

DISK STORAGE DRIVE

The present invention relates to magnetic-disk storage devices in general, and to a magnetic-disk storage drive in particular.

05 As used in this Specification (including the Claims thereof), the term "magnetic disk storage device" means a device in which bits representing data are magnetically stored in circular tracks on rigid or flexible disks which are rotated at relatively high
10 speeds. Bits are inscribed or read by a read/ write head which must be accurately positioned relative to the particular track which is being inscribed or read.

Data storage disks are suitable for storing large data quantities, which are written or read out with
15 the aid of a magnetic head arrangement if the storage disk is rotated with respect to the magnetic head arrangement. When writing or reading out data it has been found that problems sometimes occur due to dirt particles.

20 The object of the invention is to provide a driving mechanism for a data storage drive, which obviates such problems during data input and output.

The invention is based on the finding that the cause of the aforementioned problem can be dirt
25 particles emanating from the drive. The dirt may come not only from the bearings, but also from the winding with its highly structured surface. In particular, grease or dust particles can escape from the bearing

system. In general, the dirt particles from the bearing system have been held back by complicated and expensive seals, e.g. Ferrofluidic seals, which bring about a sealing action between fixed and rotary parts as a result of a combined action of magnetic fields acting there, together with lubricant emulsions containing magnetically conductive particles.

According to a first aspect of the invention, there is provided a magnetic-disk storage device (as herein defined) comprising:

means defining a contaminant-free housing accommodating at least one rotary magnetic-data storage disk;

a brushless d.c. motor having an annular stator surrounding a bearing tube, a rotor shaft journaled in a rotor bearing in said tube, and a cup-shaped rotor comprising a permanent magnet and secured to the rotor shaft for rotation therewith, said rotor surrounding the stator and spaced therefrom by a cylindrical air-gap and extending axially beyond the stator, the motor being mounted with the closed end of the rotor located in said contaminant-free enclosure; and

means connecting the storage disk directly to the rotor or rotor casing of the motor for rotation therewith;

wherein a labyrinth seal defined between a stationary first element and a second element rotatable with the rotor is located between the rotor bearing and said air-gap to prevent contaminant

particles from the rotor bearing entering the air-gap.

According to a second aspect of the invention, there is provided a driving mechanism for a magnetic-disk storage device as defined in Claim 1, said
05 mechanism comprising:-

a brushless d.c. motor having an annular stator surrounding a bearing tube, a rotor shaft journalled in a rotor bearing in said tube, and a cup-shaped
10 rotor comprising a permanent magnet and secured to the rotor shaft for rotation therewith, said rotor surrounding the stator and spaced therefrom by a cylindrical air-gap and extending axially beyond the stator, the motor being suitable for mounting with the
15 closed end of the rotor located in said contaminant-free housing; and

means to connect the storage disk directly to the rotor or rotor casing of the motor for rotation therewith in the contaminant-free enclosure;

20 wherein a labyrinth seal defined between a stationary first element and a second element rotatable with the rotor is located between the rotor bearing and the air-gap to prevent contaminant particles from the rotor bearing entering the air-
25 gap.

The labyrinth seals make it possible to prevent,

the risk of dirt particles passing from the inside of the motor into the area of the data storage disk, so that no problems occur when writing or reading out data.

05 Suitably, the rotatable element of the labyrinth seal defines a groove into which the stationary element extends. Alternatively, the labyrinth seal can be formed by stationary elements which interleave with rotatable comb-like projections constituting
10 rotational elements. Preferably, the comb-like projections have unequal spacings and the said stationary elements are of a different thickness from said rotatable elements.

 Suitably, the stationary element is part of the
15 stator. It is preferred that the labyrinth seal is located at one end of the bearing tube
 Advantageously, the end of the bearing tube can constitute the fixed element of the labyrinth seal.
 It is preferred that a further labyrinth seal defined
20 between a stationary first element and a second element rotatable with the rotor is located at the open end of the rotor to prevent contaminant particles passing from the air-gap to beyond the rotor with the open outer edge of the rotor constituting the rotatable
25 element of said further labyrinth seal.

 The, or each, labyrinth seal can have a

"U"-shaped part formed of a substantially radially extending gap joining two substantially axially extending gaps. The length (a) of one axially extending gap (measured in the axial direction) preferably is longer than the length (r) of the radially extending gap (measured in the radial direction). Also the width (d) of the axially extending gap (measured in the radial direction) preferably is smaller than r. Advantageously, a:d exceeds 10:1 and r:d does not exceed 2:1.

The driving motor is constructed as a commutatorless direct current motor of the external rotor type with a permanent magnetic rotor, the rotating rotor casing advantageously containing a one-part permanent magnetic ring or a permanent magnetic tape bent in annular manner with approximately trapezoidal radial magnetization via the pole pitch. The permanent magnet can in particular be a magnet combined with plastics or a so-called rubber magnet. Such magnets are formed from mixtures of hard ferrites and elastic material, particularly barium ferrite combined with elastomers.

The hub can be part of the rotating rotor casing. In this case, the magnetic shield is appropriately housed within the casing and the permanent magnet of the external rotor is surrounded in bell-shaped

manner by the magnetic shield, so that no magnetic stray fields can be propagated in the direction of the hub and the fixed storage plates located on the latter. In order to obtain magnetic shielding which
05 on the one hand requires a relatively small amount of shielding material, but on the other hand provides an inexpensive construction thereof for suppressing stray fields, the magnetic shield appropriately forms part of the magnetic yoke for the permanent magnet and is
10 constructed as a soft magnetic, cup-shaped, deep-drawn member, whose base has a coaxial recess in the core.

A driving mechanism of the aforementioned type generally comprises a speed control circuit and/or driving electronics which ensures the necessary
15 commutation. If the motor includes a shield ring connected to the stator, it is also possible to use the same for cooling the speed control circuit and/or the drive electronics, particularly if the semi-conductor components are kept in thermally
20 conductive contact with the shield ring.

On the end face remote from the hub, the rotor preferably has a fan for forming the ventilation area. Such a construction is not only particularly simple but also leaves the circumferential surface of the
25 rotor free as a braking surface for the brake which is frequently provided with such driving mechanisms.

It is preferred that the electric motor is a brushless d.c. reluctance-torque motor. In such a motor the stator has a stator winding which produces an alternating field, an angular-position detector, 05 and means for connecting said winding to a D.C. current source in dependence upon signals received from said detector, the magnetic resistance in the stator-part of the magnetic circuit being variable in dependence upon the angular position of the permanent 10 magnet rotor and the motor producing a reluctance moment which is offset in time relative to the electromagnetic torque produced such that, where the electromagnetic torque is zero, the reluctance moment is sufficient to move the rotor from said position of 15 zero electromagnetic torque.

The energized stator winding establishes a stator field which in cooperation with the rotor produces an electromagnetic-torque component having a magnitude which is a variable function of rotor angular position 20 and which, at fore-determined angular positions of the rotor, is of zero magnitude and thus incapable of starting the rotor from said predetermined positions. Accordingly if, when the motor is shut off, the rotor were to come to a complete stop in said predetermined 25 positions, it could not thereafter be restarted by mere application of current to the stator winding.

However, the rotor and stator are separated by an air gap and together form a magnetic circuit whose reluctance is a function of the angular position of the rotor thereby producing a reluctance-torque component, which varies as a function of rotor angular position and has a magnitude which is of a non-zero value at the aforesaid predetermined rotor angular positions of zero electromagnetic-torque component. the non-zero value of the reluctance-torque equipment precludes the rotor from becoming stuck at the said predetermined rotor angular positions during start-up of the motor.

A currently preferred type of brushless d.c. reluctance-torque motor is of the type disclosed in US Patents Nos. 3873897 and 3840761 (corresponding UK Patent Nos. 1392582 and 1436716) as well as in German Allowed Application AS 2225442. Using a brushless d.c. reluctance motor, it is possible to obtain a practically constant torque. This is possible in other motors only by using two separate windings which are electrically offset by 90° and through which usually pulses of opposite polarity must be fed. A brushless d.c. reluctance-torque motor is thus substantially simpler and less expensive since multiple windings and their associated electronic controls are omitted. Moreover, this type of motor is

of excellent operating quality and can be made more compact than other motors of similar ratings, so that the motor can be mounted within the centre holes of the disks and the bearing system can be made
05 sufficiently robust to assure a prolonged service life. In connection with this latter aspect it must be remembered that the disk hole diameter is standardized, so that overall smaller dimensions of the motor leave more room for larger bearings to be
10 used.

The following is a description, by way of example only and with reference to the accompanying drawings, of presently preferred embodiments of the invention. In the drawings:-

15 Figure 1 is a fragmentary view, in vertical section, illustrating a first embodiment of the invention;

Figure 2 is an enlarged fragmentary detail view, showing a modification of the embodiment in Figure 1;

20 Figure 3 is a view analogous to Figure 1 but illustrating another embodiment of the invention.

In the embodiment of Figure 1, the drive comprises a collectorless D.C. motor according to one of the two previously mentioned US motor patents or
25 the previously mentioned German Allowed Application. This motor has a permanent magnetic rotor 1 which surrounds a stator 2 (i.e., the motor is of the

external-rotor type). Stator 2 has a single-strand winding 3 which produces an alternating field and an auxiliary reluctance moment which, in co-operation with the electromagnetic torque, produces a total
05 torque of high constancy. Rotor 1 is journalled in stator 2 via a shaft 4 and a bearing system composed of two anti-friction bearings 20 and 21 which are spaced from one another axially of the shaft 4. The axis of rotation of the rotor 1 is designated with
10 reference character A.

Mounted directly on the outer periphery of the rotor 1 (i.e., not on the shaft 4) are two disks 5, 6 of the disk storage (there could be a single disk or more than two). Mounting is effected via rings 7, 8
15 and 9 which surround the motor 1; disks 5 and 6 are slipped over the rotor 1 (they have the usual centre holes) and retained between the rings 7, 8 and the rings 8, 9, respectively. Ring 7 is secured in suitable manner (e.g., via screws, welds or the like)
20 to the rotor 1; ring 9 has a flange portion 9a which overlaps the upper side of the rotor 1 and is secured thereto via a plurality of screws 10 (only one shown) which are spaced circumferentially about the axis A. Ring 9 presses against disk 6 and via the same presses
25 ring 8 against disk 5 which in turn is pressed against ring 7; thus, disks 5 and 6 can rotate only with, but

not relative to, the rotor 1.

In view of this direct connection of the disks 5, 6 to the rotor, and the position of the disks relative to the bearings in such a manner that the centre of gravity of the rotor 1 is located between the two bearings 20, 21, forces are transmitted substantially uniformly to both bearings and the disks 5, 6 rotate true and without, or substantially without, any vibrations or oscillations.

As mentioned before, disk storages are most usually operated in contaminant-free housings to protect them against contaminants. The drive according to the invention is particularly well adapted for such an application, because it can offer an anti-contaminant feature.

Motors, no matter how carefully manufactured, are inevitably a source of contaminant particles since lubricant, abraded metal particles are the like escape from the motor into the ambient atmosphere. In most applications this presents no problem, but it does do so under contaminant-free conditions. Under such circumstances, therefore, the motor and disks may be mounted on a base plate or surface 11 constituting a part of the wall or walls which bound the contaminant-free housing CR. Such mounting is effected in any manner known per se and requires no illustration.

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Attached to the rotor 1 and/or the ring 7 (or else integral with either of these) is another ring 12 of generally L-shaped cross-section, having a portion 12a which extends parallel to the plate 11 and defines
05 therewith a narrow gap 13 which communicates with the housing CR and with the air gap of the motor. The upper surface of portion 12a carries an annulus (one blade shown) of radially extending blades 14 which are arranged circumferentially of the ring 12. An
10 intermediate annular plate 15 is mounted above the plate 11, between the same and the lower disk 5; its radially inner edge portion overlaps but is upwardly spaced from the blades 14. Plate 15 is provided with one or more openings (one shown) in which a filter 16
15 is installed. The air-flow produced by the ring 12 and its blades 14 (acting as an impeller) causes a constant circulation of air through the filter or filters 16, so that any contaminants released by the motor become entrapped in filter(s) 16 and can do no
20 harm in the housing CR.

Two overlapping annular baffles 17, 18 on the stator 2 and rotor 1 are interposed in the air-gap between stator and rotor, defining with one another their own air-gap which serves to further retard the
25 escape of contaminants from the motor to the housing CR.

The embodiment of Figure 2 is the same as the embodiment of Figure 1, with the exceptions to be described, and therefore an illustration and discussion of the already familiar elements is not
05 needed.

Figure 2 differs from Figure 1 in the more elaborate seal which replaces the baffles 17, 18. This seal, arranged in the same location as the baffles in Figure 1, is a labyrinth seal formed by a
10 plurality of annular grooves 22 in the inner surface of rotor 1 into which a plurality of ribs 23 project from the stator 2. There is no contact of the ribs with the material bounding the grooves and the arrangement serves as a highly effective seal against
15 the escape of contaminants to the motor. Incidentally, it goes without saying that although the seal is shown radially outwardly of the winding 3, it could be located radially inwardly of the same or it could be located both radially inwardly and radially outwardly
20 to improve the effect still further.

Referring now to Figure 3, a driving mechanism 10 has a commutator-less direct current motor 11 with a rotor casing 14 fixed to rotor shaft 12 and concentric to the latter. A group of stator plates 58 carrying a
25 stator winding 29 forms part of the stator of motor 11. The stator plates 58 surround a bearing tube 44,

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which is part of a central support 22. Rotor shaft 12 is mounted in the bearing tube 44 with the aid of two bearings 48, 48', which are held in place by spaced retaining rings 50. A cup spring 52 bears against the bottom of bearing 48' and a retaining ring 54 is located on rotor shaft 12, so that bearings 48, 48' are axially spaced relative to one another. Together with an assembly flange 30 bearing tube 44 forms a one-piece die casting. As an alternative, the bearing tube 44 can be force fitted into a hub joined to flange 30.

Rotor casing 14 not only surrounds the group of stator plates 58, whilst forming a cylindrical air gap 15, but on the side remote from the assembly flange 30 is axially extended, providing a hub 70. Hub 70 is used for mounting and driving one or more (not shown) fixed storage plates having a central bore, whose diameter corresponds to the external diameter of hub 70. These plates can be commercially available 5½" or 8" plates. The illustrated construction makes it possible to adapt the diameter of hub 70 to the central bore of the storage plates without taking account of the necessary drive power of motor 11 and the resulting most favourable diameter of air gap 15. A printed wiring board 20 is housed in the free space 26 within hub 70. Wiring board 20 is circular and is

connected to the central support 22. Wiring board 20 carries the drive electronics and a speed control circuit, which includes inter alia a Hall IC 35 serving as a rotation position detector, output stage transistors 61 and a potentiometer 64. The soldered joints of the circuit components of the drive electronics and the speed control circuit, which are preferably produced in one operation, e.g. in a dip soldering process, are indicated at 65. Potentiometer 64 can be used inter alia for setting different operating points or for compensating component tolerances. It can be adjusted by means of a screwdriver via a not shown bore in flange 30 and one of the slots in stator plates 58. A line 31 leading to the printed wiring board 20 is connected to a d.c. voltage source. The side of wiring board 20 carrying the soldered joints 65 faces the base 40 of the rotor casing 14.

In this embodiment, rotor casing 14 is made from a magnetically non-conducting or poorly conducting material, e.g. an aluminium alloy die casting. A plurality of continuous segments or a one-part permanent magnet 56 is fixed to the inner surface of rotor casing 14 facing stator plates 58. The permanent magnet preferably comprises a mixture of hard ferrite, e.g. barium ferrite, and elastic

material and thus forms a so-called rubber magnet. It is trapezoidally or approximately trapezoidally radially magnetized via the pole pitch with a relatively small pole clearance. A magnetic yoke 57 is positioned between rotor casing 14 and permanent magnet 56. Magnetic yoke 57 also forms part of the magnetic shield.

It is in principle also possible to produce the rotor casing 14 from magnetically conductive material, particularly soft iron, it being constructed e.g. in the form of a deep drawn part. In such a case, there is no need for a separate soft iron yoke.

Magnetic yoke 57, including rounded portion 157, and shield ring 60 surround the magnetically active part of the driving mechanism 10 in bell-shaped manner. This effectively prevents the propagation of magnetic stray fields in the area of the fixed storage plates located on hub 70. The stray field cannot pass to any significant extent through the annular clearance between rounded portion 157, shield ring 60 and the recesses of shield ring 60 for the passage of the one or more Hall IC 35, because the soft magnetic shield rings draw said field towards them. In the represented embodiment, the fixed shield ring 60 is simultaneously used as a cooling plate for the output stage transistor 61 thermally conductively connected

to shield ring 60 by full surface engagement. If necessary, the cooling bodies of output stage transistor 61 can be electrically insulated from the shield ring 60, e.g. by means of a mica washer or the like. It is also possible to subdivide shield ring 60 as the function of the number of output stage transistors 61 in order to avoid such an electrical insulation.

Assembly flange 30 makes it possible to fit the driving mechanism 10 in a way not shown in Figure 1 to a partition 72 of the not illustrated contaminant-free housing. Partition 72 separates the ultra-clean area for receiving the fixed storage disks from the remainder of the interior of the apparatus. Any dirt particles, grease vapours or the like which may escape from bearing 48 are held back by labyrinth packings 90, 91. The labyrinth packings are formed by fixed and rotary parts, which coaxially interengage within the driving mechanism.

With respect to bearing 48, base 40 is constructed as a cylindrical bush 92 and extends into bearing tube 44. There is only a small gap 94, with a maximum axial extension for the escape of dirt particles from bearing 48, the action of labyrinth packing 90 being reinforced by the gap 95 formed by ring 93 and bearing tube 44.

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In the same way, magnetic yoke 57 forms a further labyrinth packing 91. Due to the fact that yoke 57 engages in an all-round recess of flange 30 the small, but axially extending gaps 96, 97 prevent the escape of dirt particles from the inside of the motor.

To increase the action of the labyrinth packing when holding back the dirt particles, the axially directed gaps 94, 95, 96, 97 are in each case kept as narrow as possible, i.e. they are radially small being approximately 1 to 2mm, but they have a maximum axial length, e.g. 5 to 20mm. The gap size or thickness in the radial direction cannot be randomly small, because this means high manufacturing costs and in particular high windage losses. Depending on the characteristics of the adjacent surfaces, the latter can be considerable. Such direct store drives are in fact operated at e.g. 5000 r.p.m. However, the radially divided gaps are axially e.g. 3 or 5mm "thick" and radially preferably below 100mm "long". (These values relate to a motor size, whose diameter is half that shown in Figure 1). Further gaps are also possible.

Thus, labyrinth members can additionally pass e.g. from a coil end cover in comb-like manner into recesses of opposing matching shape formed in the bottom of a bell-shaped outer rotor casing. It is preferred that the axial

extension of labyrinth gaps parallel to the rotor axis is greater than the radial extension thereof. Further it is preferred that the thickness of the labyrinth gap is small over its axial extension and large over
05 its radial extension. It also is preferred that a/d is greater than 10 and r/d is at most 2.

A fan 32 with fan blades 33 is fixed to the free end of rotor shaft 12 remote from hub 70. Fan 32 leads to an intense air movement in the vicinity of
10 the assembly flange 30, so that the flange is cooled. By means of bearing tube 44 and flange 30 dissipated heat from motor 11 is effectively conducted to the outside in this way.

To prevent an electrical charging of the rotor
15 bell which would be prejudicial to the operating reliability of the plate store, rotor shaft 12 is appropriately connected in electrically conductive manner to the apparatus chassis via a bearing ball 36 and a not shown spring contact.

20 The commutator-less d.c. motor 11 can advantageously be a single-phase electronic motor with an auxiliary reluctance moment (single or two-pulse) (US Patent 3873897) or a three-phase electronic motor as described in earlier-dated German application P30
25 21 328.6.

The idling speed of motor 11 can be 5,800 r.p.m.

and the rated speed e.g. 3,600 r.p.m.

The stator advantageously has four distinct wound poles, whose pole tips are so deformed that the width of air gap 15 is modified in the vicinity of the tips and consequently the auxiliary reluctance moment is produced.

While the invention has been illustrated and described with reference to the drawings, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the present invention as defined in the following Claims. For example, ring 7 of Figure 1 could be integral with rotor 1.

Attention is drawn to the existence of Parent Application No. 8107013 which claims a "magnetic-disk storage drive" wherein the electric motor is a "brushless d.c. reluctance torque motor". The Parent Application also claims a "magnetic-disk storage device" comprising said drive having at least one data storage disc held by rotary disc-clamping means thereof. The terms "magnetic-disk storage drive", "magnetic-disk storage device" and "brushless d.c. reluctance torque motor" have meanings defined in the Parent Application.



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CLAIMS

1. A magnetic-disk storage device (as herein defined) comprising:

05 means defining a contaminant-free housing accommodating at least one rotary magnetic-data storage disk;

10 a brushless d.c. motor having an annular stator surrounding a bearing tube, a rotor shaft journaled in a rotor bearing in said tube, and a cup-shaped rotor comprising a permanent magnet and secured to the rotor shaft for rotation therewith, said rotor surrounding the stator and spaced therefrom by a cylindrical air-gap and extending axially beyond the stator, the motor being mounted with the closed end of the rotor located in said contaminant-free enclosure; and

15 means connecting the storage disk directly to the rotor or rotor casing of the motor for rotation therewith;

20 wherein a labyrinth seal defined between a stationary first element and a second element rotatable with the rotor is located between the rotor bearing and said air-gap to prevent contaminant particles from the rotor bearing entering the air-gap.

2. A device as claimed in Claim 1, wherein the rotatable element defines a groove into which the stationary element extends.

25 3. A device as claimed in Claim 1 or Claim 2, wherein the labyrinth seal is formed by stationary



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elements which interleave with rotatable comb-like projections constituting rotational elements.

4. A device as claimed in Claim 3, wherein the comb-like projections have unequal spacings.

05 5. A device as claimed in Claim 4, wherein the said stationary elements are of a different thickness from said rotatable elements.

6. A device as claimed in any one of the preceding Claims, wherein the stationary element is part of the
10 stator.

7. A device as claimed in Claim 1 or Claim 2, wherein the labyrinth seal is located at one end of the bearing tube.

8. A device as claimed in Claim 7, wherein an end of
15 the bearing tube constitutes the fixed element of the labyrinth seal.

9. A device as claimed in any one of the preceding Claims, wherein a further labyrinth seal defined between a stationary first element and a second element
20 rotatable with the rotor is located at the open end of the rotor to prevent contaminant particles passing from the air-gap to beyond the rotor, with the open outer edge of the rotor constituting the rotatable element of said further labyrinth seal.

25 10. A device as claimed in any one of the preceding



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claims, wherein the, or each, labyrinth seal has a "U"-shaped part formed of a substantially radially extending gap joining two substantially axially extending gaps.

- 05 11. A device as claimed in Claim 10, wherein the length (a) of one axially extending gap (measured in the axial direction) is longer than the length (r) of the radially extending gap (measured in the radial direction).
- 10 12. A device as claimed in Claim 11, wherein the width (d) of the axially extending gap (measured in the radial direction) is smaller than r.
13. A device as claimed in Claim 12, wherein a:d exceeds 10:1 and r:d does not exceed 2:1.
- 15 14. A driving mechanism for a magnetic-disk storage device as defined in Claim 1, said mechanism comprising:-
- 20 a brushless d.c. motor having an annular stator surrounding a bearing tube, a rotor shaft journaled in a rotor bearing in said tube, and a cup-shaped rotor comprising a permanent magnet and secured to the rotor shaft for



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rotation therewith, said rotor surrounding the stator
and spaced therefrom by a cylindrical air-gap and
extending axially beyond the stator, the motor being
suitable for mounting with the closed end of the rotor
05 located in said contaminant-free housing; and

means to connect the storage disk directly to the
rotor or rotor casing of the motor for rotation
therewith in the contaminant-free enclosure;

wherein a labyrinth seal defined between a
10 stationary first element and a second element
rotatable with the rotor is located between the rotor
bearing and said air-gap to prevent contaminant
particles from the rotor bearing entering the air-
gap.

15 15. A mechanism as claimed in Claim 14, wherein the
rotatable element defines a groove into which the
stationary element extends.

16. A mechanism as claimed in Claim 14 or Claim 15,
wherein the labyrinth seal is formed by stationary
20 elements which interleave with rotatable comb-like
projections constituting rotational elements.

17. A mechanism as claimed in Claim 16, wherein the
comb-like projections have unequal spacings.

18. A mechanism as claimed in Claim 17, wherein the
25 stationary elements are of different thickness from
said rotational elements.



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19. A mechanism as claimed in any one of Claims 14 to 18, wherein the stationary element is part of the stator.

20. A mechanism as claimed in Claim 14 or Claim 15, wherein labyrinth seal is located at one end of the bearing tube.

21. A mechanism as claimed in Claim 20, wherein an end of the bearing tube constitutes the fixed element of the labyrinth seal.

22. A mechanism as claimed in any one of Claims 14 to 21, wherein a further labyrinth seal defined between a stationary first element and a second element rotatable with the rotor is located at the open end of the rotor to prevent contaminant particles passing from the air-gap to beyond the rotor, with the radially outer edge of the rotor constituting the rotatable element of the labyrinth seal.

23. A mechanism as claimed in any one of Claims 14 to 22, wherein the, or each, labyrinth seal has a "U"-shaped part formed of a substantially radially extending gap joining two substantially axially extending gaps.

24. A mechanism as claimed in Claim 23, wherein the length (a) of at least one axially extending gap (measured in the axial direction) is longer than the



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length (r) of the radially extending gap (measured in the radial direction).

25. A mechanism as claimed in Claim 24, wherein the width (d) of the axially extending gap (measured in the radial direction) is smaller than r.

26. A mechanism as claimed in Claim 25, wherein a:d exceeds 10:1 and r:d does not exceed 2:1.

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