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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 at least one rigid or flexible disk which is rotated at relatively high speeds by an electric motor driving rotary
- 10 disk-clamping means coupled to the rotor or rotor casing of the motor for rotation therewith and which clamps the disk at the centre thereof so that the disk is driven only at the centre thereof. Bits are inscribed or read by a read/ write head which must be accurately positioned relative to the particular track
- 15 which is being inscribed or read. This means that the disks must rotate absolutely true, or as close to it as possible.

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As used in this Specification (including the Claims thereof),
the term "magnetic-disk storage drive means a drive assembly for a
magnetic-disk storage device (as defined above), said drive
assembly comprising the said electric motor and rotary

05 disk-clamping means in which the disk-clamping means couples the
disk(s) directly to the rotor or rotor casing of said motor for
rotation therewith and the motor is adapted to extend coaxially
through the centre hole of said disk(s).

According to the present invention, there is provided a
10 magnetic-disk storage drive (as hereinbefore defined) wherein the
electric motor is a brushless d.c. reluctance-torque motor (as
hereinafter defined).

As used in this Specification (including the Claims thereof)
the term brushless d.c. reluctance-torque motor means a brushless
15 d.c. motor having a stator winding which produces an alternating
field, an angular-position detector, and means for connecting said

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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 magnet rotor and the
05 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 zero electromagnetic torque. The energized stator winding establishes
10 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 and which, at fore-determined angular positions of the rotor, is of zero magnitude and thus incapable of starting the rotor from said
15 predetermined positions. Accordingly if, when

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the motor is shut off, the rotor were to come to a complete stop in said predetermined 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
05 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
10 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-
15 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
20 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, 05 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 sufficiently robust to assure a prolonged service life. In connection with this latter aspect it 10 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 used.

By resorting to the invention direct coupling of the disk(s) to the rotor or rotor casing of the motor is obtained rather than 15 to the motor shaft, and, moreover, the need for connecting elements extending outwardly away from the motor shaft is eliminated. As a result, a very compact and rigid unit of drive motor and disk(s) is obtained. The centre of gravity of the disk(s) readily can be located between the two motor bearings, so that the disk 20 oscillating tendency is substantially reduced; the disk(s) can therefore run truer than in the aforementioned prior art and this eliminates the objectionable prior art disadvantages.

It is preferred that the device of the invention comprises two bearings journalling the rotor on the stator and being spaced

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from one another lengthwise of the axis of rotation of the rotor, the rotor and disk having a joint centre of gravity which is intermediate said bearings.

It is also preferred that the device of the invention
05 comprises means for at least reducing the escape of contaminants from said motor into the environment of the disk. Suitably the contaminants-reducing means comprises a labyrinth seal in an airgap between the stator and the rotor.

Further, it is preferred that the device of the invention
10 comprises means for expelling contaminants from the motor in a direction away from a contaminant-free housing in which the disk is located.

The brushless d.c. reluctance-torque motor preferably is of the external rotor type with a permanent magnetic rotor, the
15 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
20 magnets are formed from mixtures of hard ferrites and elastic material, particularly barium ferrite combined with elastomers.

The hub which receives the storage disk(s) can be part of the rotating rotor casing. In this case, a magnetic shield is appropriately housed within the casing. The permanent magnet of
25 the external rotor is preferably 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 storage disk(s) located on the latter. In order to obtain magnetic shielding which 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 constructed as a soft magnetic, cup-shaped, deep-drawn member, whose base has a coaxial recess in the core.

10 A driving mechanism of the aforementioned type generally comprises a speed control circuit and/or driving electronics which ensures the necessary commutation of the brushless d.c. reluctance-torque motor. If the motor includes a shield ring connected to the stator, it is also possible to use the same for
15 cooling the speed control circuit and/or the drive electronics, particularly if the semi-conductor components are kept in thermally 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
20 not only particularly simple but also leaves the circumferential surface of the rotor free as a braking surface for the brake which is frequently provided with such driving mechanisms.

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

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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;

05 Figure 3 is a view analogous to Figure 1 but illustrating still another embodiment of the invention; and

Figure 4 is a view analogous to Figure 1 but illustrating yet another embodiment of the invention.

In the embodiment of Figure 1, the drive comprises a
10 brushless d.c. reluctance-torque motor according to one of the two previously mentioned US motor patents or 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 one-strand winding 3 which
15 produces an alternating field and an auxiliary reluctance moment which, in co-operation with the electromagnetic torque, produces a total torque of high constancy. Rotor 1 is journaled 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
20 the shaft 4. The axis of rotation of the rotor 1 is designated with 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
25 via rings 7, 8 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) to the rotor 1; ring 9 has a flange portion 9a which
05 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 ring 8 against disk 5 which in turn is pressed against ring 7; thus, disks 5 and 6 can rotate only with,
10 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
15 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.
20 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
25 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. 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 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 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 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 harm in the housing CR.

Two overlapping annular baffles 17, 18 on the stator 2 and rotor 1 are interposed in the airgap between stator and rotor, defining with one another their own airgap which serves to further retard the 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
05 not 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 plurality of annular grooves 22 in the inner surface
10 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 the escape of contaminants to the motor. Incidentally, it goes without saying that although the seal is
15 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 to improve the effect still further.

The embodiment of Figure 3 is also particularly suited for
20 use with contaminant-free housings. Here, the rotor 30 is mounted in stator 31 via shaft 32 and anti-friction bearings 33, 34. The winding 35 of stator 31 is heavily potted, i.e., embedded in one of the electrically insulating materials 36 which are known per se in the art, to prevent the escape of contaminant particles. The
25 potting material 36 may in turn be surrounded by a jacket of heat-shrinkable synthetic plastics 37 (also known per se) which, when

shrunk onto the material 36, surrounds the same extremely tightly and further prevents the escape of contaminant particles. A cupped inverted cover 38 of electrically insulating material may surround the winding, being connected to the stator 31, and have
05 an upper free circumferential edge 39 which extends into an annular groove 40 of the stator 31 to provide still another seal against the escape of contaminants. The groove 40 could be omitted and the edge 39 simply abut the stator 31.

The disks 5 and 6 are shown only diagrammatically here; their
10 mounting on rotor 30, although not shown, may be analogous to that shown in Figure 1. Stator 31 is mounted beneath a supporting plate 41 and the contaminant-free housing CR is also below this plate.

Within the hub of the stator 31, intermediate the bearings
15 33, 34, the shaft 32 carries a set of blades 42 which, on rotation of shaft 32, cause an axial airflow in the direction indicated by the arrows. Thus, air is drawn from the housing CR through the bearing 33 and expelled via the bearing 34 and the opening in plate 41, into the non-controlled ambient atmosphere. Any
20 contaminant particles which may be liberated in the path of this airflow -- e.g., dust, abraded bearing metal particles -- will be expelled from the motor to the ambient atmosphere and cannot enter the housing CR.

The invention is susceptible of a variety of modifications.
25 For example, if desired a shielding element could be used to surround the rotor, being connected thereto for rotation with the

same. The disks could then be mounted on this shielding element. The element connecting the upper end of shaft 4 to rotor 1 (see Figure 1) could be constructed as a radial-flow impeller in lieu of or in addition to -- and to perform the function of -- the
05 impeller 12, 14. The drive according to the invention is suitable for use with all types of disk storages and irrespective of the diameter of the centre hole of the disks.

Referring now to Figure 4, a driving mechanism 10 has a brushless direct current reluctance-torque motor 11 with a rotor
10 casing 14 fixed to rotor shaft 12 and concentric to the latter, the rotor casing being considered to be part of the motor. A group of stator plates 58 carrying a stator winding 29 forms part of the stator of motor 11. The stator plates 58 surround a bearing tube 44, which is part of a central support 22. Rotor
15 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.
20 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.

25 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.

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 directed 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 or alternatively 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 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 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 bell which would be prejudicial to the operating reliability of the plate
05 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.

The brushless d.c. reluctance-torque motor 11 can advantageously be a single-phase electronic motor with an
10 auxiliary reluctance moment (single or two-pulse) (US Patent 3873897).

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,
15 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
20 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 Divisional Application
25 No. 8312375 which claims a magnetic-disk storage device 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
10 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
15 between the rotor bearing said air-gap to prevent contaminant particles from the rotor bearing entering the air-gap. The Divisional Application also claims a driving mechanism for a said magnetic-disk storage device, said mechanism comprising:-

a brushless d.c. motor having an annular stator surrounding a
20 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
25 suitable for mounting with the closed end of the rotor located in said contaminant-free housing; and

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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 stationary first
05 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.

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CLAIMS

1. A magnetic-disk storage drive (as hereinbefore defined) wherein the electric motor is a brushless d.c. reluctance-torque motor (as hereinbefore defined).
- 05 2. A drive as claimed in Claim 1, wherein the motor is an external-rotor motor.
3. A drive as claimed in Claim 2, wherein the rotor has a casing containing a one-part permanent magnetic ring.
4. A drive as claimed in Claim 2, wherein the rotor has a casing
10 containing a permanent magnetic tape bent in annular manner.
5. A drive as claimed in Claim 4, wherein the said tape has approximately trapezoidal radial magnetization via the pole pitch.



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6. A drive as claimed in any one of Claims 2 to 5, ³⁸wherein the rotor comprises a permanent magnet formed of a mixture of hard ferrites and elastic material.
7. A drive as claimed in any one of Claims 2 to 6, wherein a
05 magnetic shield is housed within a casing of the rotor.
8. A drive as claimed in Claim 7, wherein the rotor comprises a permanent magnet surrounded in bell-shaped manner by the magnetic shield.
9. A drive as claimed in Claim 8, wherein the magnetic shield
10 forms part of the magnetic yoke for the permanent magnet.
10. A drive as claimed in Claim 9, wherein the magnetic shield is constructed as a soft magnetic, cup-shaped, deep drawn member, whose base has a coaxial recess in the core.
11. A drive as claimed in any one of the preceding claims which
15 further comprises two bearings journalling the rotor on the stator and being spaced from one another lengthwise of the axis of rotation of the rotor.
12. A drive as claimed in Claim 11, wherein the rotor and disk
20 have a joint centre of gravity which is intermediate said bearings.
13. A drive as claimed in Claim 11 or Claim 12, wherein the two bearings substantially are contained within the axial length of the motor.
14. A drive as claimed in any one of the preceding claims which
25 further comprises means for at least reducing the escape of contaminants from said motor into the environment of the disk.



15. A drive as claimed in any one of the preceding claims which further comprises means for expelling contaminants from the motor in a direction away from a contaminant-free housing in which the disk is located.

05 16. A drive as claimed in Claim 1 and substantially as hereinbefore described with reference to and as illustrated in Figure 1.

17. A drive as claimed in Claim 1 and substantially as hereinbefore described with reference to and as illustrated in Figure 2.

18. A drive as claimed in Claim 1 and substantially as hereinbefore described with reference to and as illustrated in Figure 3.

10 19. A magnetic-disk storage device (as hereinbefore defined) comprising a drive as claimed in any one of the preceding Claims having at least one data storage disk held by the rotary disk-clamping means.

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