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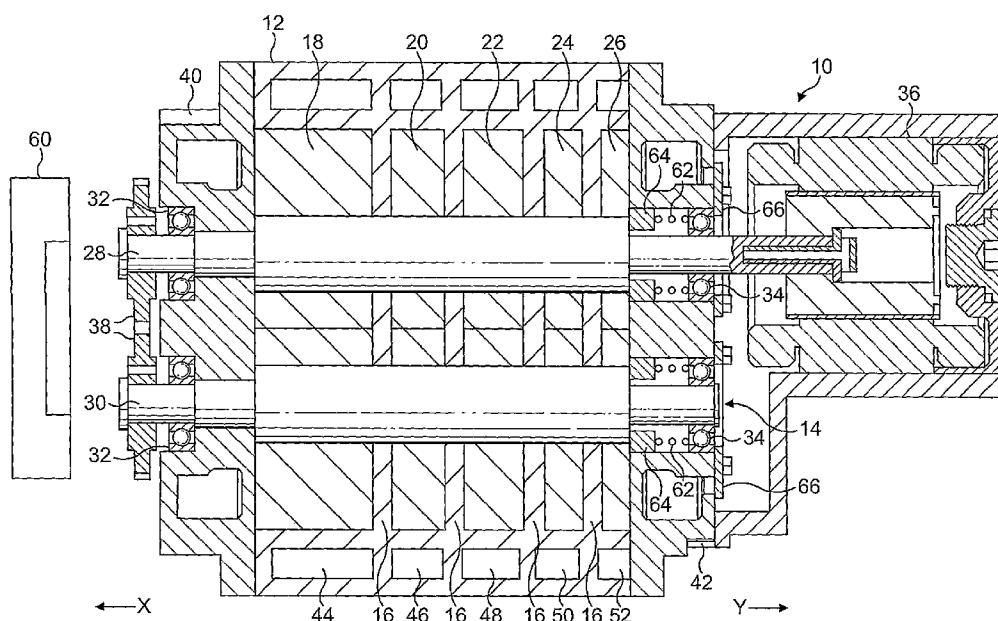
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(54) Title: VACUUM PUMP



(57) Abstract: A dry pump comprises a stator housing a rotor assembly comprising intermeshing rotor components defining a running clearance with a surface of the stator, means for applying a transient magnetic force to at least one magnetic member of the rotor assembly to move the rotor components away from the stator surface and increase the size of the running clearance to reduce a frictional force applied to the rotor components by particulates accumulated within the running clearance, and means for moving the rotor components back towards the stator surface upon reduction of the magnetic force.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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VACUUM PUMP

This invention relates to vacuum pumps, and finds particular use with Roots,
Northey (or "claw") and screw pumps which are typically used in vacuum
5 applications.

Dry pumps are widely used in industrial processes to provide a clean and/or low
pressure environment for the manufacture of products. Applications include the
pharmaceutical and semiconductor manufacturing industries. Such pumps include
10 an essentially dry (or oil free) pumping mechanism, but generally also include
some components, such as bearings and transmission gears, for driving the
pumping mechanism and which require lubrication in order to be effective.

Dry pumps incorporating Roots and/or Northey pumping mechanisms are
15 commonly multi-stage positive displacement pumps including a plurality of
pumping chambers, each pumping chamber housing a pair of intermeshing rotor
components that together provide a stage of the pump. The rotor components
may have the same type of profile in each chamber or the profile may change from
chamber to chamber.

20 A typical dry pumping mechanism comprises two parallel spaced shafts each
carrying the rotor components, the shafts being mounted in a pump body such that
the rotor components intermesh. Close tolerances between the rotor components
and with the internal surface of the pumping chambers (which acts as a stator for
25 the pump) cause volumes of gas entering at a chamber inlet to be trapped
between the rotor components and the internal surface and thereby urged towards
an outlet of the pumping chamber as the rotor components rotate. It is preferable
to make the tolerances as tight as possible in order to minimise any leakage of gas
between pumping chambers.

30 During processes such as chemical vapour deposition processing, process gases
are supplied to a process chamber to form a deposition layer on the surface of a

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substrate. As the residence time in the chamber of the process gas is relatively short, only a small proportion of the gas supplied to the chamber is consumed during the deposition process. The unconsumed process gas is subsequently pumped from the process chamber with one or more by-products from the process
5 by the vacuum pump.

The gas stream pumped from the process chamber can contain species that may cause premature failure of the pump. For example, some deposition processes generate particulates that are exhaust from the process chamber with the
10 unconsumed process gases. These particulates can accumulate within the pump and effectively fill the vacant running clearance between the rotor and stator components of the pump. When the pump is stopped the rotor and stator components will cool and shrink. Due to the different thermal expansions of the rotor and stator components of the pump, the running clearances between the
15 rotor and stator components reduce. However, if those running clearances are already full of particulates, then those particulates become crushed between the rotor and stator components, and can effectively apply a brake to the rotor components that, in severe cases, may prevent restart of the pump.

20 It is an aim of the present invention to provide a vacuum pump having a relatively simple and low cost mechanism for releasing a braking force applied to a rotor assembly by crushed particulates located between the rotor assembly and the stator of the pump.

25 In a first aspect, the present invention provides a dry pump comprising a stator housing a rotor assembly comprising intermeshing rotor components, and means for applying a transient magnetic force to at least one magnetic member of the rotor assembly to effect axial movement of the rotor components within the stator to vary at least one clearance between the rotor components and the stator.

30 By applying a transient magnetic force to at least one magnetic member of the rotor assembly, the rotor assembly can be temporarily pulled away from any

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particulates that have accumulated within the running clearance between the rotor components and the stator, thereby temporarily relieving the braking force applied to the rotor components by the particulates to enable the pump to be restarted.

- 5 As discussed above, the magnetic force applying means is preferably arranged to move the rotor assembly to increase the distance between a surface of the rotor components and a surface of the stator. The magnetic force applying means is preferably arranged to move the rotor components away from a location proximate the surface of the stator, with the pump preferably comprising means for returning
10 the rotor components to said location upon cessation or reduction of the magnetic force, and thereby re-establish a small clearance between the surface of the rotor components and a surface of the stator. Therefore, in a second aspect the present invention provides a dry pump comprising a stator housing a rotor assembly comprising intermeshing rotor components defining a running clearance
15 with a surface of the stator, means for applying a transient magnetic force to at least one magnetic member of the rotor assembly to move the rotor components away from the stator surface and increase the size of the running clearance to reduce a frictional force applied to the rotor components by particulates accumulated within the running clearance, and means for moving the rotor
20 components back towards the stator surface upon reduction of the magnetic force.

The returning means preferably comprises means for biasing the rotor components towards the stator surface. For example, where the rotor assembly comprises a bearing assembly for supporting the rotor assembly within the
25 housing, the biasing means may be arranged to apply a biasing force to the bearing assembly, and may comprise a resilient member, for example a spring, located between the bearing assembly and a fixed member mounted on or integral with the stator.

- 30 The mean value of the magnetic force applied to the rotor assembly is preferably approximately equal to the biasing force applied to the rotor assembly so that no position feedback or control device is required.

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The magnetic force applying means may be arranged to apply a pulsed magnetic field to said at least one magnetic member of the rotor assembly, and thereby cause a degree of vibration of the rotor assembly. This can enable the rotor
5 assembly to “shake” particulates from the surface of the rotor components and reduce the frictional force applied thereto. Pulsed actuation of the magnetic force applying means can minimise damage to the set bearings of the rotor assembly, and thereby enhance pump lifetime.

- 10 The magnetic force applying means may comprise an electromagnet and means for supplying a time variant or switched current to the electromagnet to generate the pulsed magnetic field. The electromagnet may be provided with a plurality of coils, which may be selectively connected in series or in parallel. Alternatively, the magnetic force applying means may comprise at least one permanent magnet and
15 means for moving said at least one permanent magnet relative to said at least one magnetic member of the rotor assembly to apply the transient magnetic force to the rotor assembly.

- The at least one magnetic member of the rotor assembly may comprise a gear
20 assembly for transmitting torque between shafts of the rotor assembly, or alternatively at least one disc mounted on the rotor assembly.

The magnetic force applying means may be actuated manually. Alternatively, control means may be provided for actuating the magnetic force applying means.

- 25 The control means may actuate the magnetic force applying means each time the pump is re-started, upon demand, periodically and/or under certain conditions. For example, the control means may be configured to monitor an operating characteristic of the pump, such as the current drawn by a motor of the pump, which may be indicative of the degree of blocking of the pump, and to actuate the
30 magnetic force applying means depending on the monitored characteristic, for example if the current drawn exceeds a predetermined amount. Other operating characteristics that may be monitored include, but are not limited to:

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- motor power
- pump temperature
- exhaust pressure
- bearing vibration

5 as variation in any of the above operating characteristics or any combination thereof could be used to indicate pump blockage. Periodic actuation of the magnetic force applying means during use of the pump, say every few minutes, can be beneficial during the pumping of a gas stream containing particulates or condensable species to periodically shake deposits from the rotor assembly

10

Our co-pending International patent application WO2004/38222, the contents of which are incorporated herein by reference, describes a procedure for reducing the incidence of restart failure in a dry pump, in which following the cessation of the operation of the pump, the temperature of the pumping mechanism is
15 monitored. Once the temperature of the pumping mechanism has fallen by a predetermined amount, for example 10°C, the pump is operated for a short period of time, typically 30 seconds, to remove from the pump particulates that have accumulated within the running clearances. The magnetic force applying means of the present invention can be utilised in this procedure during the periodic
20 operation of the pump to enhance the removal of particulates from the pump.

In addition to the aforementioned magnetic force applying means, the pump may further comprise additional means for applying a transient magnetic force to at least one magnetic member of the rotor assembly to effect radial movement of the
25 rotor components within the stator to vary at least one other clearance between the rotor components and the stator. For example, the additional magnetic force applying means may comprise an electromagnet and means for supplying a time variant or switched current to the electromagnet to generate a pulsed magnetic field. The electromagnet may be provided with a plurality of coils, which may be
30 selectively connected in series or in parallel. Alternatively, the magnetic force applying means may comprise at least one permanent magnet and means for moving said at least one permanent magnet relative to said at least one magnetic

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member of the rotor assembly to apply the transient magnetic force to the rotor assembly.

The rotor components may typically have one of a Roots, Northey or screw profile.

5 However, movement of the rotor assembly to reduce a frictional force applied to the rotor assembly by particulates accumulated within the running clearance can also be usefully applied to vacuum pumps having alternative pumping mechanisms which do not utilise intermeshing rotor components, such as scroll, regenerative and centrifugal pumping mechanisms. Therefore, in a third aspect
10 the present invention provides a vacuum pump comprising a stator housing a rotor assembly defining a running clearance with a surface of the stator, means for applying a transient magnetic force to at least one magnetic member of the rotor assembly to move the rotor assembly away from the stator surface and increase the size of the running clearance to reduce a frictional force applied to the rotor
15 assembly by particulates accumulated within the running clearance, and means for moving the rotor assembly back towards the stator surface upon reduction of the magnetic force.

In a fourth aspect, the present invention provides a method of operating a pump,
20 the pump comprising a stator housing a rotor assembly defining a running clearance with a surface of the stator, the method comprising the steps of applying a transient magnetic force to at least one magnetic member of the rotor assembly to move the rotor assembly away from the stator surface and increase the size of the running clearance to reduce a frictional force applied to the rotor assembly by
25 particulates accumulated within the running clearance, and subsequently moving the rotor assembly back towards the stator surface upon reduction of the magnetic force.

During the time period during which the magnetic force is applied to the rotor
30 assembly, the rotor assembly is caused to heat by induction. As the rotor assembly heats up, this can have the effect of increasing the size of the running clearances between the rotor and stator components, which can reduce the size of

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the frictional force applied to the rotor assembly by particulates accumulated within the running clearance. Consequently, before the pump is re-started following the cessation of the operation of the pump, a magnetic force applying means may be actuated to apply a magnetic force to the rotor assembly for a period of time, for example around 10 minutes, to heat the rotor assembly. The size of the magnetic force applied to the rotor assembly may be equal to or less than that applied to move the rotor components away from the stator surface. In view of this, in a fifth aspect the present invention provides a vacuum pump comprising a stator housing a rotor assembly defining a running clearance with a surface of the stator, means for applying a magnetic force to at least one magnetic member of the rotor assembly for a period of time to heat the rotor assembly and increase the size of the running clearance to reduce a frictional force applied to the rotor assembly by particulates accumulated within the running clearance.

In a sixth aspect, the present invention provides a method of starting a pump, the pump comprising a stator housing a rotor assembly defining a running clearance with a surface of the stator, the method comprising the steps of applying a magnetic force to at least one magnetic member of the rotor assembly to heat the rotor assembly to increase the size of the running clearance and reduce a frictional force applied to the rotor assembly by particulates accumulated within the running clearance, and subsequently rotating the rotor assembly.

Features described above in relation to the first and second aspects of the invention are equally applicable to the third to sixth aspects of the invention, and vice versa.

By way of example, preferred embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 illustrates a first embodiment of a dry pump;

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Figure 2 illustrates the variation of a running clearance between a rotor component and a surface of the stator of the pump of Figure 1;

Figure 3 illustrates a control system for controlling the movement of the rotor assembly within the dry pump of Figure 1;

Figure 4 illustrates a second embodiment of a dry pump; and

Figure 5 illustrates a third embodiment of a dry pump.

10

With reference first to Figure 1, a dry pump 10 comprises a stator 12 housing a rotor assembly 14. In this example, the pump is a multi-stage vacuum pump 10 housing a multistage rotor assembly 14, the stator 12 comprising a plurality of transverse walls 16 defining a plurality of pumping chambers. In this example, the stator 12 is divided into five pumping stages, although the stator 12 may be divided into any number of pumping stages (one or more) required to provide the pump 10 with the desired pumping capacity.

The rotor assembly 14 comprises two intermeshing sets of rotor components 18, 20, 22, 24, 26, each set being mounted on a respective shaft 28, 30. The rotor components may have a Roots or a Northey (or "claw" profile). For a dry pump having a single pumping stage, the rotor components may have one of a Roots, Northey or screw profile. As illustrated in Figure 2(a), the sets of rotor components are profiled in order to maintain a small running clearance 31 between the faces of the rotor components and the facing surfaces of the stator 12.

Each shaft 28, 30 is supported by bearings 32, 34 for rotation relative to the stator 12. The shafts 28, 30 are mounted within the stator 12 so that each pumping chamber houses a pair of intermeshing rotor components, which together provide a stage of the pump 10. A motor 36 is connected to one end of shaft 28. The other shaft 30 is connected to shaft 28 by means of meshed timing gears 38 so

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that the shafts 28, 30 are rotated synchronously but in opposite directions within the stator 12. In this example, the gears 38 are formed from magnetic material.

A pump inlet 40 communicates directly with the inlet pumping stage, which
5 comprises rotor components 18 and pump outlet 42 communicates directly with the exhaust pumping stage, which comprises rotor components 26. Gas passageways 44, 46, 48, 50, 52 are provided within the pump 10 to permit the passage therethrough of pumped gas from the inlet 40 to the outlet 42.

10 As discussed above, particulates that pass through the pump 10 with the pumped gas can accumulate within the pump 10 and effectively fill the vacant running clearances 31 between the rotor components and the stator, particularly towards the exhaust stages of the pump 10. When the pump 10 is stopped, these
15 particulates can become crushed between the facing surfaces 54, 56 of the rotor components and the stator 12 as the pump 10 cools, and can effectively apply a brake to the rotor components by applying a frictional force to the rotor components that opposes rotation thereof, which can in severe cases prevent re-start of the pump 10.

20 In order to overcome this re-start issue, the pump 10 comprises an electromagnet 60 for applying a transient magnetic force to the magnetic gears 38 of the rotor assembly 14 to pull the rotor assembly 14, including shafts 28, 30 and bearings 34, in the direction X illustrated in Figure 1. This has the effect of moving the
25 surfaces 54 of the rotor components away from the surface 56 of the stator 12 and increase the size of the running clearance 31 from d_1 , as illustrated in Figure 2(a), typically by only a few tens of microns to d_2 , as illustrated in Figure 2(b). By moving the surfaces 54 of the rotor components away from the surface 56 of the stator 12, the frictional force applied to the rotor components by particulates accumulated within the running clearance 31 can be reduced to a level that can
30 enable the motor 36 to rotate the shafts 28, 30 and thus enable the pump 10 to be re-started. Whilst in this example one electromagnet 60 is used to pull the rotor assembly 14 in the direction X, two electromagnets may be used, each for pulling

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a respective shaft 28, 30 in the direction X. Actuation of these electromagnets may be synchronised so that the shafts 28, 30 are pulled simultaneously.

To maintain a tight running clearance 31 between the surfaces 54 of the rotor components and the surface 56 of the stator 12 during use of the pump 10, it is preferable to reduce to the size of the running clearance 31 back to d_1 once the pump 10 has been re-started. In this example, the rotor components are moved back towards the stator surface 56 upon reduction of the magnetic force by the action of clamping springs 62 or other resilient members located between the bearings 34 of the rotor assembly 14 and fixed rings 64 mounted on the stator 12. The clamping springs 62 serve to bias the rotor assembly 14 in the direction Y illustrated in Figure 1 by urging the bearings 34 against plates 66 mounted on the stator 12. The mean value of the magnetic force applied to the rotor assembly 14 by the electromagnet preferably roughly balances the biasing force applied to the rotor assembly 14 by the clamping springs 62 so that no position feedback or control device is required to ensure that the faces 57 of the rotor components do not clash against the facing surfaces 58 of the stator 12.

The magnetic force is preferably only applied to the rotor assembly 14 for a few seconds, in which time it is anticipated that the frictional force applied to the rotor components by the particulates accumulated within the running clearances 31 can be sufficiently reduced to enable the pump 10 to be re-started. A transient dc or ac voltage may be applied to the electromagnet 60 for a few seconds to actuate the electromagnet 60. Alternatively, a time variant current may be applied to the electromagnet 60 to cause a degree of vibration of the rotor assembly, which can also serve to shake particulates from the rotor assembly 14.

The electromagnet 60 may be actuated manually, or, as illustrated in Figure 3, a control system may be provided for actuating the electromagnet 60. The control system comprises a controller 70 for applying current to the electromagnet 60 for actuation of the electromagnet 60 each time the pump 10 is to be started, periodically, and/or under certain operational conditions of the pump 10. For

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example, the controller 70 may be configured to monitor the current drawn by the motor 36 of the pump 10 to rotate the rotor assembly, and to actuate the electromagnet 60 when the current drawn by the motor is equal to or greater than a predetermined value. Alternatively, or additionally, a sensor 72 may be provided to monitor the pressure of gas exhaust from the pump 10, and to output signals indicative of the monitored pressure to the controller 70, in response to which the controller 70 actuates the electromagnet 60. Alternatively, or additionally, another sensor 74 may be provided for monitoring the temperature of the pump 10 or the degree of vibration of the pump 10, each of which can be indicative of blocking of the running clearances of the pump 10.

As an alternative to applying the magnetic field to the gears 38 of the rotor assembly 14, the magnetic force may be applied to discs or other magnetic members fitted on to the rotor assembly 14. This can enable the discs, electromagnet 60 and clamping spring 62 to be readily retrofitted to existing dry pumps.

In the above embodiment, the magnetic field is applied to the gears 38 of the rotor assembly by one or more electromagnets 60. In the second embodiment illustrated in Figure 4, the electromagnet(s) 60 are replaced by one or more permanent magnets 80. One permanent magnet 80 is illustrated in Figure 4, although two magnets 80 may be provided, one for each shaft 28, 30. The or each magnet 80 is moveable towards and away from the gears 38 to apply a transient magnetic force to the gears 38 to pull the rotor assembly 14 in the X direction. The or each magnet 80 may be moved, for example by a servo motor 82 which rotates a lead screw 84 attached thereto and engaging a conformingly-threaded aperture in the magnet 80 so that the magnet 80 moves relative to the rotor assembly to increase or decrease the magnetic force acting on the gears 38. The motor 82 may be actuated manually, or using the controller 70 illustrated in Figure 3 which supplies current to the motor 82 to move the magnet 80 towards and away from the rotor assembly each time the pump 10 is to be started, periodically, and/or under certain operational conditions of the pump 10.

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In the third embodiment illustrated in Figure 5, one or more further electromagnets 90 are provided to the side of the rotor assembly 14 for moving the rotor assembly 14 radially in the Z direction to shake particulates from the rotor components.

- 5 These further electromagnets 90 may be actuated at the same time as the electromagnet 60, or separately therefrom.

During the time period during which the magnetic force is applied to the rotor assembly 14, the rotor assembly 14 is caused to heat by induction. As the rotor
10 assembly 14 heats up, this can have the effect of increasing the size of the running clearances between the rotor and stator components, which can reduce the size of the frictional force applied to the rotor assembly 14 by particulates accumulated within the running clearance. Consequently, before the pump 10 is re-started following the cessation of the operation of the pump, the controller may
15 be configured to actuate the electromagnet 60 to apply a magnetic force to the rotor assembly 14 for a period of time, for example around 10 minutes, to heat the rotor assembly. The size of the magnetic force applied to the rotor assembly may be equal to or less than that applied to move the rotor components away from the stator surface. Once the magnetic force has been applied for this period of time,
20 the motor 36 is actuated to rotate the rotor assembly 14 to start the pump 10. If required, the electromagnet 60 may be actuated to apply the transient magnetic force to the rotor assembly prior to, or subsequent to, the rotation of the rotor assembly 14 to shake particulates from the rotor assembly.

CLAIMS

1. A dry pump comprising a stator housing a rotor assembly comprising
5 intermeshing rotor components, and means for applying a transient magnetic force to at least one magnetic member of the rotor assembly to effect axial movement of the rotor components within the stator to vary at least one clearance between the rotor components and the stator.
- 10 2. A pump according to Claim 1, wherein the magnetic force applying means is arranged to move the rotor assembly to increase the distance between a surface of the rotor components and a surface of the stator.
- 15 3. A pump according to Claim 2, wherein the magnetic force applying means is arranged to move the rotor components away from a location proximate the surface of the stator, the pump comprising means for returning the rotor components to said location upon
20 cessation or reduction of the magnetic force.
- 25 4. A dry pump comprising a stator housing a rotor assembly comprising intermeshing rotor components defining a running clearance with a surface of the stator, means for applying a transient magnetic force to at least one magnetic member of the rotor assembly to move the rotor components away from the stator surface and increase the size
30 of the running clearance to reduce a frictional force applied to the rotor components by particulates accumulated within the running clearance, and means for moving the rotor components back towards the stator surface upon reduction of the magnetic force.

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5. A pump according to Claim 3 or Claim 4, wherein the returning means comprises means for biasing the rotor components towards the stator surface.
- 5 6. A pump according to Claim 5, wherein the rotor assembly comprises a bearing assembly for supporting the rotor assembly within the housing, and wherein the biasing means is arranged to apply a biasing force to the bearing assembly.
- 10 7. A pump according to Claim 6, wherein the biasing means comprises a resilient member located between the bearing assembly and a fixed member mounted on or integral with the stator.
- 15 8. A pump according to Claim 6 or Claim 7, wherein the mean value of the magnetic force applied to the rotor assembly is approximately equal to the biasing force applied to the rotor assembly.
- 20 9. A pump according to any preceding claim, wherein the magnetic force applying means is arranged to apply a pulsed magnetic field to said at least one magnetic member of the rotor assembly.
- 25 10. A pump according to Claim 9, wherein the magnetic force applying means comprises an electromagnet and means for supplying a time variant current to the electromagnet to generate the pulsed magnetic field.
- 30 11. A pump according to any of Claims 1 to 8, wherein the magnetic force applying means comprises at least one permanent magnet, and means for moving said at least one permanent magnet relative to said at least one magnetic member of the rotor assembly.

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12. A pump according to any preceding claim, wherein said at least one magnetic member of the rotor assembly comprises a gear assembly for transmitting torque between shafts of the rotor assembly.
- 5 13. A pump according to any of Claims 1 to 11, wherein said at least one magnetic member of the rotor assembly comprises at least one disc mounted on the rotor assembly.
- 10 14. A pump according to any preceding claim, comprising control means for actuating said magnetic force applying means.
- 15 15. A pump according to Claim 14, wherein the control means is arranged to actuate said magnetic force applying means in dependence on an operating characteristic of the pump.
16. A pump according to Claim 14 or Claim 15, wherein the control means is arranged to actuate said magnetic force applying means periodically during use of the pump.
- 20 17. A pump according to any preceding claim, further comprising additional means for applying a transient magnetic force to at least one magnetic member of the rotor assembly to effect radial movement of the rotor components within the stator.
- 25 18. A vacuum pump comprising a stator housing a rotor assembly defining a running clearance with a surface of the stator, means for applying a transient magnetic force to at least one magnetic member of the rotor assembly to move the rotor assembly away from the stator surface and increase the size of the running clearance to
30 reduce a frictional force applied to the rotor assembly by particulates accumulated within the running clearance, and means for moving the

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rotor assembly back towards the stator surface upon reduction of the magnetic force.

19. A method of operating a pump, the pump comprising a stator housing
5 a rotor assembly defining a running clearance with a surface of the
stator, the method comprising the steps of applying a transient
magnetic force to at least one magnetic member of the rotor
assembly to move the rotor assembly away from the stator surface
and increase the size of the running clearance to reduce a frictional
10 force applied to the rotor assembly by particulates accumulated
within the running clearance, and subsequently moving the rotor
assembly back towards the stator surface upon reduction of the
magnetic force.

15 20. A vacuum pump comprising a stator housing a rotor assembly
defining a running clearance with a surface of the stator, means for
applying a magnetic force to at least one magnetic member of the
rotor assembly for a period of time to heat the rotor assembly and
increase the size of the running clearance to reduce a frictional force
20 applied to the rotor assembly by particulates accumulated within the
running clearance.

21. A method of starting a pump, the pump comprising a stator housing a
rotor assembly defining a running clearance with a surface of the
25 stator, the method comprising the steps of applying a magnetic force
to at least one magnetic member of the rotor assembly to heat the
rotor assembly to increase the size of the running clearance and
reduce a frictional force applied to the rotor assembly by particulates
accumulated within the running clearance, and subsequently rotating
30 the rotor assembly.

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22. A method according to Claim 21, wherein the magnetic force is applied for a period of time, and after said period of time has elapsed a transient magnetic force is applied to said at least one magnetic member of the rotor assembly to move the rotor assembly away from the stator surface and increase the size of the running clearance, the rotor assembly being subsequently moved back towards the stator surface upon reduction of the transient magnetic force.

5

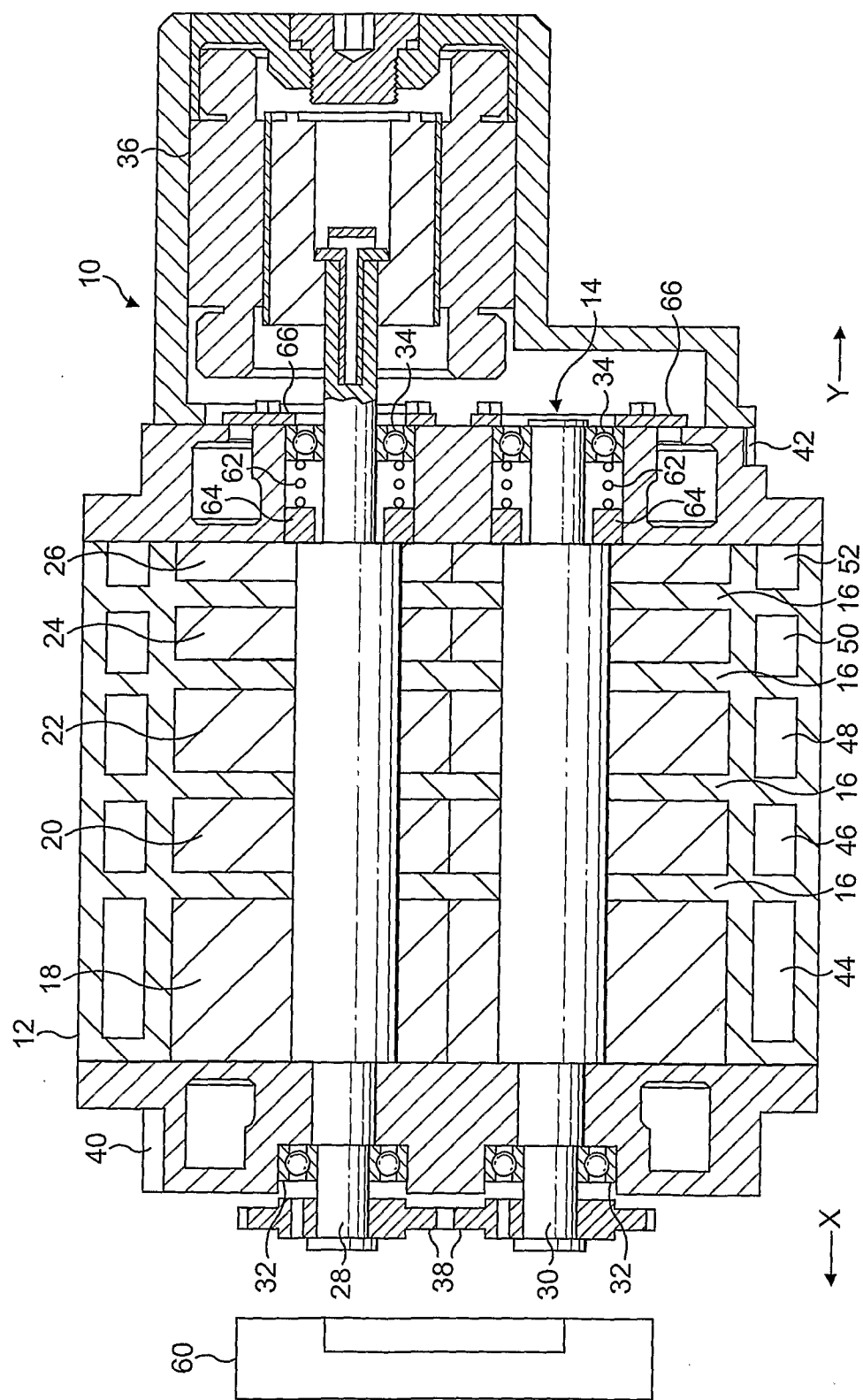


FIG. 1

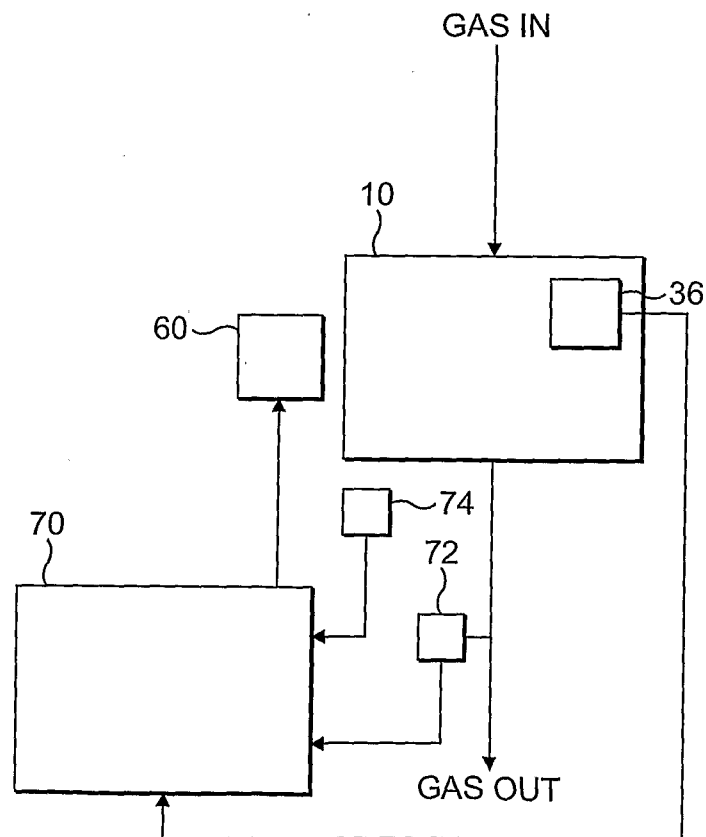
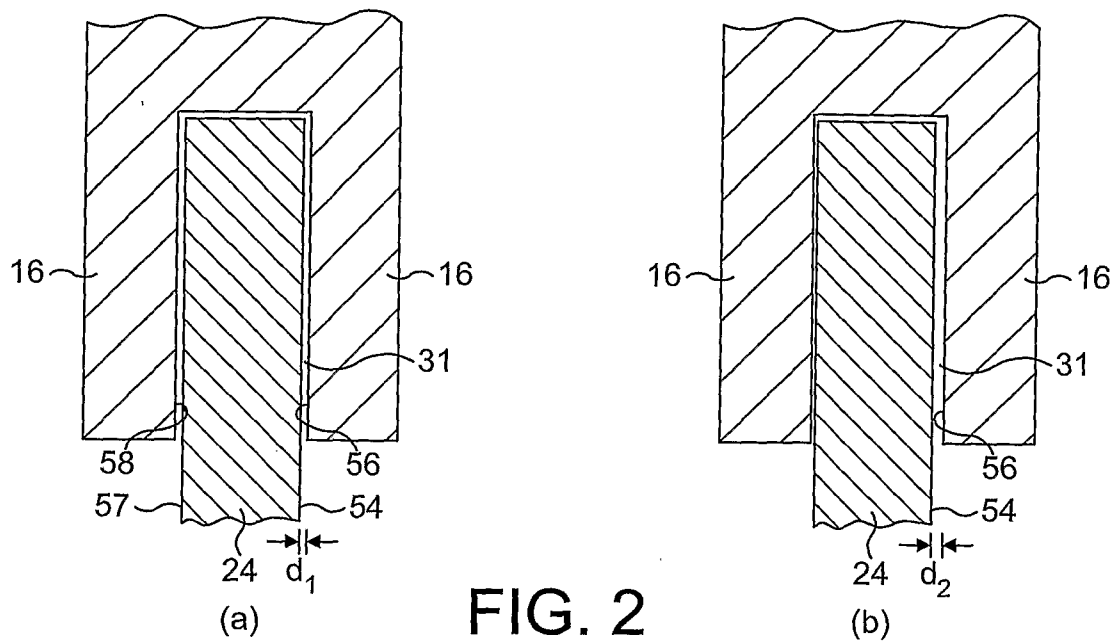


FIG. 3

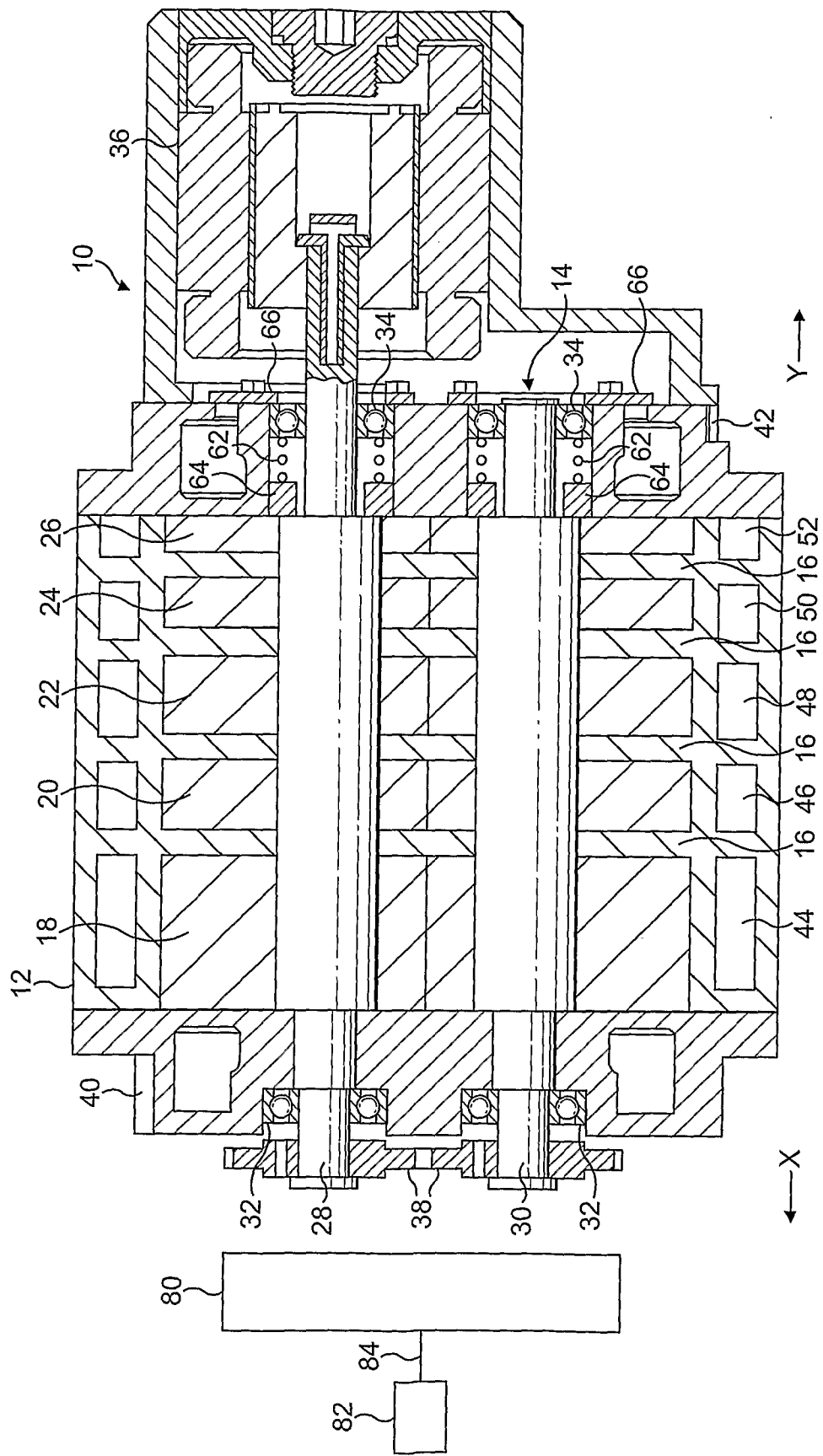


FIG. 4

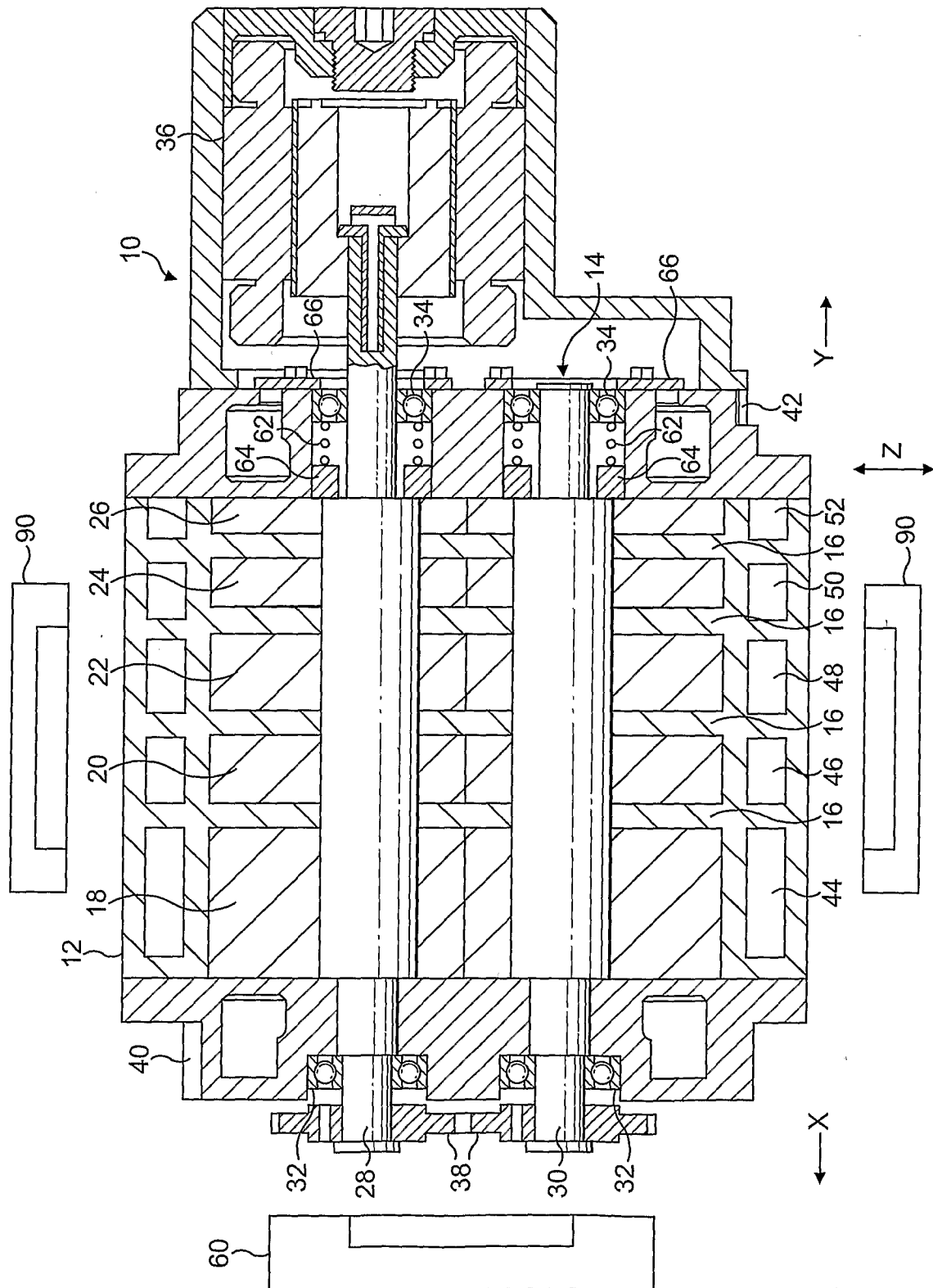


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2006/003284

A. CLASSIFICATION OF SUBJECT MATTER
 INV. F04C29/00 F04C29/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 F04C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2005/047706 A (BOC GROUP PLC [GB]; TUNNA CLIVE MARCUS LLOYD [GB]; MCDIARMID ALLAN EDM) 26 May 2005 (2005-05-26) page 4, line 25 - page 5, line 10; figures 3,6,8 page 10, line 28 - line 31 page 14, line 7 - line 12 page 14, line 29 - page 15, line 10 -----	1-16, 18-22
X	US 4 405 286 A (STUDER PHILIP A [US]) 20 September 1983 (1983-09-20) the whole document -----	1-5, 9-11, 13-19
X	DE 198 20 622 A1 (FRIEDEN PETER [DE]) 11 November 1999 (1999-11-11) column 4, line 23 - line 26 ----- -/--	1,2,14, 17

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search

29 December 2006

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Descoubes, Pierre

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/003284

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 514 924 A (MCMULLEN PATRICK T [US] ET AL) 7 May 1996 (1996-05-07) abstract -----	1-22
A	US 4 154 489 A (LYMAN JOSEPH [US]) 15 May 1979 (1979-05-15) abstract -----	1-22
A	US 4 638 643 A (SAKAZUME AKIO [JP] ET AL) 27 January 1987 (1987-01-27) abstract; figure 7 -----	20-22

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2006/003284

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 2005047706	A	26-05-2005	EP 1687540 A1	09-08-2006
US 4405286	A	20-09-1983	NONE	
DE 19820622	A1	11-11-1999	NONE	
US 5514924	A	07-05-1996	NONE	
US 4154489	A	15-05-1979	DE 2825877 A1	08-03-1979
			FR 2394710 A1	12-01-1979
			GB 1599958 A	07-10-1981
US 4638643	A	27-01-1987	JP 61052560 A	15-03-1986