 Claims, 34 Drawing Figures

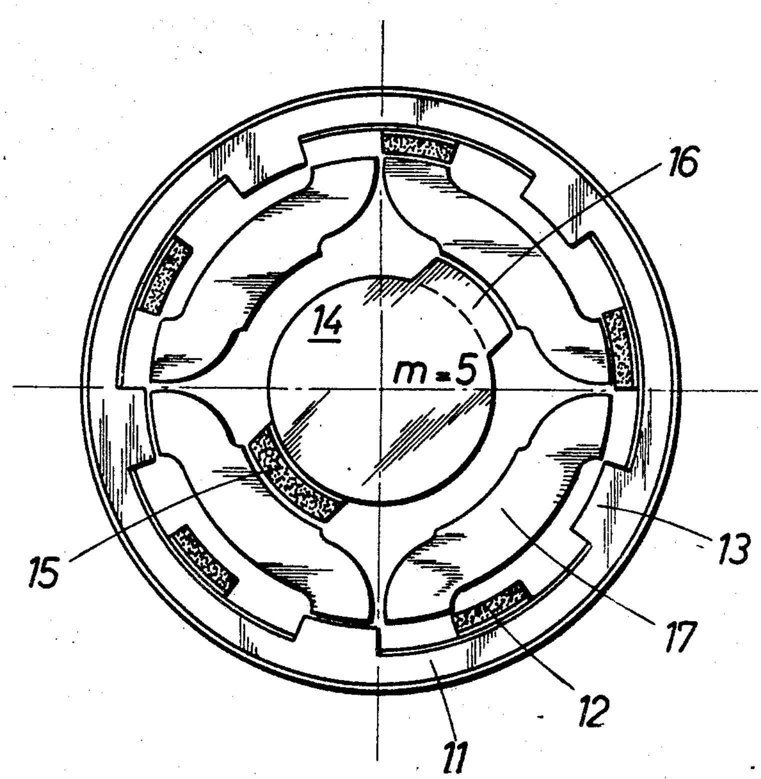


FIG 1a

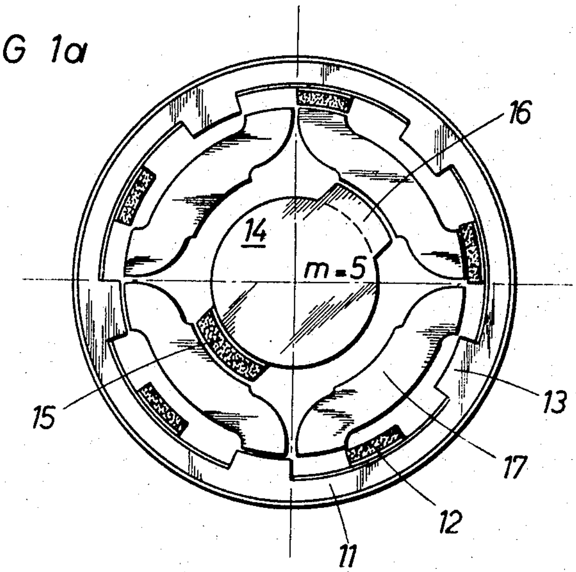


FIG. 1b

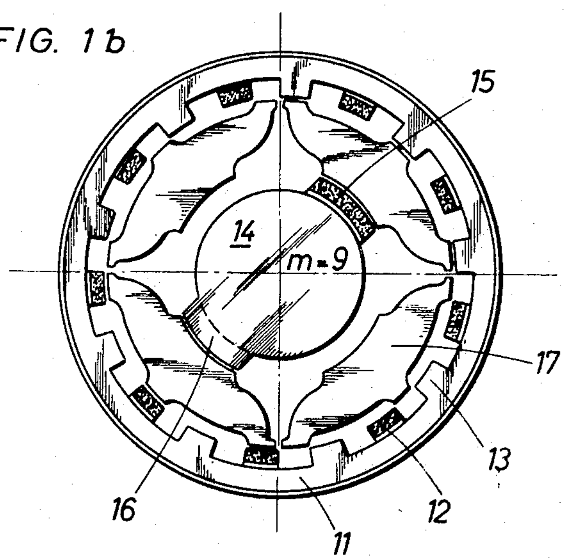


FIG. 1c

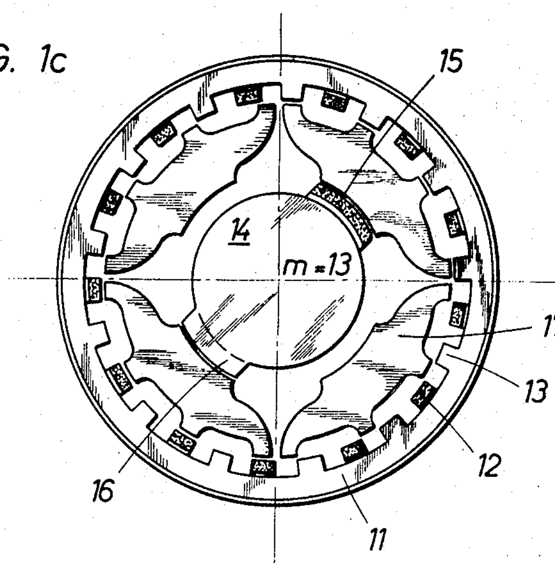


FIG. 1d

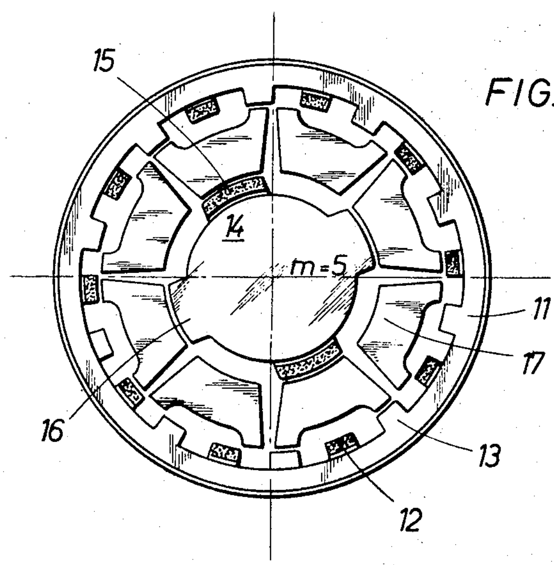


FIG. 2a

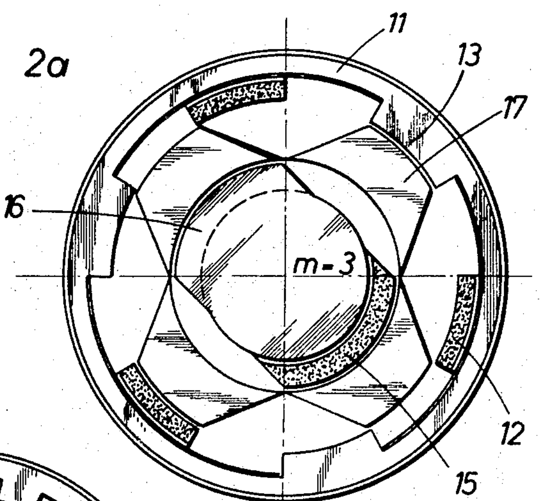


FIG. 2b

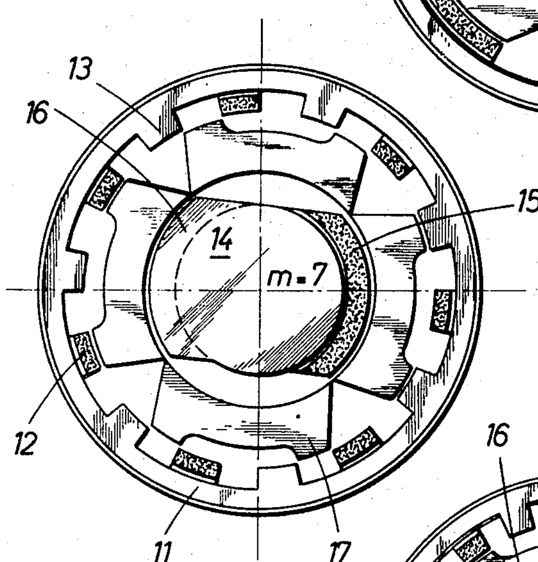
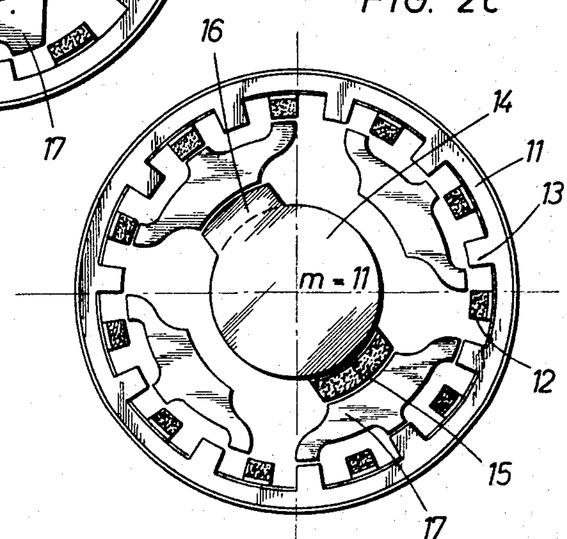


FIG. 2c



Nikolaus Laing

FIG. 3a

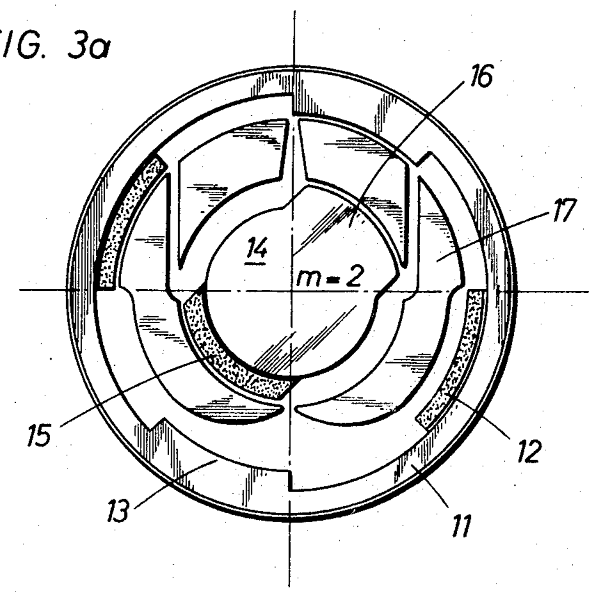


FIG. 3b

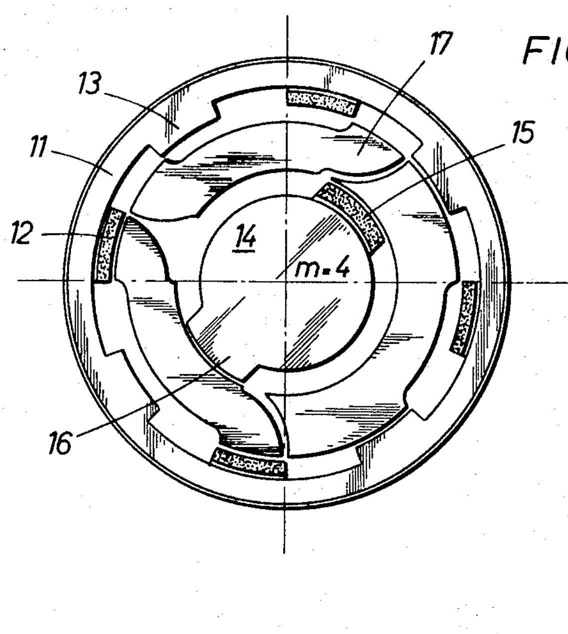


FIG. 3c

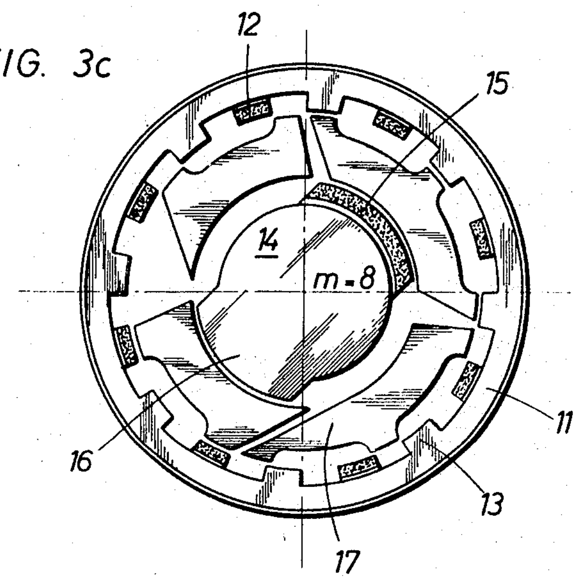


FIG. 3d

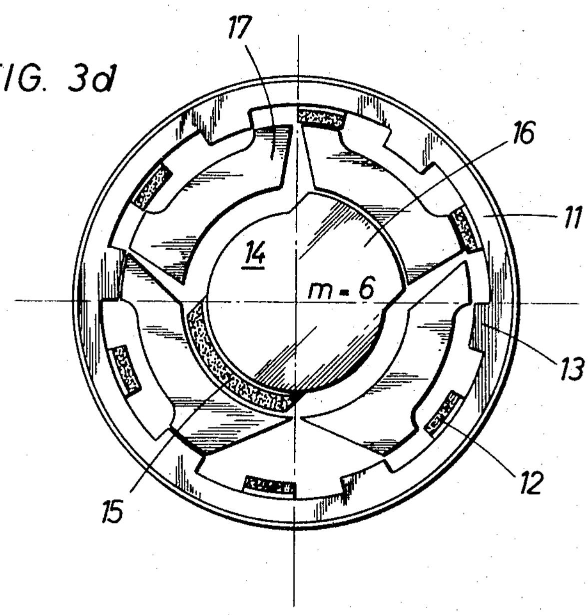
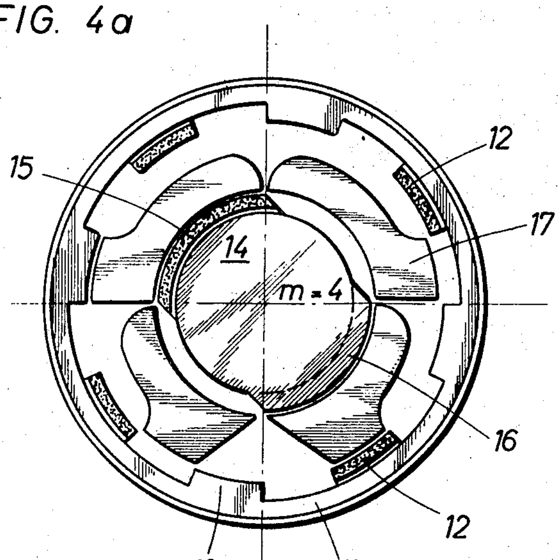


FIG. 4a



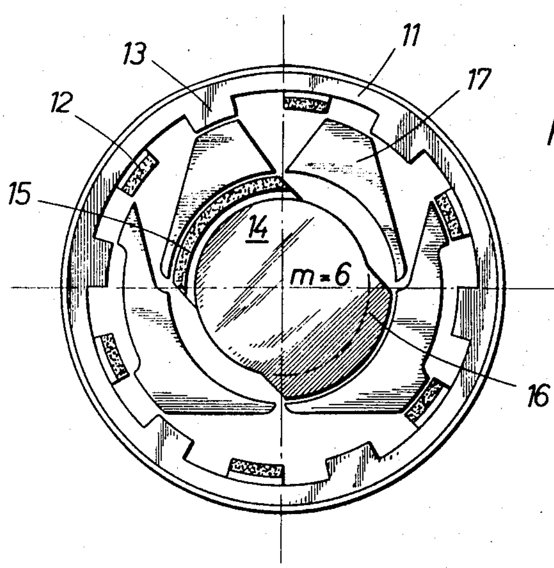


FIG. 4b

FIG. 4c

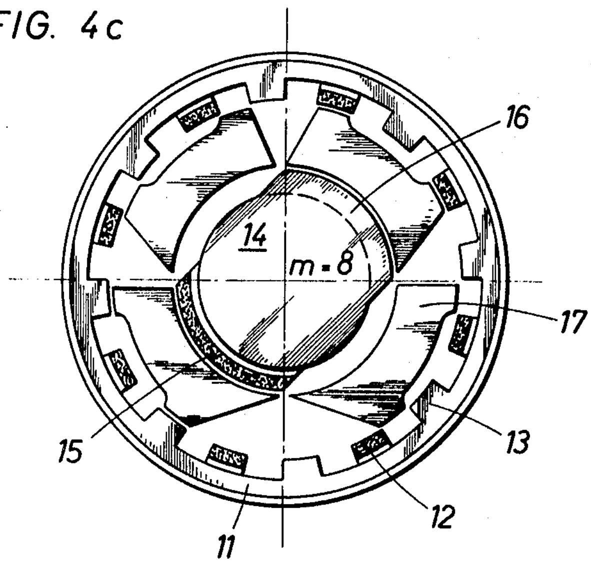


FIG. 4d

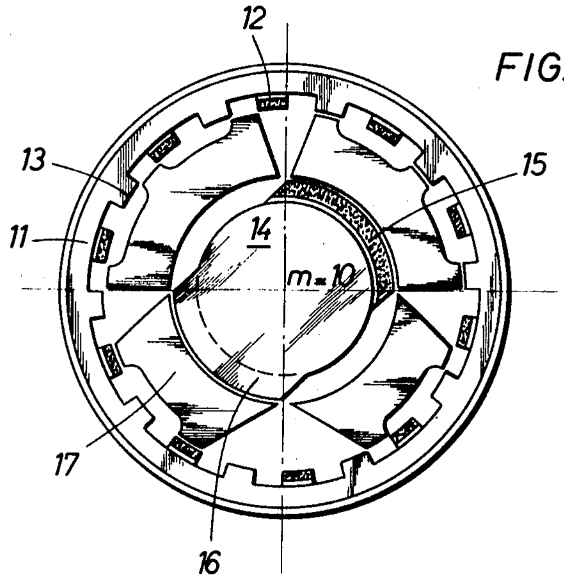


FIG. 5

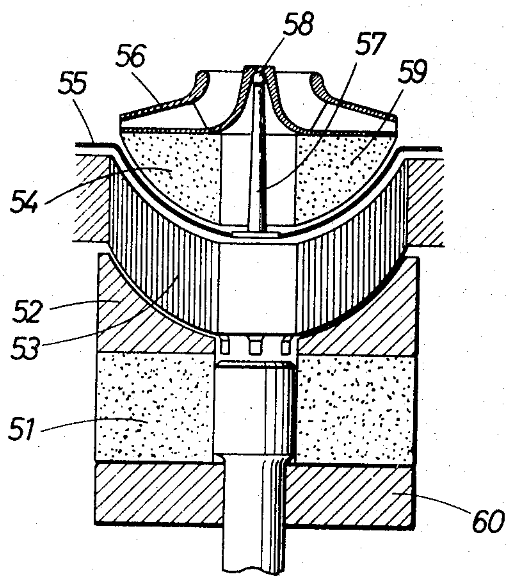


FIG. 6

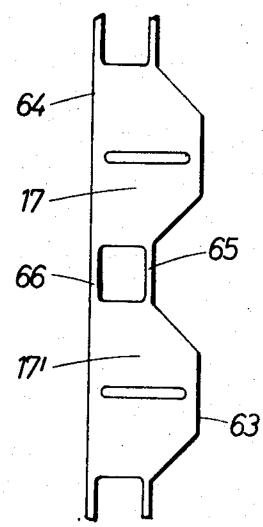
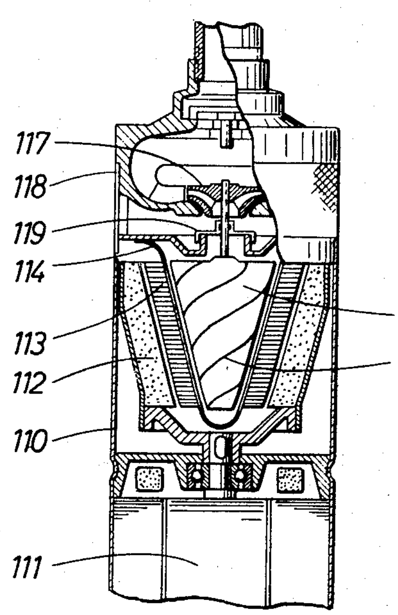


FIG. 13



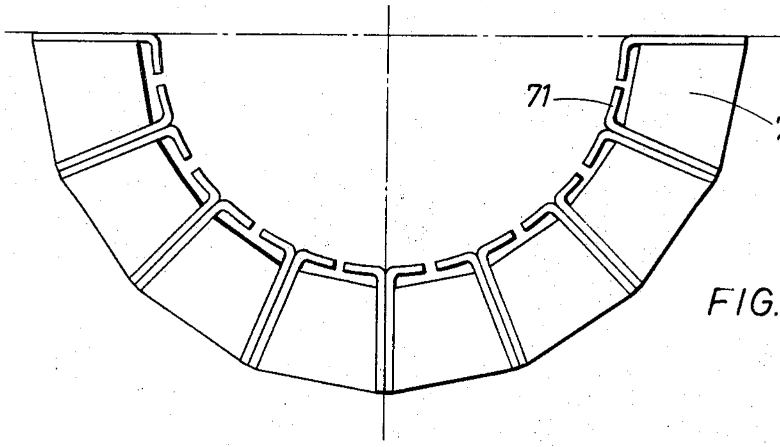


FIG. 7a

FIG. 7b

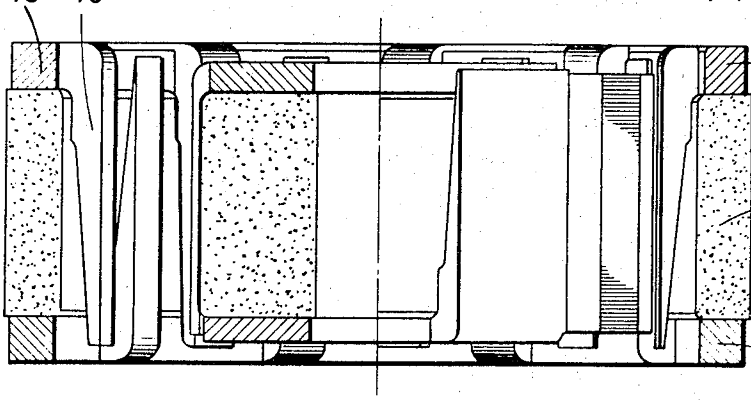


FIG. 7c

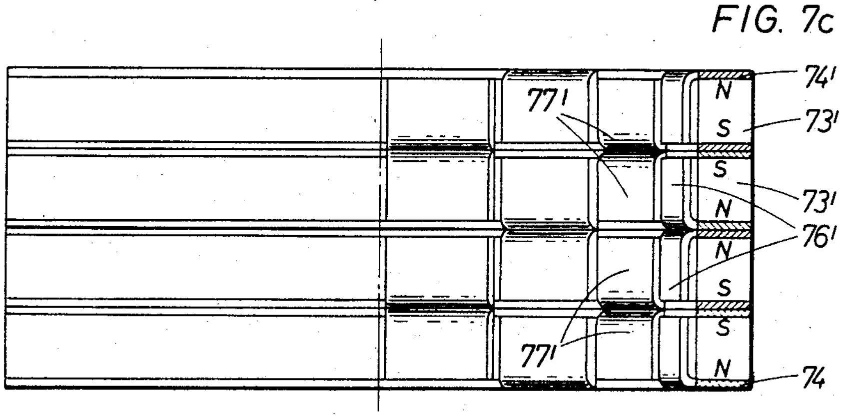


FIG. 8a

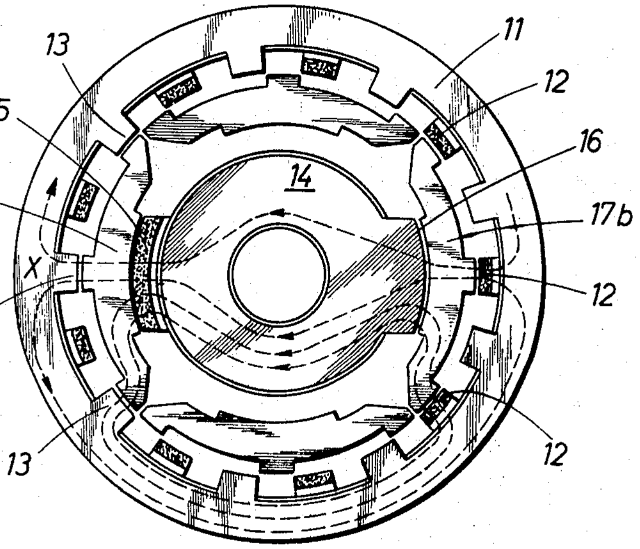
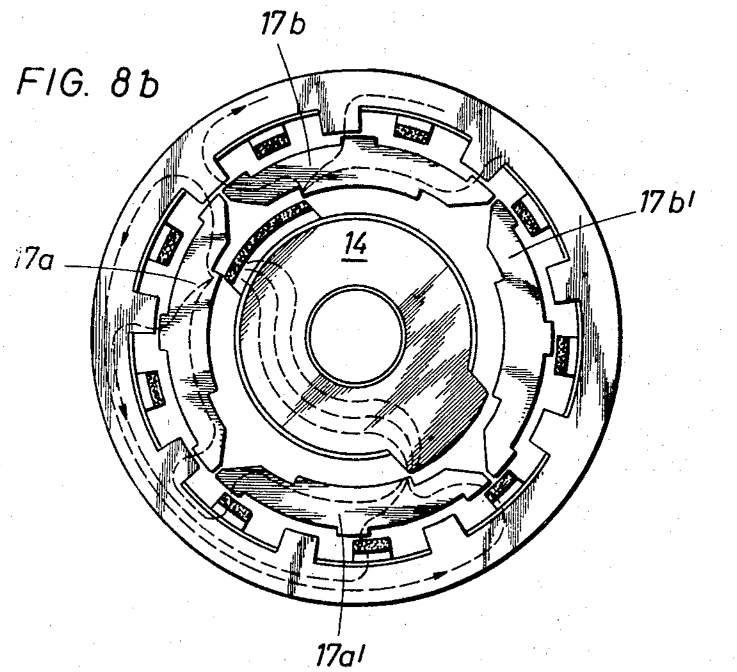
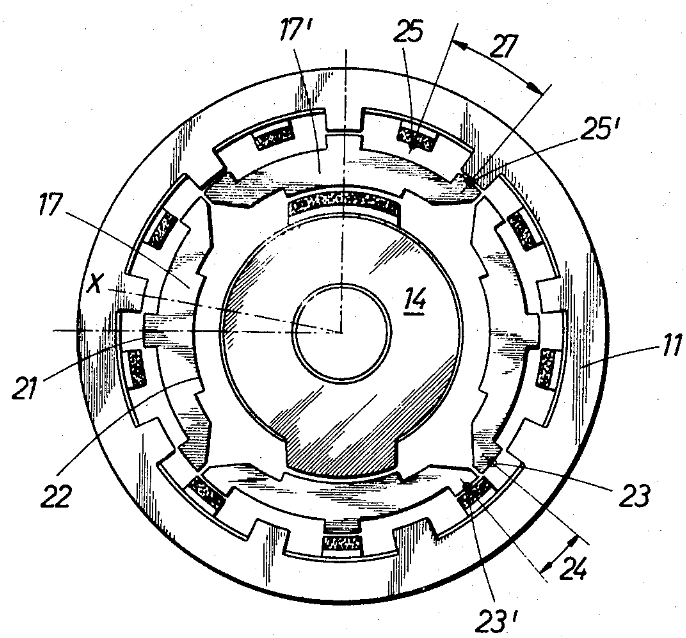


FIG. 8b



[signature]

FIG. 8c



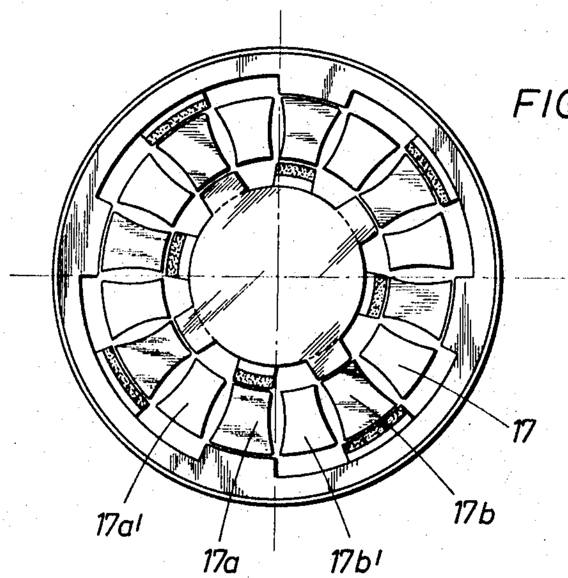


FIG. 9a

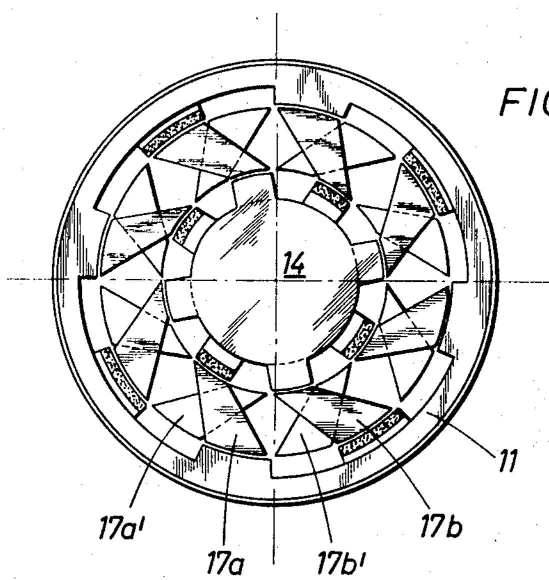


FIG. 9 b

FIG. 10a

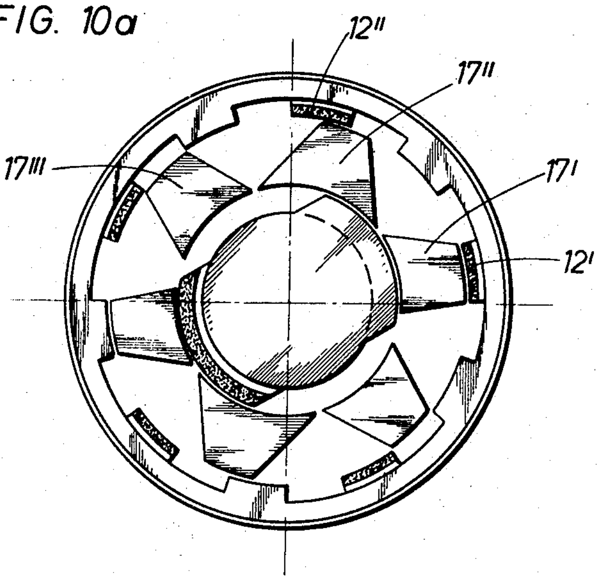


FIG. 10 b

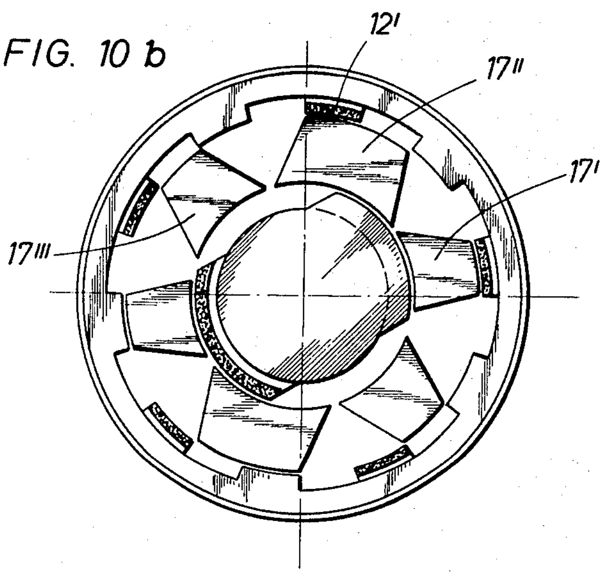


FIG. 10c

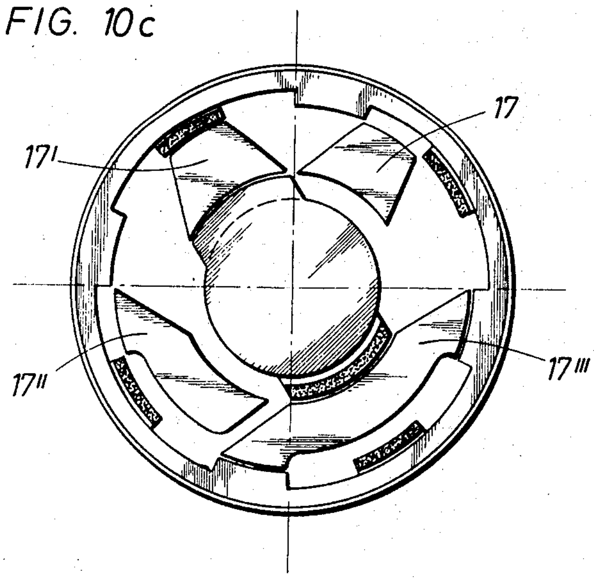
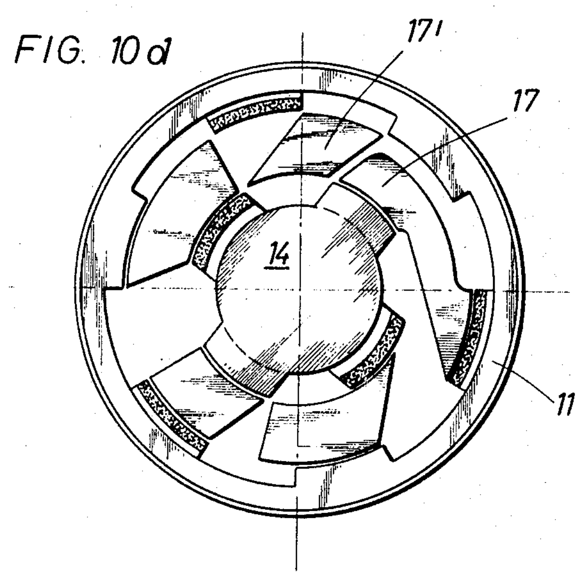


FIG. 10d



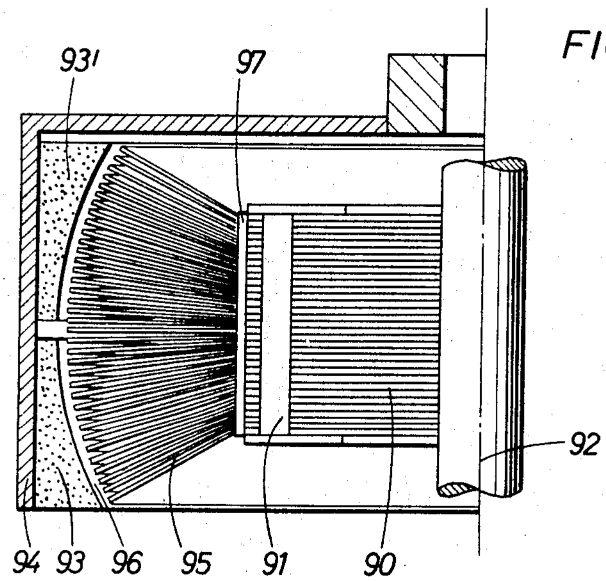


FIG. 11

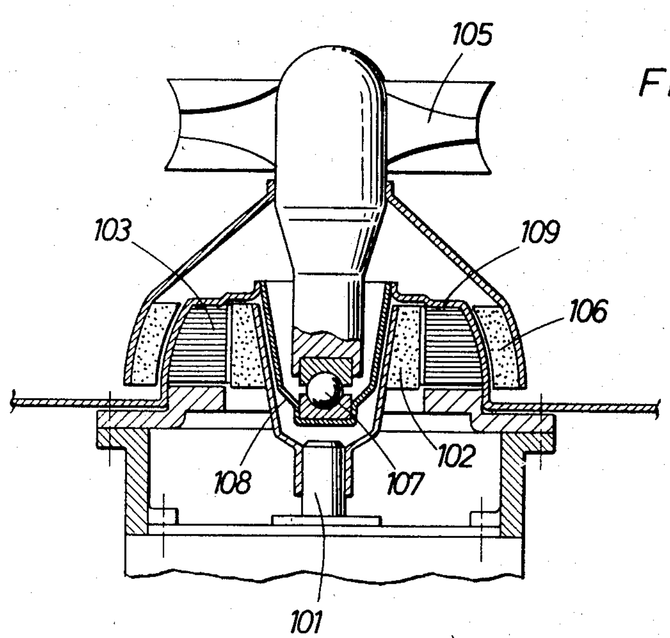


FIG. 12

FIG. 14

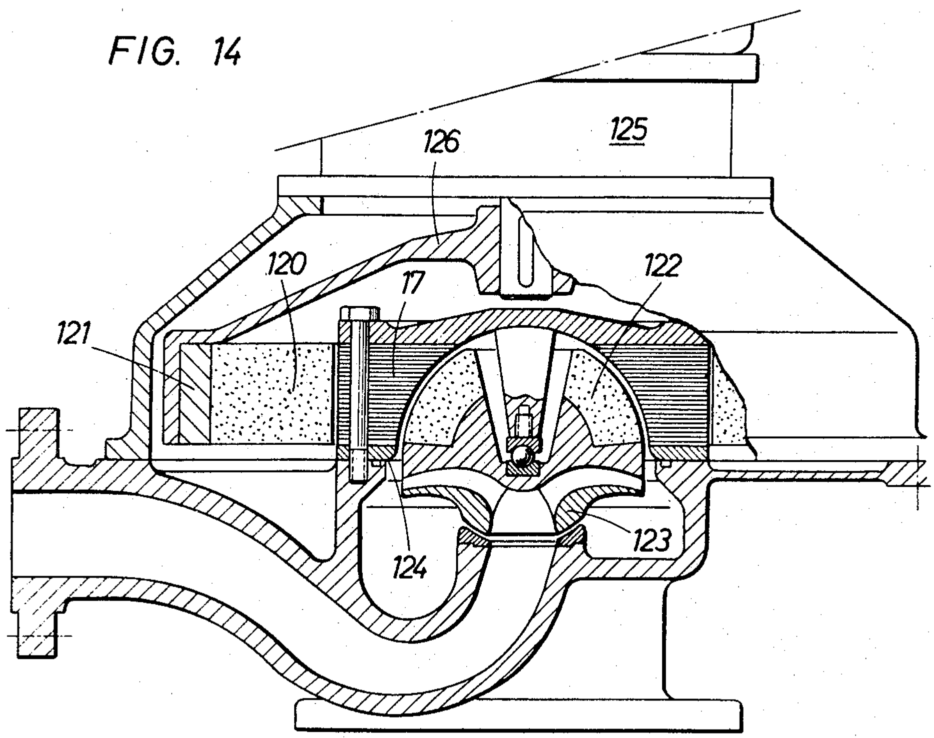
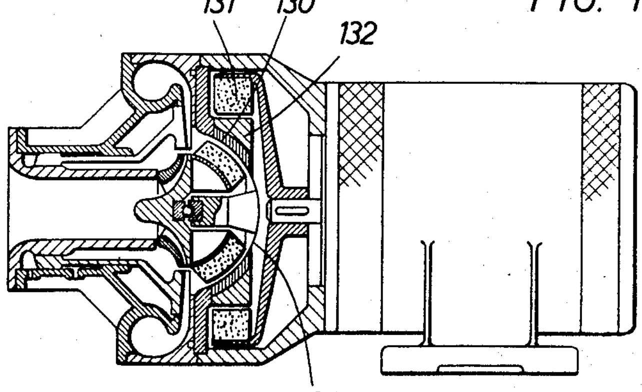


FIG. 15



MAGNETIC TRANSMISSION

BACKGROUND OF THE INVENTION

The invention relates to a magnetic transmission with three elements, one of which being arranged between the other two, at least one containing a permanent magnet or an electromagnet and at least two of the three elements being arranged for rotation independently of each other, whereby the two elements between which the third one is arranged are pole rings with permanent or induced poles facing this third element, the number of the poles in the two pole rings corresponding to the transmission ratio and their signs alternating along the circumference of the pole rings, whereby further the third element, which is arranged between the pole rings consists of magnetically relatively practically separated conductors of ferromagnetic material distributed over the circumference, whose direction of magnetization is readily reversible and whose number is larger than the number of poles of the pole ring having the smaller number of poles, the conductors having pole faces facing of the two pole rings, and whereby the centers of the pole faces of adjacent conductors (viewed circumferentially) which face the pole ring with the larger number of poles are relatively spaced at an angle which differs from the angular spacing of the centers of adjacent poles of this pole ring with the larger number of poles, as well as from an integral multiple thereof.

DESCRIPTION OF THE PRIOR ART

A magnetic transmission with three relatively coaxially arranged elements, at least two of which are rotatable independently of each other, is known. Two of these elements consist of rings, separated by an airgap, with nonmeshing, magnetically conductive teeth, which form regions of alternately high and low magnetic reluctance, the difference between the number of teeth on the two rings being small, so that, on one diameter only, two teeth of the outer ring are positioned exactly opposite two teeth of the inner ring. One of these rings may be permanently magnetized or provided with a winding which magnetizes the ring so that a magnetic field is produced which causes alignment of two oppositely positioned teeth of the rings. This transmission constitutes the magnetic analogue of the mechanical hypocycloid gear in which only two teeth of the outer ring mesh at any one time. Whereas extremely high stresses for power transmission can be employed with gears, only very small shear forces can be transmitted by magnetic transmissions with poles on either side of an airgap which enables contactless running. In consequence, only small torques can be transmitted by any known magnetic transmissions, so that they cannot be considered for the transmission of larger powers. Moreover, this kind of transmission is possible only for very high transmission ratios of, for example, 1:20 or 1:50, but not transmission ratios of 1:2 or 1:5, so that this kind of transmission does not present a usable substitute for gears for the transmission of larger powers.

A frictionless magnetic transmission is also known, in which ferromagnetic coupling elements are separated by a predetermined distance from a driving and a driven part, the whole assembly being accommodated in a housing which provides a closed magnetic circuit. In this form of transmission, only one coupling element at a time carries the maximum magnetic flux, so that therefore only the principle of the stepping gear is applied, in which only a very small region of the circumference is actively employed for the transmission of torque at any one time. This magnetic transmission also has the disadvantages already mentioned.

Furthermore, a magnetic transmission is known, in which a driven magnetic system is coupled to a driving magnetic system by fields of magnetic force and the transmission ratio is formed by branching of the magnetic flux in a ferromagnetic coupling member. In a simple construction the direction of rotation of the output of this transmission is not defined. Only by means of a plurality of systems which are angularly displaced and axially juxtaposed, can the direction of rotation of

such transmissions be predetermined. The latter, however, has the disadvantage that the effective flux is at any one time confined to a region of not more than ⅓ of the axial length and that the magnetic paths become very large; for this reason again they are not suitable for the transmission of large powers.

GENERAL DESCRIPTION OF THE INVENTION

By comparison, it is the purpose of the invention to provide a magnetic transmission, capable of transmitting large mechanical powers with minimum material cost and any desired transmission ratio, and particularly at low transmission ratios.

In one embodiment this is accomplished by an arrangement, whereby the conductors are formed in such a manner, that the magnetic flux through one pole of the pole ring with the smaller number of poles is distributed over at least two poles of the pole ring with the larger number of poles. In a practical embodiment according to the invention of this type one conductor has at least two pole faces which face the pole ring with the larger number of poles.

In another embodiment of the invention at least one pole face of the conductor which faces the pole ring with the larger number of poles is at least as wide as the distance between two adjacent pole centers of this pole ring.

Preferably the three elements of a magnetic transmission according to the invention are in the form of three concentric rings. If, with this arrangement, the number of conductors equals twice the number of poles of the inner pole ring rotating at the higher speed, then the alternating magnetic field which the driving pole ring generates in each conductor can be transformed into a two-phase, circular and substantially sinusoidal rotating field with phase symmetry, so that the conditions which apply to the driven pole ring are the same as for the rotor of a three-phase induction motor.

The radial flux, which in an electric motor is provided by windings, is generated by permanent magnets of a rotating pole ring in these magnetic transmissions. By the use of high quality magnetic materials, the same induction as in the case of an electric motor can be provided, so that the transmittable torque correspond to those of electric motors having rotors of the same size. By contrast with simple motors, magnetic transmissions may also be built in synchronous form, if the driven pole ring is not in the form of an induction rotor (squirrel cage rotor) as in the case of an electric motor, but in the form of a permanent magnet rotor. This is not possible in the case of an electric motor, since the rotor would have to be accelerated to its full speed in 1/50 (or 1/60) of a second, whereas the magnetic transmission is driven and therefore accelerated over a longer period at a lower angular acceleration.

By providing two permanent magnet pole rings for the input and output, all eddy current losses are eliminated; in the case of an electric motor, these usually account for more than 50 percent of all losses. The only source of losses left is the iron loss in the conductors, which however only amounts to a few watts per kilogram of iron. The efficiency of the new magnetic transmission, if both pole rings contain permanent magnets, is therefore nearly unity, which is of decisive importance, having regard to the large powers which are to be transmitted.

The main area of application of the magnetic transmission is the conversion of the speed of mains-fed induction motors whose maximum speed is limited. Since power is the product of torque and speed, the volume of the driven rotor, by comparison with rotors of electric motors of equal rating, will be smaller than that of the electric driving rotor, in inverse proportion to the speed ratio.

If the number of the conductors is three times that of the poles of the fast pole ring with the smaller number of poles, it is also possible to produce a three-phase circular rotating field, which however is of advantage only where the degree of lack of uniformity of rotation which is dependent on the number of poles could be objectionable.

It is emphasized that in a magnetic transmission according to the invention, any of the three elements can be the driving and any of the three elements the driven element. It is further emphasized that one of the three elements must be held stationary or supported by a stationary system, which is usually done by supporting it by a housing element.

Transmissions according to the invention may be built up in the form of a cylinder, superimposed by a hollow cylinder and a further hollow cylinder surrounding them. The inner and outer pole rings may also be arranged relatively eccentrically. The airgaps need, however, not necessarily lie on cylindrical envelopes; they may also lie on conical envelopes, spherical surfaces and planes. In the latter version the arrangement consists of three discs, and it is not necessary for the rotating discs to be geometrically coaxial.

As a rule, a substantially sinusoidal rotating field is desired, since this ensures a high degree of uniformity of rotation. By simple, geometric means the characteristics of the rotating field may be influenced in such a way that stepwise rotation results, i.e., that angular oscillations are superimposed on the rotation. The limiting case is the conversion of rotation into a pure oscillation without rotation of the driven pole ring. Irregular and oscillator movements are often desired in mixing, grinding and conveying devices. A preferred field of application of the new magnetic transmissions is in drives for runners for pumps for liquids or gases. These runners must be driven at high speeds and the high speed pole ring of the magnetic transmission is therefore assembled into a unit with the impeller of the pump, the low speed pole ring being driven by the motor. In this way the third element, the conductor ring, is separated from the pump runner by a wall, so that hermetic sealing is effected. Hermetically sealed pumps with thin-walled, magnetically permeable separating walls are known. The invention enables the construction of pumps in which the walls through which magnetic forces are fed into the interior of the pump can be made of any desired thickness, so that hermetically sealed pumps made with magnetic transmissions in accordance with the invention can be manufactured for pressures which can be practically as high as desired and at which thin-walled, magnetically permeable separating walls of magnetic couplings would tear. For such pumps also magnetic transmissions with a transmission ratio $m=1$ are meaningful.

Since the torque is transmitted by a rotating magnetic field, the new magnetic transmissions can also be combined with magnetic bearing systems, so that besides contactless transmission of the torque, the bearing can also be contactless, except for a support at the center of a spherical section.

The magnetic transmission in accordance with the invention may be classified according to their geometric parameters; these include the number of poles of the low speed and high speed pole ring, the number of conductors, the number of pole areas of the conductors, as well as the spacing of the pole areas of adjacent conductors. Accordingly, let, by definition:

- p-Number of poles of the low speed pole ring (large number of poles)
- q-Number of poles of the high speed pole ring (small number of poles)
- m-Transmission ratio of the transmission, where m always = p/q
- r-Number of conductors
- r_p=Number of pole areas of the conductor facing the low speed pole ring
- r_q=Number of pole areas of the conductor facing the high speed pole ring
- j=Spacing of the pole centers of the pole areas facing the low speed pole ring, of different adjacent conductors, relative to the spacing of the centers of adjacent poles of the low speed pole ring.

The highest transmission ratio is always given by the ratio

$$m=p/q.$$

In this case the conductor ring formed by conductors (17) is held stationary. If, instead of the conductor ring, the low speed pole ring is held stationary, then, for the same embodiment, we get the lower transmission ratio of the conductor ring to the high speed pole ring,

$$m_1=-(m-1).$$

Using the same transmission, we get the lowest transmission ratio when the high speed pole ring is held stationary. We then get between the low speed pole ring (11) and the conductor ring, the transmission ratio

$$M_2=m/m-1.$$

All the transmissions in accordance with the invention thus enable three transmission ratios to be obtained, the direction of rotation for the transmission ratio m changing in the case of the ratio m_1. These speed ratios are exactly true only where two pole rings are magnetized by permanent or electromagnets. If one of the pole rings is in the form of a hysteresis magnet or a short-circuited rotor like the rotor of an electric motor, then the slip of such a pole ring is superimposed on the transmission ratio. In magnetic transmissions according to the invention, it is not necessary for the driving portion to be provided with permanent or electromagnets. It is also permissible for the driven pole ring only to effect the magnetization. According to a preferred feature of the invention, a claw pole construction is provided for the magnetic material, in which adjacent poles of the same polarity are short-circuited together by soft magnet rings, so that a large portion of the entire magnetic material is operative at all times.

As a result of the particular arrangement of the conductors conducting the magnetic flux between the pole rings the active magnetic material of the pole ring with the larger number of poles is almost completely utilized. This has the effect that the torque transmitted by the magnetic transmission is much higher than the torque transmitted in the known magnetic transmission, in which only that portion of the active magnetic material, which corresponds to the transmission ratio, contributes to the torque transmission.

Some advantageous forms of the magnetic transmissions will now be described with reference to the drawings, as well as some typical applications of such magnetic transmissions, and these will also be described in combination with a magnetic bearing arrangement for one of the pole rings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a preferred form of the magnetic transmission with odd series cascading of the transmission ratio m, in the same direction of rotation.

FIG. 2 shows another preferred form with odd series cascading of the transmission ratio m, in the opposite direction of rotation.

FIG. 3 shows a further preferred form with even series cascading of the transmission ratio m, in the same direction of rotation.

FIG. 4 shows even series cascading of the transmission ratio m, in the opposite direction of rotation, analogous to FIG. 2.

FIG. 5 shows a spherical construction of the magnetic transmission according to the invention, preferably for pumps.

FIG. 6 shows a developed view of a metallic strip for producing the conductors according to the invention.

FIG. 7 shows different forms of a magnetic transmission according to the invention, in which the magnetic flux from the permanent magnets is conducted to the airgap by magnetically conductive pole shoes.

FIG. 8 shows an example of the system of motion in a magnetic transmission according to the invention, in accordance with FIG. 1.

FIG. 9 shows the construction according to the invention of the magnetic transmission for a transmission ratio of 1:1 and (−1):1ay.

FIG. **10** shows further forms of the magnetic transmissions according to the invention.

FIG. **11** shows a short-circuited rotor in a magnetic transmission according to the invention with a special construction of conductor ring.

FIG. **12** shows a stirring device with a stepdown magnetic transmission according to the invention.

FIG. **13** shows a borehole pump with a step-up magnetic transmission according to the invention.

FIG. **14** shows a pump with a magnetic transmission according to the invention.

FIG. **15** shows a turbocompressor drive with a magnetic transmission according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGS. **1***a*–**1***d* show forms of the magnetic transmission according to the invention, to which the mathematical law

$$m=4k+1$$

applies, where k is zero or any desired natural number. Moreover, for all the transmissions shown in this figure

$$r=4 \text{ and}$$

$$j=0.5$$

were chosen.

Then we get for

FIG. **1***a* with $k=1$ $m=5$

FIG. **1***b* with $k=2$ $m=9$

FIG. **1***c* with $k=3$ $m=13$

Reference numeral **1** designates the low speed pole ring with the salient north poles **12**, which, in FIGS. **1***a, b, c* are m in number, and the salient south poles **13** which, in FIGS. **1***a, b, c* are also m in number. Reference numeral **14** designates, in FIGS. **1***a–d*, the high speed pole ring, the reference numeral **15** in each case designating the north pole and **16** the south pole.

In FIGS. **1***a*–**1***c*

$$q=2$$

was selected, i.e., the lowest possible value. Then, in accordance with the invention, the number of conductors **17** is preferably twice this value, viz 4.

In the embodiments shown in FIGS. **1***a*–**1***d* each particular conductor has a plurality of pole faces facing the outer pole ring, i.e., in the embodiments shown in FIGS. **1***a* and **1***d* two each, in those shown in FIG. **1***b* three and in those shown in FIG. **1***c* four.

For the example in which the transmission ratio

$$m=5,$$

FIG. **1***d* shows an arrangement which, compared with FIG. **1***a*, is characterized by twice the number of elements **12, 13, 15, 17**, the transmission ratio m being the same.

In accordance with the invention, any desired integral multiple can be selected instead of the doubling described. It will be seen that the 4-pole arrangement of FIG. **1***d* has arisen from developing the circumference of FIG. **1***a* twice, so that the same laws must apply to the aforesaid multiples as to the simplest arrangement, i.e., the 2-pole arrangement, whose operation will be described in greater detail with reference to FIG. **8**.

FIGS. **2***a*–**2***c* show other preferred arrangements of the magnetic transmission according to the invention, which follow the mathematical law

$$m=-(4k-1),$$

where k is any desired natural number, but not zero.

Furthermore, in this figure,

$$r=4$$

and

$$j=1.5$$

were selected for all the transmissions shown.

Then we get for

FIG. **2***a* with $k=1$ $m=-3$

FIG. **2***b* with $k=2$ $m=-7$

FIG. **2***c* with $k=3$ $m=-11$

In FIGS. **2***a*–**2***c* the same reference numerals are used for parts performing the same functions, as in FIGS. **1***a*–**1***d*.

FIGS. **3***a*–**3***d* show further preferred forms of the magnetic transmission according to the invention, which follow the mathematical law

$$m=2(k+1),$$

where k is zero or any desired natural number. Furthermore, in these figures,

$$r=4$$

and

$$j_1=0.5 \text{ and } j_2=2.5$$

were chosen.

As per the definition, by j_1 is to be understood the smallest ratio j which occurs three times per magnetic transmission, and by j_2 the largest ratio j which occurs once per magnetic transmission, of this group of magnetic transmissions characterized by the above formula, which is characterized by the number of conductors

$$r=4.$$

Then we get for

FIG. **3***a* with $k=0$ $m=2$

FIG. **3***b* with $k=1$ $m=4$

FIG. **3***c* with $k=2$ $m=6$

FIG. **3***d* with $k=3$ $m=8$

In FIGS. **3***a*–**3***d* the same reference numerals are used for parts performing the same functions, as in FIGS. **1***a*–**1***d*.

FIGS. **4***a*–**4***d* show further preferred forms of the magnetic transmission according to the invention, which follow the mathematical law

$$m=-2(k+1),$$

where k is any desired natural number, but not zero.

Furthermore, in these figures,

$$r=4$$

and

$$j_1=1.5 \text{ and } j_2=3.5$$

were chosen

Then we get for

FIG. **4***a* with $k=1$ $m=-4$

FIG. **4***b* with $k=2$ $m=-6$

FIG. **4***c* with $k=3$ $m=-8$

FIG. **4***d* with $k=4$ $m=-10$

In FIGS. **4***a*–**4***d* the same reference numerals are used for parts performing the same functions, as in FIGS. **1***a*–**1***d*.

The number of the pole faces of each conductor, which, according to the invention, leads to the excellent results, depends only on the number of these conductors and of the number k. Therefore, the arrangements shown in FIGS. **1**a–**1**d, in which k can be zero or any natural number, the number of the pole faces on one conductor facing the pole ring with the higher pole number follow the mathematical law

$$r'_p=r/4(k+1),$$

while the arrangement shown in FIGS. **2**a–**2**c, where k is any natural number, follows the mathematical law

$$r'_p=r/4k.$$

The sum of the pole faces for the arrangements shown in FIGS. **3**a–**3**d follow the mathematical law

$$r_p=m-2,$$

while it is for those arrangements shown in FIGS. **4**a–**4**d

$$r_p=m;$$

where $r'_p=r_p/r$ respectively

$$r'_{p_1}=r_p/r \text{ and } r'_{p_2}=r_p/r+1,$$

inasfar as for r_p/r remains a rest.

FIG. **5** shows a magnetic transmission according to the invention in longitudinal section, in which the low speed pole ring consists of a ring magnet **51** and soft magnetic inserts **52** affixed thereto by adhesive, whose number corresponds to the number of poles of the magnet. They produce a periodic change of polarity in the stationary conductors **53**.

This acts on the high speed pole ring **54** which has the smaller number of poles and consists of a shaped magnetic part. In the present case, a spherical separator **55**, preferably of nonmagnetic material of low electrical conductivity, is arranged between the conductors **53** and the high speed pole ring **54**, whilst the high speed pole ring **54** forms a unit with a pump runner **56**. At the nadir of the separator, a column **57** is provided which terminates in a sphere and supports the pump runner **56** and **58** in the center of the separator **55**. The centers of the magnetic poles of the conductors **53** as well as those of the pole ring **54** are located at the point of intersection of a cone **59** with the concave and convex areas respectively forming the boundaries of the airgap, whereby a magnetic bearing is provided for the pump runner **56**. Number **60** shows an iron ring which increases the magnetic flux.

FIG. **6** is a developed view of a metal strip, which forms a spiral body **53** in accordance with FIG. **5**, when the strip is wound up. The poles **63** occupy only a portion of the circumferential region of the poles **64**. The connecting bridges **65** and **66** between the conductors **17** and **17'** are so narrow that they provide adequate mechanical strength but present no significant magnetic short circuit.

FIG. **7**a shows a plan view of a form of the low speed pole ring, oxide magnets **70** being provided between soft iron angles **71**. By this means it is possible to obtain greater flux density towards the airgap than can otherwise be achieved by means of sintered magnets.

FIG. **7**b shows a section through an externally rotating pole ring, which consists of a permanent magnet ring **73**, magnetized axially, and two symmetrically arranged shaped soft iron parts **74** and **74'**. The soft iron parts consist of connecting rings **75** and claw poles **76** which are preferably tapered. The fewer of the poles **76** are operative at any one time, the larger must be the cross section of the circuit closing rings **75**, so that the entire circumferential range of the magnet **73** is utilized.

FIG. **7**c shows a similar construction of a ring with claw poles, in which again a plurality of axially magnetized magnet rings **73'** are arranged between claw pole rings **74'**. The adjacent claw poles **76'** form a north pole and the adjacent claw poles **77** form a south pole. This arrangement makes possible the use of materials of extremely high coercive force, particularly Samarium or Cerium based materials, which require the use of magnets extending over an extremely small range in the direction of magnetization.

The transmissions in accordance with the invention, which have been particularly described with reference to FIGS. **1–4** are constructed in the form of two-phase, circular or ellyptical rotating field systems, in which the four conductors **17** each produce two alternating fields, relatively displaced in time by $\pi/2$, when one of the two pole rings is moved relative to the conductor ring.

FIGS. **8**a–c show details of the magnetic flux for three particular positions of the two pole rings, which in this case are movable, relative to the fixed conductor ring which consists of the totality of the conductors **17**.

FIG. **8**a shows the high speed pole ring **14** in a horizontal position with its north pole **15** on the left; the lines of force from it traverse the conductor **17**a, returning to the south pole **16** of the inner pole ring, via three south poles **13**, the middle one of which is marked with an x, and the ferromagnetic envelope of the pole ring **11** as well as its north pole **12** and the conductor **17**b. The relative position of the pole rings which is fixed in this way, is stable.

If now, as is shown in FIG. **8**b, the pole ring **11** is moved clockwise by half a width of its pole face, then the magnetic flux branches into the conductors **17**a/**17**b and **17**a '/ and *17b'*; in this way the pole ring **14** is subjected to a force which also tends to turn it clockwise. The two pole rings **11** and **14** reach their next stable position in the position shown in FIG. **8**c; the high speed pole ring **14** will then have traversed an angle which is larger by the factor m=9 than the low speed pole ring **11**.

The movements described are determined by the position of the pole faces **21** of the conductors **17** which face the low speed pole ring and the position of the pole faces **22** of the conductors which face the high speed pole ring. The pole faces **21** of one and the same conductor always each connect poles of the same polarity with each other; their angular spacing is thus determined by the angular spacing **27** of the centers **25** and **25'** of adjacent poles of the low speed pole ring **11**. Apart from the ratio of numbers of poles of the two pole rings **11** and **14**, the angular spacing **24** of the centers **23** and **23'** of adjacent conductors **17** and **17'** primarily determines the transmission ratio and direction of rotation of the transmission. In the preferred embodiments described with reference to FIGS. **1**a to **4**d it was also shown that this angular spacing mathematically defines the laws governing entire groups of transmissions.

In the foregoing description of the movements which take place, it was assumed that the conductor ring is kept stationary. However, if instead the low speed pole ring **11** with the larger number of poles is kept stationary, then in all cases we get a transmission ratio

$$m_1=-(m-1).$$

Finally, if the high speed pole ring **14** with the smaller number of poles is kept stationary, then we get between the conductor ring and the low speed pole ring a transmission ratio

$$m_2=m_1/(m-1).$$

Thus all the magnetic transmissions make it possible, in principle, to provide three different transmission ratios by means of a single transmission unit, by selecting one of the elements **11**, **14** or **17** for coupling to the stationary housing. This advantage can be made use of in full measure by the coaxial construction of the magnetic transmissions described, in accordance with the invention.

The two magnetic transmissions shown in FIGS. **9**a and **9**b are characterized by the special case of the value of m=1.

In the examples drawn, a 4-pole form of construction has been chosen but this is not a significant in principle.

These transmissions have the principle of the two-phase rotating field construction in common with the examples shown in FIG. **1**a–**4**d, but do not constitute typical representatives of larger groups of transmissions. In both cases, the parameters referred to above as characteristics, have the following values:

$$p=q=8$$

$$r=r_p=r_q=16.$$

The difference between FIG. **9**a and **9**b resides in the fact that in the first case the conductors **17** are arranged radially, whereas in the second case the conductors **17**a and **17**a' are arranged in a relatively crossed formation, and likewise the conductors **17**b and **17**b', so that, in accordance with the manner of operation explained with reference to FIG. **8**, the direction of rotation of the pole ring **14** in FIG. **14**b is opposite to that in FIG. **14**a.

FIGS. **10**a–**10**d show further possible forms of construction of magnetic transmissions according to the invention; from each of the forms shown, a series of them can again be deduced. However, since these do not find much application, this has not been done.

FIG. **10**a shows a magnetic transmission with a three-phase rotating field. When the conductor **17'** is in full alignment with the north pole **12'**, the conductor **17''** is still only in partial alignment with the north pole **12''**, so that the flux density in this pole is lower. There is no flux density yet in the conductor **17'''**. Its flux density increases at the same rate as that at which the flux density in the conductor **17'** decreases.

FIG. **10**b shows the same kind of construction, in which the conductors **17'** and **17'''** are practically identical to the conductors in FIG. **10**a, whilst the conductor **17''** offers twice the pole width to the low speed pole ring. The conductors **17'** and **17'''** produce a pure two-phase operation. The conductor **17''** serves the purpose of increasing the flux, since the north pole **12'** is positioned opposite the pole **17''** for as long as the two conductors **17'** and **17'''** are successively so positioned.

FIG. **10**c shows a construction with four conductors, three conductors **17**, **17'**, **17''** of which are at any one time positioned opposite a pole of the low speed pole ring, whereas the fourth conductor **17''''** is at any one time positioned opposite two poles of the same polarity of the low speed pole ring, whereby the airgap flux density is reduced; this leads to less leakage and a greater factor of utilization.

FIG. **10**d shows an arrangement for the transmission ratio $m=2{:}3$. The four-pole high speed pole ring **14** receives, via the conductors, a nonuniform rotating field which is produced by the six poles of the low speed pole ring **11**. The conductors **17** and **17'** produce a two-phase rotating field in the opposite direction, while the remaining conductors serve the purpose of closing the magnetic circuit and only offer alternating magnetic fields for torque production. The degree of nonuniformity, which is substantial with this form of construction in particular, can be put to advantage in mixing and emulsifying devices. If a high degree of uniformity is desired, this can be accomplished by a helical arrangement of poles and conductors in the manner known in relation to the armatures of electric motors.

FIG. **11** shows a short-circuited rotor **90** with the squirrel cage winding, in section, only one half symmetrical about the axis of rotation **92** being shown. The outer pole ring consists of two concave rotational bodies **93** and **93'** of permanent magnet material, which are held in an iron ring **94** for completing the magnetic circuit. The stationary soft iron pole **95** is of inwardly converging construction, so that the flux density which in the airgap **96** is limited by the quality of the magnets, is increased in the airgap **97**.

FIG. **12** shows a stirring mechanism which is driven by a stepdown magnetic transmission in accordance with the invention. The inner, high speed pole ring **102** is mounted on the motor shaft **101** of the motor (shown broken); the conductor

ring is made up of laminar conductors **103** and, with its rotating field, drives the low speed outer pole ring **106** with the stirrer **105**, whose hub is supported on a spherical bearing **107**. A conical sheath **108** serves to support the spherical bearing, the sheath being hermetically joined to the separating membrane **109**, which envelopes the conductors **103** and seals the motor against the liquid space of the stirring mechanism.

FIG. **13** shows a borehole pump, in which a motor **111**, which is accommodated in a hermetically sealed housing **110**, drives the pole ring **112** of a magnetic transmission with the conductor ring **113**. The high speed pole ring **115** rotates in a conical separating wall **114**, the pole ring being conical and provided with helical channels **116**, which convey a small quantity of liquid into the magnetic "airgap." This results in hydrodynamic lubrication, so that further bearing can be dispensed with.

Water is admitted through the orifices **118**! The cap **119**, which also rotates, prevents the ingress of sand into the space formed by the separating wall. Since the velocity pressure of the pump varies with the square of the speed, a pump runner **117** in a construction according to the invention with a transmission ratio of 3:1 takes the place of a total of nine conventional runners, with the result that the pump is considerably simplified.

FIG. **14** shows a magnetic transmission according to the invention, in accordance with FIG. **5** for increasing the speed of a pump runner **123**, whereby the pump may be constructed in a very compact manner. The conductors **17** are made up of foils arranged one above the other; the pole ring **120** consists of radially magnetized permanent magnets which are joined to each other in magnetically conducting manner by the ring **121** for closing the magnetic circuit. The pole ring **122** is constructed in the manner described with reference to FIG. **5** and drives the pump runner **123**. A separating wall **124**, of spherical form, is provided for hermetically sealing the interior of the pump. The motor **125** shown drives the outer pole ring via the disclike wheel **126**.

FIG. **15** shows a turbomachine of the same kind as that of FIG. **14**, but designed as a compressor, particularly for refrigerants. In these compressors, hermetic sealing is of very great importance, since refrigerant is always lost through the shaft seals. Since compressors run at appreciably higher speeds than pumps, the invention provides for the conductors **130**a construction of extremely thin laminae with minimum hysteresis and eddy current losses, such as those used in sound frequency transformers. Pole shoes **132** of soft magnetic material are provided between the permanent magnet pieces **131** of the outer pole ring and the conductors **130**.

What is claimed is:

1. A magnetic transmission comprising a first pole ring having at least two magnetic poles of alternating polarity, a second pole ring comprising a plurality of individually separate soft magnetic conductors of high magnetic conductivity, a third pole ring comprising at least twice as many magnetic poles of alternating polarity as said first pole ring, said second pole ring being positioned between said first and said third pole rings and separated therefrom by an airgap, each said conductor of said second pole ring having a salient pole facing one pole of said first pole ring and at least two salient poles facing poles of said third pole ring having the same polarity, two of the three pole rings being mounted for rotation, and one of said first or said third pole rings having magnets whereby when two of the pole rings are rotated relative to the remaining pole ring, a cyclic alternating magnetic flux is created in said conductors having the frequency of at least the frequency of rotation of said first pole ring relative to said third pole ring.

2. Magnetic transmission according to claim 1, characterized in that the pole ring (11) with the largest number of poles and the ring containing the conductors (17) are hollow cylinders disposed within each other.

3. Magnetic transmission according to claim 2, characterized in that the pole ring (14) with the smallest number of

poles is surrounded by a cylinder whose axial length coincides approximately with the other pole ring (11) and that it forms an airgap with the ring which contains the conductors (17).

4. Magnetic transmission according to claim 1, characterized in that the pole rings (11) and (14) are disc-shaped and form a plane airgap with the ring which contains the conductors (17), whereby either the outer pole ring is concave and the pole face of the conductor which faces the pole ring is convex or the inner pole ring is convex and the pole faces of the conductors which face said pole ring are concave.

5. Magnetic transmission according to claim 1, characterized in that at least one the airgaps between the rings (11 or 14) and the ring containing the conductors (17) is bordered by concentric spherical surfaces.

6. Magnetic transmission according to claim 1, characterized in that at least one of the airgaps between the rings (11 or 14) and the ring containing the conductors (17) is bordered by concentric conical areas.

7. Magnetic transmission according to any one of claim 1, characterized in that the number of conductors (17) is twice the number of poles (15, 16) of the pole ring (14) with the smallest number of poles.

8. Magnetic transmission according to any one of claim 1, characterized in that the number of conductors (17, 17″, 17‴) is three times that of the poles (15, 16) of the pole ring (14) with the smallest number of poles.

9. Magnetic transmission according to claim 7, characterized in that the width of the pole faces (28) of the conductors (17) in the circumferential direction is less than or equal to half of the spacing between poles of the same polarity.

10. Magnetic transmission according to claim 9, characterized in that the angular distance (24) between the centers of the pole faces of adjacent conductors (17, 17′) is equal to k times the angular distance between poles of the same polarity (12) including the width of the pole faces (28) in the circumferential direction, where k may be either zero or an integral number.

11. Magnetic transmission according to claim 1, for the transmission ratio $1:(4k+1)$, where k is either zero or a natural number, characterized in that the angular distance (24) between the centers (23, 23′) of the pole faces (21) of adjacent conductors (17, 17′) which face the pole ring (11) with the largest number of poles, equals half the distance (27) between the pole centers (25, 25′) of adjacent poles (12, 13) of the pole ring (11).

12. Reversible magnetic transmission according to claim 1, having a transmission ratio of $1:(4k-1)$, where k is a natural number, characterized in that the angular distance (24) between the centers (23, 23′) of the pole faces (21) of adjacent conductors (17, 17′) facing the pole ring (11) with the larger number of poles corresponds to 1.5 times the angular distance (27) between the centers of adjacent poles.

13. Magnetic transmission according to claim 1, for the transmission ratio $1:2(k+1)$, where k equals zero or a natural number, characterized in that the centers (23, 23′) of the pole faces (21) of adjacent conductors facing the pole ring (11) with the larger number of poles on the one hand are relatively angularly spaced by an angle (24) corresponding to 2.5 times the angular distance (27) between the centers of poles of the same polarity, and that the angular distance between the centers of adjacent pole faces of different conductors on the remainder of the circumference corresponds to half the angular distance between the centers of adjacent poles of opposite polarity.

14. Reversible magnetic transmission according to claim 1, for the transmission ratio $1:2(k-1)$, where k is a natural number, characterized in that the centers (23, 23′)of the pole faces (21) of adjacent conductors facing the pole ring (11) with the larger number of poles on the one hand are relatively angularly spaced by an angle (24) corresponding to 3.5 times the angular distance (27) between the centers (25, 25′) of poles of the same polarity, and that the angular distance between the centers of adjacent pole faces of different conductors on the remainder of the circumference corresponds to half the angular distance between the centers of adjacent poles of opposite polarity.

15. Magnetic transmission according to claim 1, characterized in that at least one of the pole rings (11, 14) is separated from the ring containing conductors (17) by a hermetically sealing but magnetically permeable wall (55).

16. Magnetic transmission according to claim 5, having an airgap disposed on a spherical plane, characterized in that the salient poles of the ring containing conductors (17) and those of the pole ring (14) having the smaller number of poles are disposed on the curved surface of a cone, whose apex passes through the center of the support, whereby the pole ring is being replaced into the rotation position after having tumbled.

17. Torque transmission device according to claim 1, characterized in that both pole rings (11, 14) have the same number of poles.

18. Magnetic transmission according to claim 1, characterized in that one of the pole rings (11 or 14) is constructed like the squirrel cage rotor of an electric motor.

19. Magnetic transmission according to claim 1, characterized in that one of the pole rings (11 or 14) is made of permanent magnet material whose direction of magnetization is readily reversible.

20. Magnetic transmission according to claim 1, characterized in that the conductors (17, 17′, etc.) are interconnected by narrow bridges.

21. Magnetic transmission according to claim 1, characterized in that the conductors (17) are made up of mutually insulated metal laminae laid on top of each other.

22. Magnetic transmission according to claim 1, characterized in that the ring containing the conductors (17) is built up from a helically wound metal strip.

23. Magnetic transmission according to claim 1, characterized in that the ring containing the conductors (17) is in the form of a metal strip, wound into a helix of double conical or double spherical configuration.

24. Magnetic transmission according to claim 1, characterized in that the metal foils (95) follow the curved surface of a cone.

25. Magnetic transmission according to claim 1, characterized in that the poles (12, 13 or 15, 16) or the conductors (17) lie on helices.

26. Magnetic transmission according to claim 1, characterized in that the common area of one of the pole rings (11, 14) and the ring made up of conductors (17) is in the form of a hermetically sealing wall and that this wall or the pole ring which rotates opposite this wall or the ring containing conductors have spiral grooves in which a hydrodynamic pressure is built up as a result of the medium disposed between the two elements being dragged along with them, the pressure causing adequate lubrication of the areas which glide past each other.

27. Magnetic transmission according to claim 1, characterized in that one of the pole rings (11 or 14) consists of an axially magnetized ring magnet (73) into which claw poles (76) extend and in which the rings (75) connecting the claw poles are of soft magnetic material and have a cross section which is adequate for conducting the entire magnetic flux to the claw pole which is operative at any given time.

28. Magnetic transmission according to claim 1, with a pole ring (11 and/or 14), characterized in that the pole ring consists of a plurality of axially magnetized permanent magnet rings (73′), which enclose soft iron rings (74) with claw poles (76, 77) between them.

29. Centrifugal pump for liquids or gases, characterized in that a motor (111) drives a pole ring (112) which DRIVES a pole ring (115) in the form of a section of a cone, via a magnetic conductor ring (113) intermediate and spaced from said pole rings by airgaps, spiral channels (116) being provided on the cone facing the adjacent airgap.

30. Centrifugal pumps according to claim 29, characterized in that the motor (111) and the pole ring (112) are hermetically sealed in a housing (110) by a separating wall (114).

31. Centrifugal pump according to claim 29, characterized in that a pump runner (117) is connected to the pole ring (115), with its suction side towards the latter.

32. Centrifugal pump with a magnetic drive according to claim 1, characterized in that the high speed pole ring (54) is of spherical construction and is unitary with the runner (56) and that the centers of the magnet poles of the pole ring (54) and of the conductors (53) lie on the curved surface of a cone (59) and that the runner is axially supported at the center of the sphere in a manner known per se.

33. Centrifugal pump according to claim 32, characterized in that the conductor ring is made up of a metal foil spiral.

34. Centrifugal pump with magnetic transmission according to claim 1, characterized in that the low speed pole ring (120) forms a hollow cylinder and drives the pole ring (122) via conductors (17) assembled from laminar metal discs.

35. Pump according to claim 34, characterized in that the conductors (130) lie between two concentric spherical shells.

36. Pump according to claim 34, characterized in that the volume of the magnetic material (120, 121) of the iron pole ring is many times the volume of the magnetic material (122) of the low speed pole ring.

37. Pump for liquids and gases with magnetic transmission according to claim 1, characterized in that the spherical separator (134) is made of nonmetallic material.

38. Magnetic transmission according to claim 1, particularly for driving turbine runners, characterized in that magnets with Samarium or Cerium are used as the permanent magnet material.

39. Magnetic transmission according to claim 38, particularly for driving turbine runners, characterized in that only the high speed pole ring carries Samarium or Cerium magnets.

40. Magnetic transmission according to claim 1, whereby at least one pole ring consists of one axially magnetized permanent annular magnet and of claw poles connected with the annular magnet by connection rings (75), characterized in that the cross section of the iron of each connection ring has such an area that the total magnetic flux of the annular magnet is transmitted without losses to the poles, which are in correlation with the conductors.

41. Magnetic transmission according to claim 40, characterized in that the cross sections of the connection rings (75) have the same relation to the mean cross sections of the claws (76, 77) as the largest distance between adjacent pole faces of the conductor to the pole distance of the pole ring having the higher number of poles.

42. Magnetic transmission according to claim 1, characterized in that the minimum distance of the pole faces on the same side of the same convector is twice as large or larger as the distance of the pole centers of the pole ring facing the above-mentioned pole faces.

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