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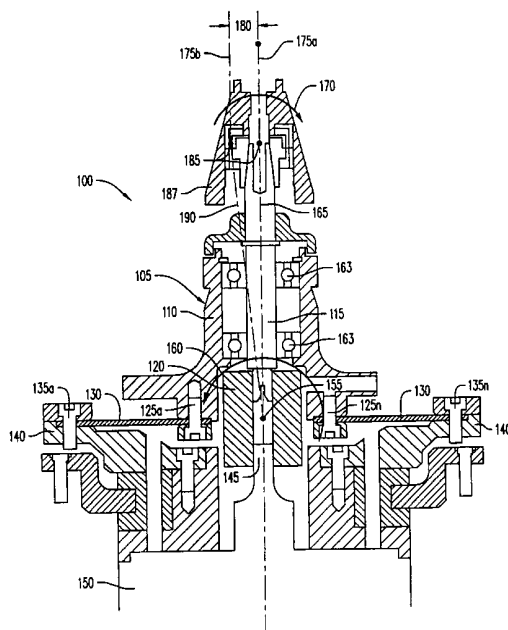
(43) International Publication Date
28 December 2000 (28.12.2000)

PCT

(10) International Publication Number
WO 00/78465 A1

- (51) International Patent Classification⁷: **B04B 9/14** William, Andrew; 185 Main Street North, Southbury, CT 06488 (US).
- (21) International Application Number: PCT/US00/16619
- (22) International Filing Date: 16 June 2000 (16.06.2000) (74) Agent: GREELEY, Paul, D.; Ohlandt, Greeley, Ruggiero & Perle, L.L.P., 9th floor, One Landmark Square, Stamford, CT 06901-2682 (US).
- (25) Filing Language: English (81) Designated State (national): JP.
- (26) Publication Language: English (84) Designated States (regional): European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).
- (30) Priority Data: 09/334,956 17 June 1999 (17.06.1999) US
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— With international search report.
— With amended claims.
- (72) Inventors: CARSON, David, Michael; 36 Hi Barlow Road, Newtown, CT 06470 (US). ROMANAUSKAS, 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.

(54) Title: CENTRIFUGE GYRO DIAPHRAGM CAPABLE OF MAINTAINING MOTOR SHAFT CONCENTRICITY



(57) Abstract: In a centrifuge (100) comprising a drive shaft assembly (105), a diaphragm (130) disposed about the drive shaft assembly reduces noise and vibration. The diaphragm permits the drive shaft assembly to pivot off a vertical axis while substantially limiting horizontal displacement thereof. Also, where a centrifuge includes a rotor shaft (705) and a drive shaft (710), a member (725) situated between the rotor shaft and the drive shaft substantially limits vertical displacement of the rotor shaft while allowing angular deflection of the rotor shaft with respect to the drive shaft.



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CENTRIFUGE GYRO DIAPHRAGM CAPABLE OF MAINTAINING MOTOR SHAFT CONCENTRICITY

Background of the Invention

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1. Field of the Invention

The present invention relates to a centrifuge drive shaft assembly, and more particularly to a centrifuge assembly where a diaphragm is
10 disposed about the drive shaft assembly to permit the drive shaft assembly to pivot while substantially limiting horizontal displacement thereof. Also, a member situated between a rotor shaft and a drive shaft substantially limits vertical displacement of the rotor shaft, while allowing angular deflection of the rotor shaft with respect to the drive shaft.

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2. Description of the Prior Art

A centrifuge instrument is a device by which liquid samples may be subjected to a centrifugal force. The samples are typically carried in tubes
20 situated within a member known as a centrifuge rotor. The rotor is mounted at the top of a rotor shaft, which is connected to a drive shaft that provides a source of motive energy. Centrifuge drive systems must be designed to accommodate unbalanced rotating loads. The imbalance may exist initially when loading samples into the centrifuge rotor, or it may result
25 from a tube failure during operation of the centrifuge. The imbalance represents a non-uniform distribution of matter throughout the mass of the rotor.

Any given mass, or centrifuge rotor, has a geometric center based
30 on the dimensions of the mass, and a mass center based on the distribution of matter within the mass. The mass center is also referred to as the center of gravity. In an actual mass or centrifuge rotor, the mass center is offset from the geometric center due to machining errors and density variations. A rotating mass mounted on a drive and suspension

system, has a critical speed at which the mass laterally shifts its axis of rotation from rotating about its geometric center to rotating about its mass center.

5 Centrifuge drive systems operate below and above a critical speed. Below the critical speed, the centrifuge rotor rotates about its geometric center. Above the critical speed, the centrifuge rotor attempts to rotate about its mass center. Because centrifuge drive and suspension systems need to have some type of spring in the system to allow the transition
10 through critical speed, the centrifuge rotor approaches rotation about its mass center. A vibration is induced because centrifuge rotor mass center and the centerline of the drive system do not fully align. The amount of vibration that the rotor produces at a given speed is dependent on the distance between the rotor's mass center and drive geometric center. If the
15 components of the drive system for the centrifuge are rigidly interconnected, then the vibration would subject the drive system to damaging stresses that could possibly destroy the centrifuge. Accordingly, centrifuge drive systems are typically designed to enjoy a certain degree of flexibility.

20

For a centrifuge rotor to approximate rotation about its mass center, the rotor shaft must be allowed to horizontally shift its axis of rotation. Accordingly, two flexible joints are required between the drive shaft and the rotor shaft. Flexible shafts and gyros, which are well known in the prior art,
25 both allow the required horizontal shift.

A flexible shaft must bend or deflect in order to allow a rotor to spin about its mass center. The greater the flexibility of the shaft, the further it can be deflected to accommodate the horizontal shift and thus reduce the
30 load on the centrifuge motor bearings, motor suspension and instrument frame. However, there is a tradeoff. Greater flexibility is generally achieved by reducing the diameter of the flexible shaft. Smaller diameter shafts have a greater difficulty in making the critical speed transition, and they can be more easily damaged by an unbalanced rotor or by a rotor that

has been dropped on the shaft. Smaller diameter shafts also limit the amount of torque that can be transmitted, thus limiting the acceleration rate.

5 Gyro systems are more robust and less expensive to replace than flexible shaft systems. A gyro system is basically comprised of a rotor shaft pivotally connected to a drive shaft or motor shaft through an intermediate coupling. The intermediate coupling serves as a universal joint that allows the axis of the rotor shaft to assume a position different from that of the
10 drive shaft. The centrifuge rotor is connected to the rotor shaft with a flexible coupling.

The problem associated with centrifuge operation above critical speed is well recognized in the prior art. The following patents illustrate
15 several mechanisms that have been developed to reduce vibrations.

U.S. Patent No. 3,770,191 (Blum) discloses a centrifuge drive system that automatically causes the center of gravity of a rotor to become aligned with the axial center of the drive system. An articulated rotor
20 shaft[JY1] permits lateral movement of the rotor whereby the geometric center of the rotor can be displaced so that its center of gravity becomes aligned with the axis of the drive system[JY2]. A sliding block element[JY3] is disposed about the articulated rotor shaft to reduce undue vibration of the shaft.

25 U.S. Patent No. 4,568,324 (Williams) discloses a drive shaft assembly including a damper[JY4] disposed between a flexible shaft[JY5] and a bearing shaft[JY6]. The damper accommodates the flexure of the flexible shaft while damping vibrations that are imposed on the flexible shaft
30 by a rotor.

U.S. Patent No. 5,827,168 (Howell) discloses a disk[JY7], rotatably attached to a centrifuge drive shaft, for reducing vertical vibrations of the drive shaft. Damping bearings[JY8] are positioned against a surface of the

disk to reduce vibrations thereof.

Fig. 1 shows a cross section of a typical centrifuge gyro drive shaft assembly of the prior art. A gyro housing 10 generally encloses one end of a rotor shaft 15 and one end of a drive shaft 25, which are interconnected through a coupling 20. The other end of drive shaft 25 is housed within a motor 40. Rotor shaft 15 is supported within gyro housing 10 by bearings 30a and 30b, and flexible mounting 35. The flexible mounting 35 is composed of a bearing housing 36 and two elastomeric rings 37a and 37b. A rotor (not shown) is positioned on top of rotor shaft 15.

At rest, and at speeds below the critical speed, rotor shaft 15 and drive shaft 25 share a common vertical axis 45. During centrifuge operation, motor 40 provides a rotational motive force that rotates drive shaft 25, coupling 20 and rotor shaft 15. Motor 40 accelerates, thus increasing the angular velocity of rotor shaft 15. At the critical speed, the rotational axis of rotor shaft 15 shifts both horizontally and at an angle away from vertical axis 45. This shift is permitted by flexible mounting 35.

Bearings 30a and 30b are horizontally displaced by the horizontal displacement or shift of rotor shaft 15. Flexible mounting 35 compresses and expands to accommodate the displacement of bearings 30a and 30b. As with any spring mass system, the elastic stiffness of flexible mounting 35 results in a resonant frequency that is within the normal operating range of most centrifuge systems.

A drive assembly configured as shown in Fig. 1 suffers from several inherent deficiencies. First, the horizontal shift of rotor shaft 15 and bearings 30a and 30b is itself a source of resonant vibration. A resonance is undesirable in a system where an objective is to minimize vibration. Second, to accommodate the shift and provide an adequate degree of torsional flexibility, flexible mounting 35 is typically composed of an elastomer. As rotational velocity increases, the elastomer becomes less flexible, and less responsive to the horizontal shift. Third, the elastomer is

not a very good thermal conductor. Consequently, heat generated by bearings 30a and 30b is not efficiently dissipated, and they are therefore stressed and susceptible to premature fatigue.

5 Another undesirable degree of freedom can be found in the vertical movement of rotor shaft 15. Because bearings 30a and 30b are mounted by elastomeric rings 37a and 37b, rotor shaft 15 can move vertically. This vertical movement introduces another mode of vibration at a resonant frequency within the normal operating range of most centrifuge systems.

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 There is a need for a centrifuge drive assembly that can accommodate the tendency of a rotor to shift its axis of rotation from its geometric center to its mass center while minimizing vibration introduced by horizontal displacement of the drive shaft assembly.

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 There is also a need for a centrifuge drive assembly that minimizes vibration caused by a vertical displacement of a rotor shaft while allowing angular deflection of the rotor shaft with respect to a drive shaft.

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Summary of the Invention

 The present invention provides a centrifuge assembly that comprises a drive shaft assembly and a diaphragm disposed about the drive shaft assembly. The diaphragm permits the drive shaft assembly to pivot off a vertical axis while horizontal displacement of the drive shaft assembly is substantially limited.

 This unique centrifuge assembly typically comprises a rotor, a drive shaft assembly and a diaphragm flexibly secured about the drive shaft assembly. The drive shaft assembly may include a drive shaft, a rotor shaft coupled to the drive shaft via an intermediate coupling, and, optionally, a gyro housing enclosing one end of the rotor shaft and one end of the coupling.

In one embodiment, the diaphragm is comprised of a plurality of radially directed bars.

5 In a second embodiment, the diaphragm is comprised of an inner flange and an outer flange having a common center point. The flanges are connected by radially directed bars.

10 In a third embodiment, the diaphragm is a disk with a centrally located hole. The disk provides flexible security throughout a 360° arc.

The centrifuge may additionally comprise one or more springs to vertically support the drive shaft assembly. The springs can be situated beneath the base of the drive shaft assembly, or formed from an elastomeric ring and disposed about a load bearing perimeter of the drive shaft assembly, or can be incorporated into a drive coupling.

20 The present invention allows nutation of the rotor about the drive shaft assembly and limits horizontal displacement of the axis of rotation of the coupling. Accordingly, the vibration associated with the horizontal displacement is substantially reduced due to the avoidance of any resonant frequencies within the operating range of the centrifuge rotor. That is, the greater the horizontal stiffness, the higher the resonant frequency is pushed above the operating range of the centrifuge.

25 Additionally, a member situated between a rotor shaft and a drive shaft limits vertical movement of the rotor shaft while allowing angular deflection of the rotor shaft with respect to the drive shaft. The member takes up a gap between the rotor shaft and the drive shaft caused by manufacturing tolerances. In one embodiment, the member is comprised of a cylindrical spacer and two disk-shaped pads. In a second embodiment, the member is comprised of a first sleeve disposed substantially around an end of the rotor shaft, a second sleeve disposed substantially around an end of the drive shaft, and a column disposed

between the two sleeves.

Brief Description of the Drawings

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Fig. 1 is a cross section of a centrifuge gyro drive shaft assembly of the prior art;

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Fig. 2 is a cross section of a centrifuge drive shaft assembly;

Fig. 3 is a top planar view of a diaphragm according to one embodiment of the present invention;

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Fig. 4 is a top planar view of another embodiment of a diaphragm according to the present invention;

Fig. 5 is a top planar view of still another embodiment of a diaphragm according to the present invention;

20

Fig. 6 is a cross-sectional of a centrifuge assembly according to the present invention, including springs for vertical support of a drive shaft assembly;

25

Fig. 7 is a top planar view depicting the relationship between the springs and diaphragm bars;

Fig. 8 is a cross-sectional view of a centrifuge drive shaft assembly with another embodiment of a spring;

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Fig. 9A is a graph depicting the vibratory force produced by a conventional gyro of the prior art;

Fig. 9B is a graph depicting the vibratory force produced by a horizontal spring gyro of the present invention;

Fig 10 is a cross-sectional view of one embodiment of a member situated between a rotor shaft and a drive shaft according to the present invention;

5

Fig. 11A is a cross-sectional view of a second embodiment of a member situated between a rotor shaft and a drive shaft according to the present invention;

10 Fig. 11B is a top planar view of a sleeve with a slit as seen along line A-A of Fig. 11A;

Fig. 12A is a side elevation of a flexible coupling; and

15 Fig. 12B is an end view of a flexible coupling as seen along line B-B of Fig. 12A.

Detailed Description of the Invention

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Fig. 2 shows a cross section of a centrifuge assembly 100 according to the present invention. Centrifuge assembly 100 has a motor 150, a motor housing 140, a diaphragm 130, a drive shaft assembly 105, a drive spud 187 and a rotor (not shown).

25

Drive shaft assembly 105 includes a drive shaft 145 coupled to a rotor shaft 115 via a coupling 120. It also includes a gyro housing 110, which encloses one end of rotor shaft 115 and one end of coupling 120. Rotor shaft 115 is supported within gyro housing 110 by bearings 163.

30 Drive spud 187 is pivotally connected to rotor shaft 115, and the rotor is positioned on top of drive spud 187.

Diaphragm 130 is disposed about coupling 120 and flexibly couples drive shaft assembly 105 to motor housing 140. Diaphragm 130 is,

optionally, connecte to gyro housing 110 by bolts 125a an 125n, an connecte to motor housing 140 by bolts 135 an 135n. As will be describe below, diaphragm 130 permits drive shaft assembly 105 to pivot on a drive shaft assembly pivot point 155.

5

During centrifuge operation, motor 150 provides a rotational motive force that rotates drive shaft 145, coupling 120, rotor shaft 115, drive spu 187, and ultimately the rotor. At speeds below a critical speed the rotor rotates about its geometric center. The rotor's geometric axis is located at an axis 175a, which coincides with a vertical axis 165. Gyro housing 110, rotor shaft 115 and drive shaft 145 are also centered along vertical axis 165. Diaphragm 130 lies in a plane substantially perpendicular to drive shaft 145.

At an speed above the critical speed, the rotor rotates about its mass center. The mass center is offset from the geometric center by a distance 180. The rotor's mass center aligns with axis 175a, and consequently, the rotor's geometric axis is forced to shift horizontally to axis 175b. The relationship between axis 175a and 175b as shown in Fig. 2 represents an instant in time. As the rotor rotates about its mass center at axis 175a, the rotor's geometric axis revolves around axis 175a. That is, the geometric axis travels in a circle with a centerpoint at axis 175a and a radius of distance 180. Since axis 175a coincides with vertical axis 165, which is also the axis of drive shaft 145, the rotation of the rotor shaft about its mass center is concentric with the rotation of drive shaft 145.

Since the rotor is pivotally connected to drive spu 187 at drive spu pivot point 185, the rotor and its geometric axis are allowed to pivot along an arc 170 and remain vertical. However, the axis of rotor shaft 115 is deflected from vertical axis 165 to an axis 190. Axis 190 is defined by endpoints at drive spu pivot point 185 and drive shaft assembly pivot point 155. As the rotor rotates about its mass center at axis 175a, axis 190 revolves, and defines a cone of precession, around vertical axis 165.

As the axis of rotor shaft 115 is deflected to axis 190, diaphragm 130 permits gyro housing 110 to pivot along an arc 160 so that the centerline of gyro housing 110 likewise coincides with axis 190. In this illustration, which shows an instant in time, gyro housing 110 pivots on drive shaft assembly pivot point 155 in a counter-clockwise direction as shown by arc 160. The side of gyro housing 110 that is connected to diaphragm 130 by bolt 125a moves down, and the other side of gyro housing 100, which is connected to diaphragm 130 by bolt 125n, moves up. During centrifuge operation, gyro housing 110 oscillates about vertical axis 165. This oscillatory movement on the part of gyro housing 110 is referred to as "nutation". Gyro housing 110 is thus permitted to pivot off vertical axis 165 but its horizontal displacement is substantially limited.

In an actual centrifuge system, the difference between a rotor's mass center and geometric center, i.e., distance 180, is typically about 0.05 (50 thousandths) inches, and arc 160 represents about 1° of angular displacement off the vertical axis 165. The nutation of a gyro housing 110 is barely discernible to the naked eye, but a tremendous amount of force must be constrained. For example, a 57 pound rotor rotating at 9,000 cycles per minute (CPM) is subjected to approximately 6,000 pounds of centrifugal force.

Gyro housing 110 nutates, and diaphragm 130 flexes, at the same rate that the rotor rotates. Diaphragm 130 must be flexible enough to accommodate the nutation of gyro housing 110, yet strong enough to endure the stress imposed during centrifuge operation. Ideally, diaphragm 130 would have a zero spring rate and freely allow the rotor to shift its axis of rotation from its geometric center to its mass center. However, all objects oscillate at a natural frequency that is a function of their spring rate and mass. In practical application, diaphragm 130 is designed with a spring rate greater than the operating frequency of the centrifuge system. That is, a lower spring rate can be used in a centrifuge system with a heavy rotor and a low operating frequency, than in a system with a light rotor or high operating frequency. Several alternative embodiments of diaphragms

are presented below.

Fig. 3 is a top planar view of one embodiment of a diaphragm 192 according to the present invention. Diaphragm 192 is comprised of a plurality of radially directed bars 193 disposed about the circumference of a coupling 199 at regular angular intervals 198. Bars 193 are connected to a motor housing 194 by bolts placed through holes 195, and connected to a gyro housing 196 by bolts placed through holes 197. Bars 193 are approximately 0.180 inches wide and 0.060 inches thick, and manufactured of stainless steel.

Fig. 4 shows another embodiment of a diaphragm 200 according to the present invention. An outer flange 210 and inner flange 215 share a common center point 220. Inner flange 215 and outer flange 210 are connected by radially directed bars 225. Bars 225 are spaced at regular angular intervals 240 to partition diaphragm 200 into substantially equal arcs. Diaphragm 200 is connected to a gyro housing by bolts placed through holes 230, and connected to a motor housing by bolts placed through holes 235. Bars 225 are approximately 0.180 inches wide and 0.060 inches thick. Diaphragm 200 is manufactured of stainless steel.

Fig. 5 depicts still another embodiment of a diaphragm 300, comprising a disk 310 with a centrally located hole 315. Diaphragm 300 is connected to a gyro housing by bolts placed through holes 320, and connected to a motor housing by bolts placed through holes 325. Diaphragm 300 is manufactured of 16 gauge stainless steel.

Fig. 6 is a cross-sectional view of a centrifuge assembly in which vertical springs provide support for a drive shaft assembly. Drive shaft assembly 405 includes a drive shaft 445 coupled to a rotor shaft 415 via a coupling 420. It also includes a gyro housing 410, which encloses one end of rotor shaft 415 and one end of coupling 420. A flexible drive spud 487 is pivotally connected to rotor shaft 415, and a rotor (not shown) is positioned on top of drive spud 487. A diaphragm with radially directed bars 430a and

430b is disposed about coupling 420. Springs 450a and 450b are positioned to support drive shaft assembly 405.

5 Springs 450a and 450b are intended to relieve some of the vertical force imposed upon diaphragm bars 430a and 430b by the combined weight of drive shaft assembly 405 and the centrifuge rotor. Springs 450a and 450b serve to extend the useful life of diaphragm bars 430a and 430b.

10 Springs 450a and 450b can be manufactured of a metallic or elastomeric material. Practical examples include helical springs, wound springs, machined springs and elastomeric springs such as a Lord FlexBolt™, manufactured by Lord Corporation of Erie, Pennsylvania. However, elastomeric springs, as compared to metallic springs, provide better damping of vertical and oscillatory ringing of drive shaft assembly
15 405.

Fig. 7 is a top planar view showing the relationship of springs to diaphragm bars. Springs 450a and 450b, and bars 430a and 430b, are subsets of a plurality of springs 450a - 450n, and bars 430a - 430n,
20 respectively. Springs 450a - 450n and bars 430a - 430n are disposed about the perimeter of coupling 420. Any given spring 450a - 450n is located in an arc 460 formed between two adjacent bars 430a - 430n.

Fig. 8 is a cross-sectional view of a centrifuge assembly with another
25 embodiment of a spring for vertical support of a drive shaft assembly. A drive shaft assembly 505 includes a gyro housing 520 generally enclosing one end of a rotor shaft 525 and one end of a drive shaft 535, which are interconnected through a coupling 515. A flexible drive spud (not shown) and a rotor shaft (not shown) are positioned on top of rotor shaft 525. A
30 diaphragm 530 is disposed about coupling 515. Spring 510 is disposed about a load-bearing perimeter of gyro housing 520.

Spring 510 is a solid elastomer ring. It absorbs some of the vertical force imposed upon diaphragm 530 by the combined weight of drive shaft

assembly 505 and the centrifuge rotor. Spring 510 serves to extend the useful life of diaphragm 530.

5 Figs. 9A and 9B are graphs comparing the performance of a conventional gyro (Fig. 9A) to a horizontal spring gyro of the present invention (Fig. 9B). The horizontal axes of these graphs represent rotor cycles per minute (CPM) and the vertical axes represent units of acceleration (G).

10 A conventional gyro, represented in Fig. 9A, produces significant vibrations of approximately 7G at 6k CPM (ref. 610), and increases to approximately 14.3G at 18.8k CPM (ref. 620).

15 In contrast, a horizontal spring gyro of the present invention, represented in Fig. 9B, produces vibrations of approximately 4G at 6k CPM (ref. 630) and 2G at 18.8k CPM (ref. 640). The vibrations of the horizontal spring gyro are significantly lower than those of the conventional gyro in the range of 6k CPM to 18.8k CPM. Vibratory acceleration peaked at approximately 32.3G at 20.5k CPM (ref. 650). 20.5k CPM is therefore
20 the resonant frequency of the system. The frequency at which the peak occurs is adjustable by altering the thickness and width of the bars in the various embodiments of the diaphragm of the present invention. As the bars are made thicker and wider, the spring rate and the resonant frequency of the system increases. The spring rate can be increased to
25 set the resonant frequency above the operating frequency range of the system.

Fig. 10 shows one embodiment of a member situated between a rotor shaft and a drive shaft for limiting vertical displacement of the rotor shaft. A member 725 is situated between a rotor shaft 705 and a drive shaft 710. Member 725 is accommodated within an axially directed center hole through a coupling 730, and is held in place by coupling 730.
30

Member 725 is comprised of a metal cylindrical spacer 720 and two

rubber disk-shaped pads 715a and 715b. However, a spacer 720 or pad 715a alone may be adequate in some applications. Spacer 720 and pads 715a and 715b can be made of metal, rubber, nylon, polymeric material or any stiff elastomeric material.

5

Downward movement of rotor shaft 705 is limited by member 725. Pads 715a and 715b will compress to allow an angular deflection of rotor shaft 705 in relation to drive shaft 710.

10

Fig. 11A shows a second embodiment of a member situated between a rotor shaft and a drive shaft for limiting vertical displacement of the rotor shaft. A member 750 is situated between a rotor shaft 705 and a drive shaft 710. Member 750 is accommodated within an axially directed center hole through a coupling 730, and is held in place by coupling 730.

15

Member 750 is comprised of a column 760 disposed between a first sleeve 755 and second sleeve 765. Sleeve 755 slides over and substantially around an end of rotor shaft 705. Sleeve 765 slides over and substantially around an end of drive shaft 710. Member 750 can be made of metal, rubber, nylon, polymeric or any stiff elastomeric material.

20

The diameter of column 760 is small enough, and flexible enough, to allow an angular deflection of rotor shaft 705 in relation to drive shaft 710. Vertical movement of rotor shaft 705 will be limited by the firmness of column 760.

25

Referring to Fig. 11B, sleeve 765 includes axial slits 770. Sleeve 755, in Fig. 11A, also includes slits. The slits 770 allow sleeves 755 and 765 to more easily slide over the ends of their respective shafts 705 and 710.

30

As shown in Figs. 12A and 12B, coupling 730 includes a clamping mechanism 775 to compress slits 770 and secure sleeves 755 and 765 to shafts 705 and 710, respectively. A single piece flexible shaft coupling

such as that shown in Figs. 12A and 12B is available from Helical Products Co. of Santa Maria, California. Generally, coupling 730 can be any type of shaft coupling with a center hole.

- 5 Alternatively, instead of including and compressing slits 770, sleeves 755 and 765 can be secured to shafts 705 and 710 using set screws (not shown).

- 10 Those skilled in the art, having the benefit of the teachings of the present invention may impart numerous modifications thereto. Such modifications are to be construed as lying within the scope of the present invention, as defined by the appended claims.

What is claimed is:

1. A centrifuge assembly comprising:
 - 5 a rotor;
 - a drive shaft assembly; and
 - a motor which is capable of rotating said drive shaft assembly
 - 10 thereabout;
 - wherein the improvement comprises:
 - 15 a diaphragm disposed about said drive shaft assembly to permit said drive shaft assembly to pivot off a vertical axis while substantially limiting horizontal displacement thereof.
2. The centrifuge assembly of claim 1, wherein said drive shaft
20 assembly comprises a drive shaft, a rotor shaft disposed between said drive shaft and said rotor, and means for coupling said drive shaft to said rotor shaft.
3. The centrifuge assembly of claim 2, wherein said diaphragm is
25 disposed about said coupling means.
4. The centrifuge assembly of claim 2, wherein said drive shaft has an
axis of rotation, and said diaphragm is situated in a plane substantially
perpendicular to said axis of rotation.
- 30 5. The centrifuge assembly of claim 1, wherein said rotor has a center
of mass, and said diaphragm permits rotation of said rotor about said
center of mass.

6. The centrifuge assembly of claim 2, wherein said drive shaft assembly further comprises a gyro housing enclosing one end of said rotor shaft and one end of said coupling.
- 5 7. The centrifuge assembly of claim 1, further comprising a motor housing disposed about said motor, wherein said diaphragm flexibly couples said drive shaft assembly to said motor housing.
8. The centrifuge assembly of claim 1, wherein said diaphragm
10 comprises a plurality of radially directed bars.
9. The centrifuge assembly of claim 8, wherein said plurality of radially directed bars are spaced at angular intervals to partition said diaphragm into substantially equal arcs.
- 15 10. The centrifuge assembly of claim 8, wherein said diaphragm comprises an inner flange and an outer flange having a common center point, said plurality of radially directed bars connect said inner flange to said outer flange, and said inner flange is disposed about said drive shaft
20 assembly and between said outer flange and said drive shaft assembly.
11. The centrifuge assembly of claim 1, wherein said diaphragm comprises a disk having a centrally located circular hole disposed about said drive shaft assembly.
- 25 12. The centrifuge assembly of claim 1, further comprising a spring to vertically support said drive shaft assembly.
13. The centrifuge assembly of claim 12, wherein said spring is selected
30 from the group consisting of helical spring, wound spring, machined spring and elastomeric spring.
14. The centrifuge assembly of claim 12, wherein said spring comprises

an elastomer ring disposed about a load-bearing perimeter of said drive shaft assembly.

15. A centrifuge assembly comprising:

5

a rotor;

a drive shaft;

10

a rotor shaft disposed between said drive shaft and said rotor; and

a motor which is capable of rotating said drive shaft thereabout;

wherein the improvement comprises:

15

a member situated between said rotor shaft and said drive shaft for limiting vertical displacement of said rotor shaft while permitting angular deflection of said rotor shaft with respect to said drive shaft.

20

16. The centrifuge assembly of claim 15, wherein said member comprises a disk-shaped pad.

17. The centrifuge assembly of claim 15, wherein said member comprises a cylindrical spacer.

25

18. The centrifuge assembly of claim 15, wherein said member comprises a disk-shaped pad and a cylindrical spacer.

30

19. The centrifuge assembly of claim 15, wherein said member comprises a first sleeve that is disposed substantially around said drive shaft, a second sleeve that is disposed substantially around said rotor shaft, and a column disposed between said first sleeve and said second sleeve.

20. The centrifuge assembly of claim 19, further comprising an axial slit within at least a portion of said first sleeve.
- 5 21. The centrifuge assembly of claim 19, wherein the outer diameter of said column is less than the outer diameter of said first sleeve.
22. The centrifuge assembly of claim 15, wherein said member comprises a material selected from the group consisting of metal, rubber,
10 nylon, polymeric material and elastomeric material.

AMENDED CLAIMS

[received by the International Bureau on 01 December 2000 (01.12.00);
original claims 15 – 22 cancelled; original claims 1,2,4,6 and 13 amended;
other claims unchanged (3 pages)]

1. A centrifuge assembly comprising:

5 a rotor;

a drive shaft assembly coupled to said rotor; and

**10 a motor coupled to said drive shaft assembly via a drive shaft, for
rotating said rotor via said drive shaft assembly;**

wherein the improvement comprises:

**15 a diaphragm disposed about said drive shaft assembly that
substantially aligns an axis of said drive shaft with a geometric axis
of said rotor when said rotor is at rest, and that permits said drive
shaft assembly to pivot off a vertical axis when said rotor is rotating.**

**2. The centrifuge assembly of claim 1, wherein said drive shaft
20 assembly further comprises a rotor shaft disposed between said drive
shaft and said rotor, and means for coupling said drive shaft to said rotor
shaft.**

**3. The centrifuge assembly of claim 2, wherein said diaphragm is
25 disposed about said coupling means.**

**4. The centrifuge assembly of claim 1, wherein said drive shaft has an
axis of rotation, and said diaphragm is situated in a plane substantially
perpendicular to said axis of rotation.**

30

**5. The centrifuge assembly of claim 1, wherein said rotor has a center
of mass, and said diaphragm permits rotation of said rotor about said
center of mass.**

6. The centrifuge assembly of claim 2, wherein said drive shaft assembly further comprises a gyro housing enclosing one end of said rotor shaft and one end of said coupling means.

5

7. The centrifuge assembly of claim 1, further comprising a motor housing disposed about said motor, wherein said diaphragm flexibly couples said drive shaft assembly to said motor housing.

10 8. The centrifuge assembly of claim 1, wherein said diaphragm comprises a plurality of radially directed bars.

9. The centrifuge assembly of claim 8, wherein said plurality of radially directed bars are spaced at angular intervals to partition said diaphragm into substantially equal arcs.

15

10. The centrifuge assembly of claim 8, wherein said diaphragm comprises an inner flange and an outer flange having a common center point, said plurality of radially directed bars connect said inner flange to said outer flange, and said inner flange is disposed about said drive shaft assembly and between said outer flange and said drive shaft assembly.

20

11. The centrifuge assembly of claim 1, wherein said diaphragm comprises a disk having a centrally located circular hole disposed about said drive shaft assembly.

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12. The centrifuge assembly of claim 1, further comprising a spring to vertically support said drive shaft assembly.

30 13. The centrifuge assembly of claim 12, wherein said spring is selected from the group consisting of a helical spring, a wound spring, a machined spring and an elastomeric spring.

14. The centrifuge assembly of claim 12, wherein said spring comprises an elastomer ring disposed about a load-bearing perimeter of said drive shaft assembly.

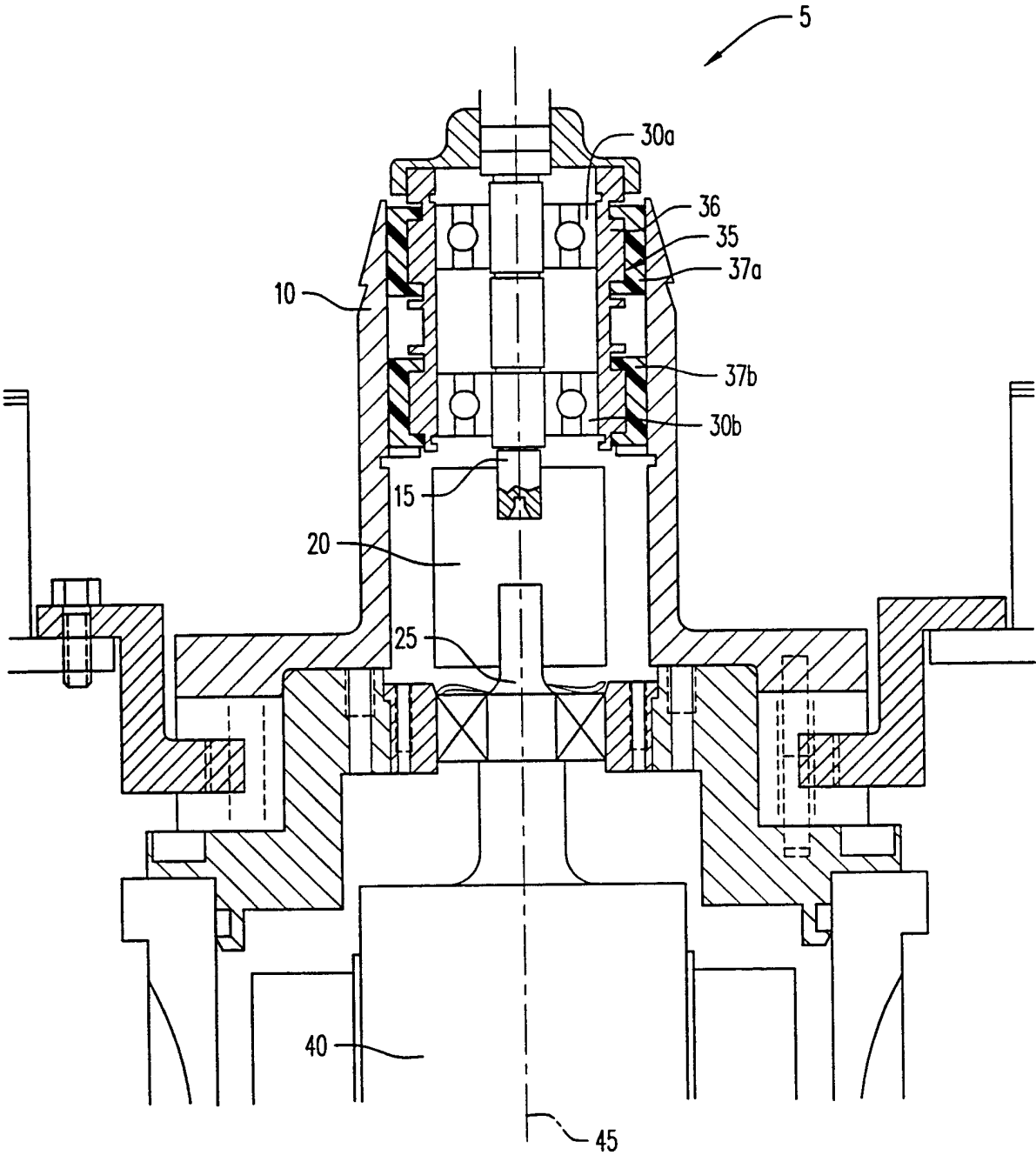


FIG. 1
(PRIOR ART)

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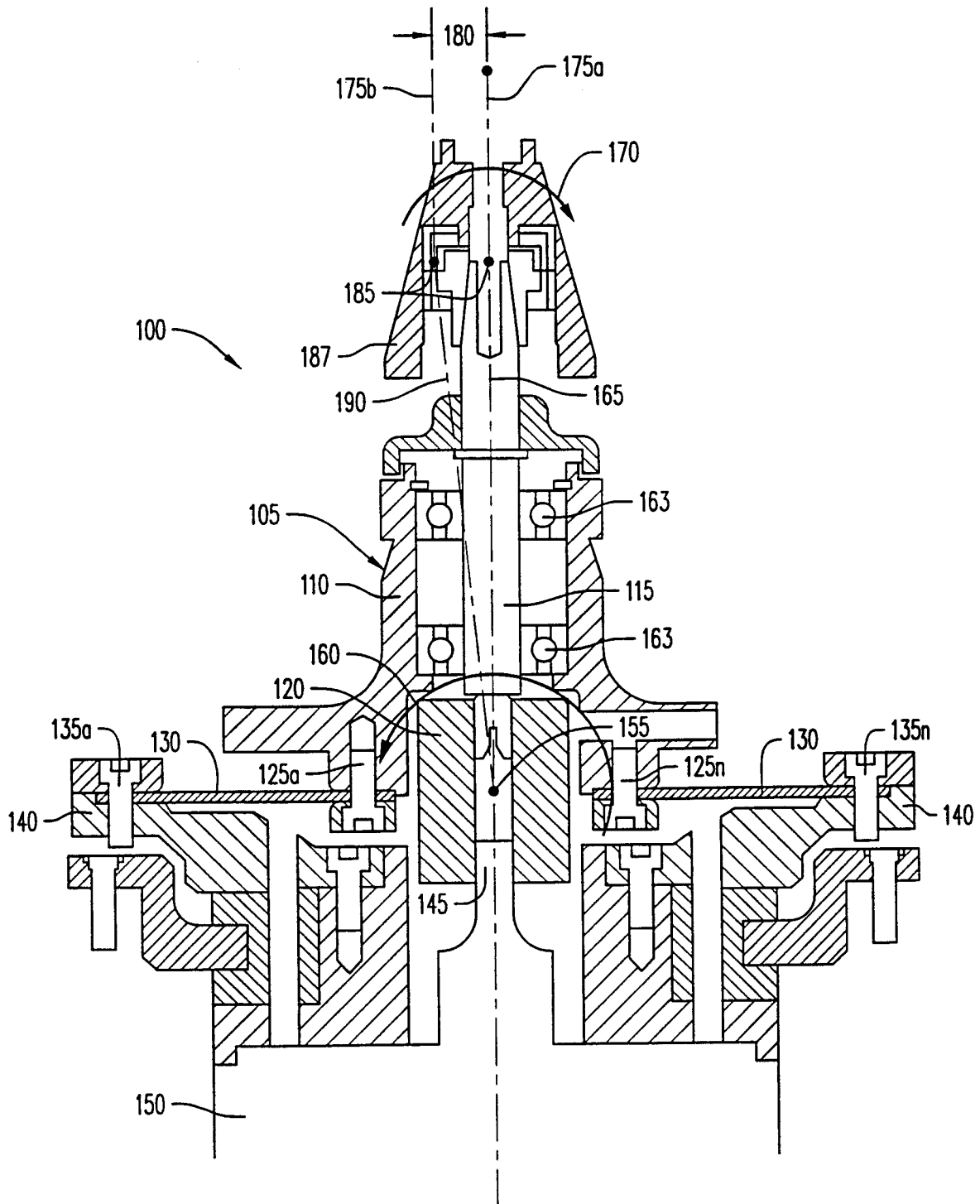


FIG. 2

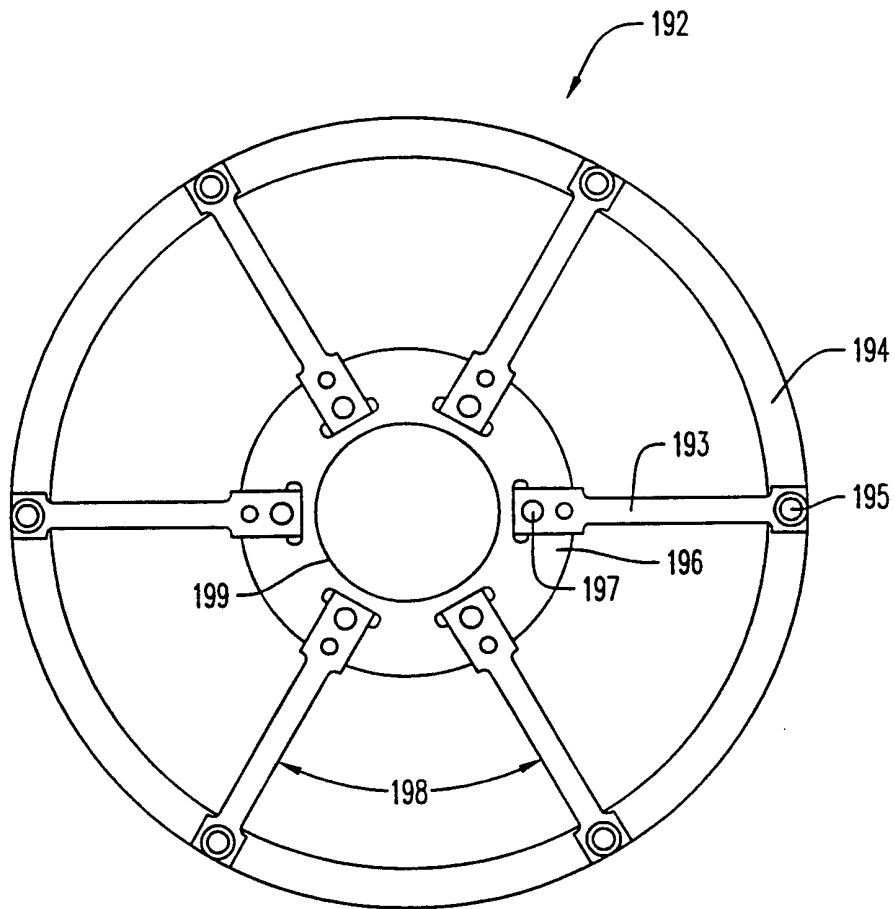


FIG. 3

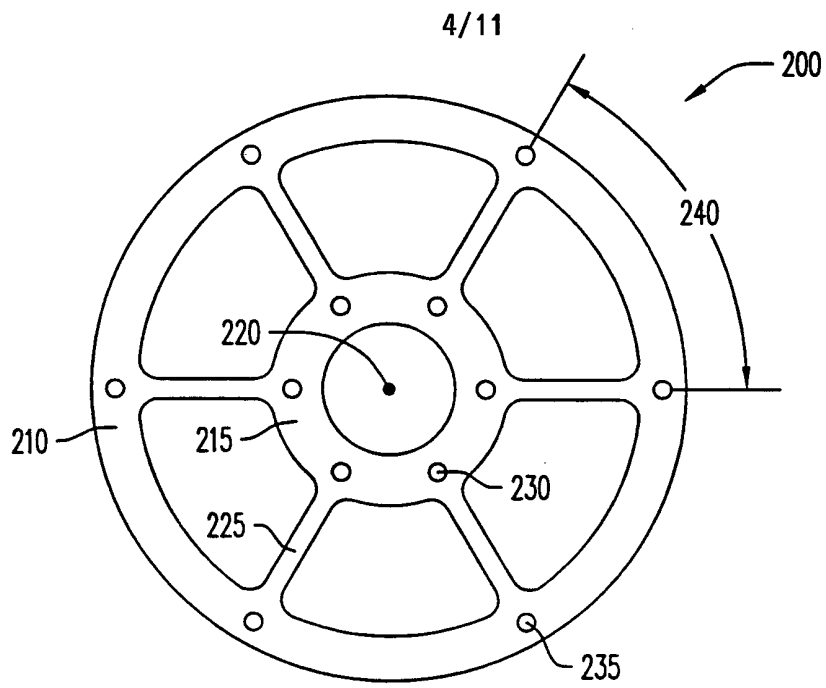


FIG. 4

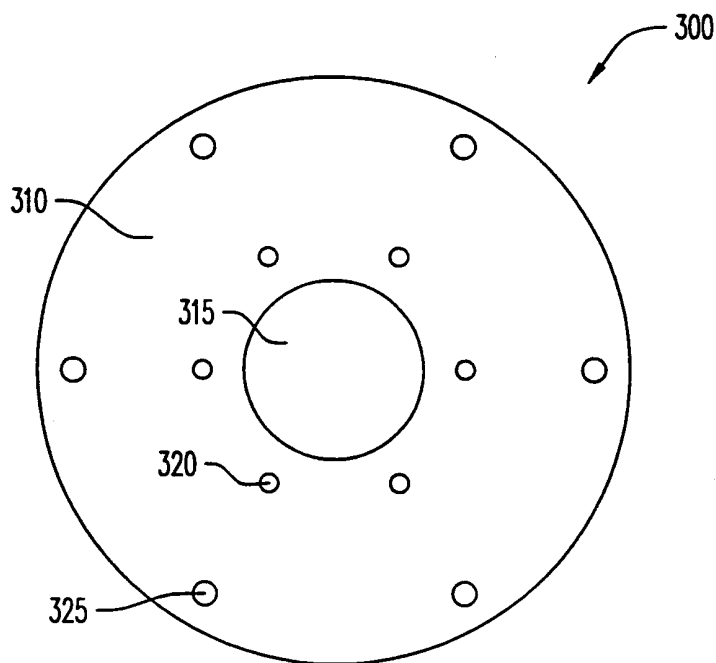


FIG. 5

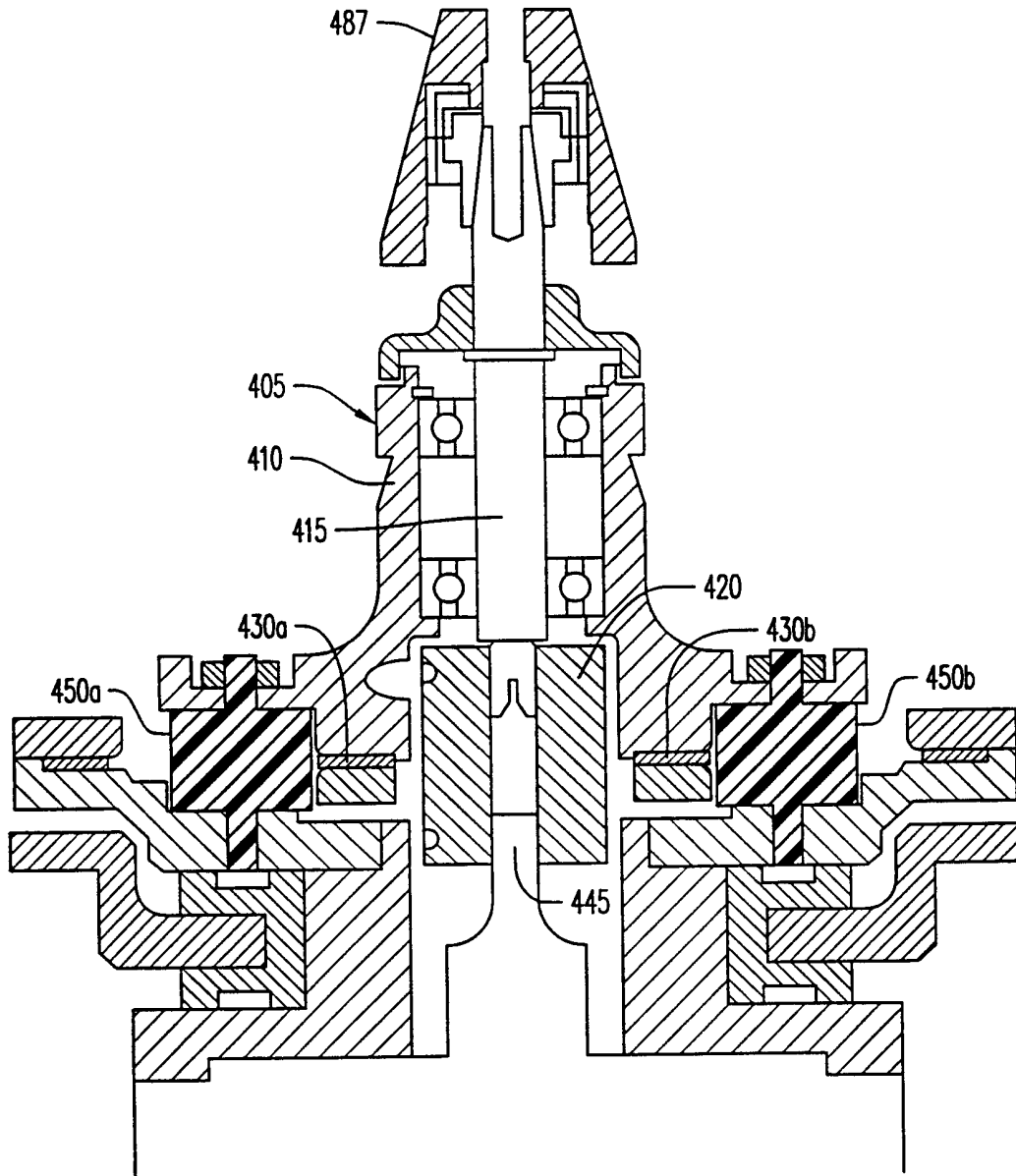


FIG. 6

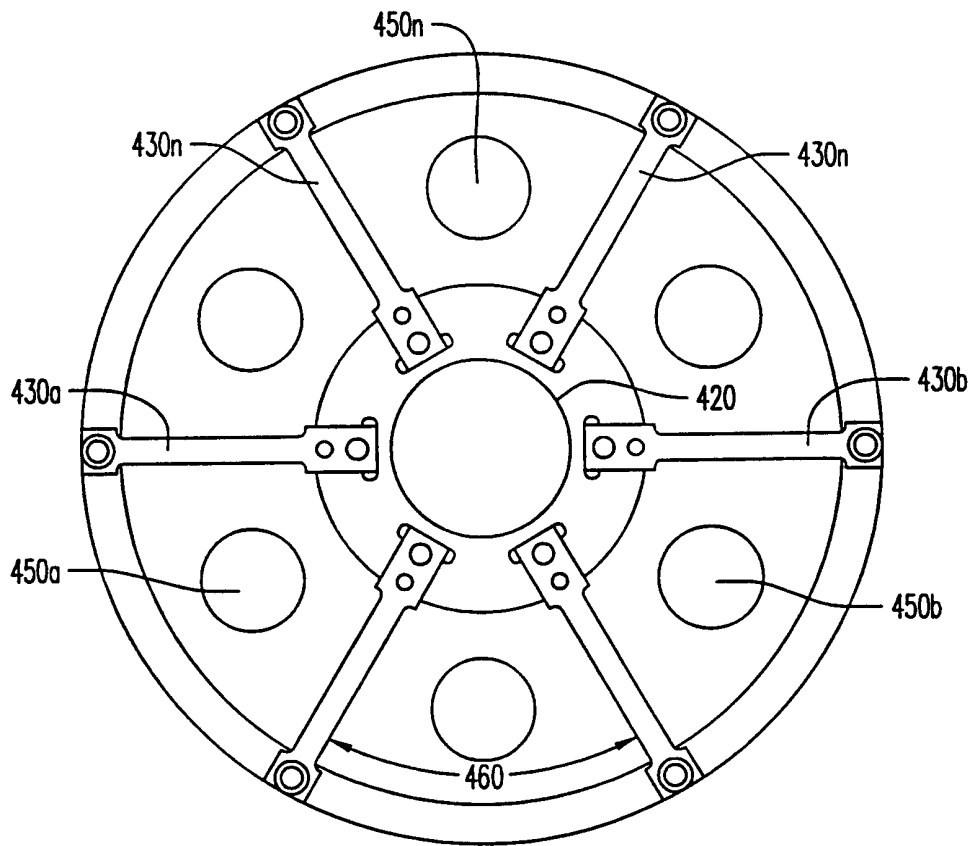


FIG. 7

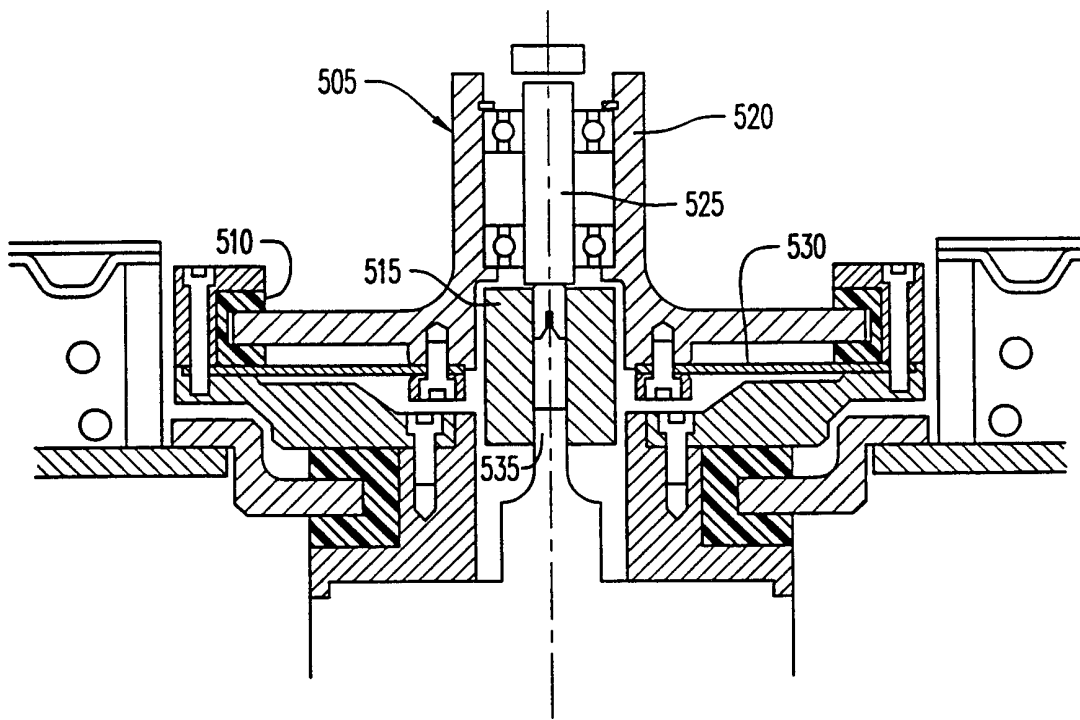


FIG. 8

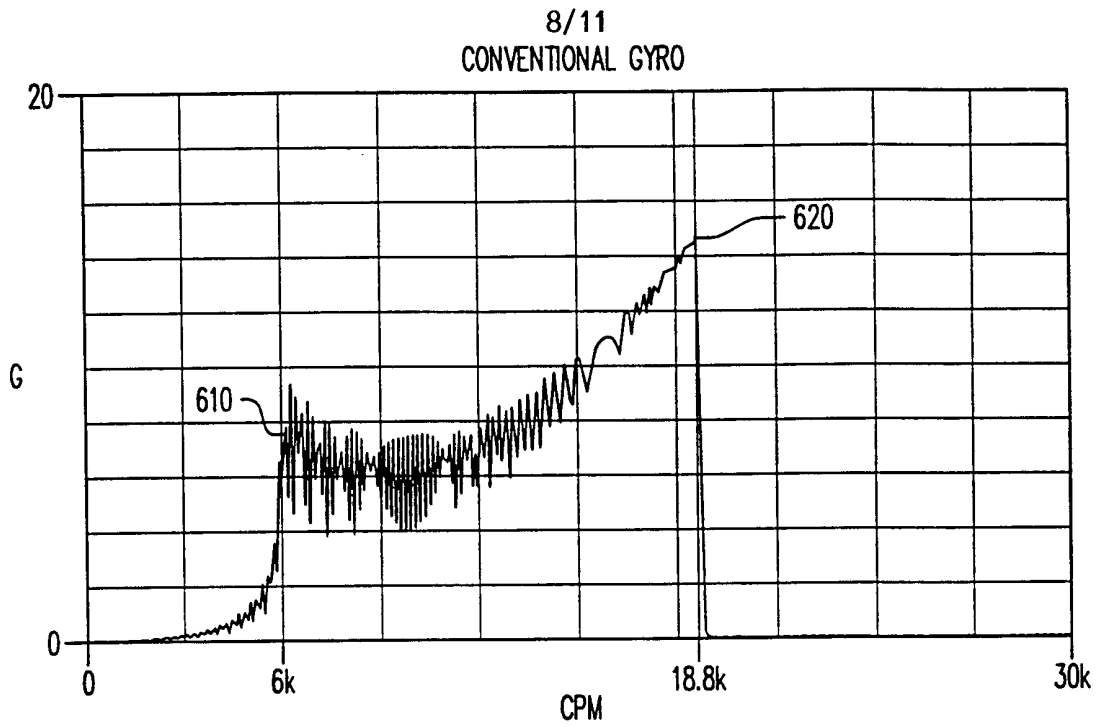


FIG. 9A

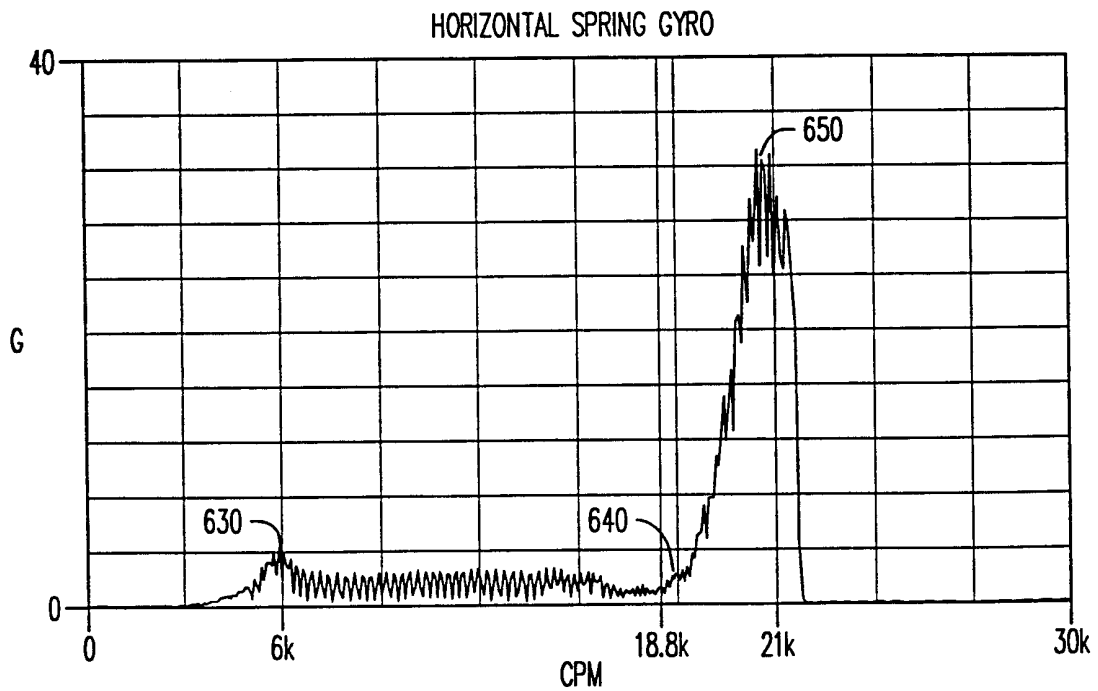


FIG. 9B

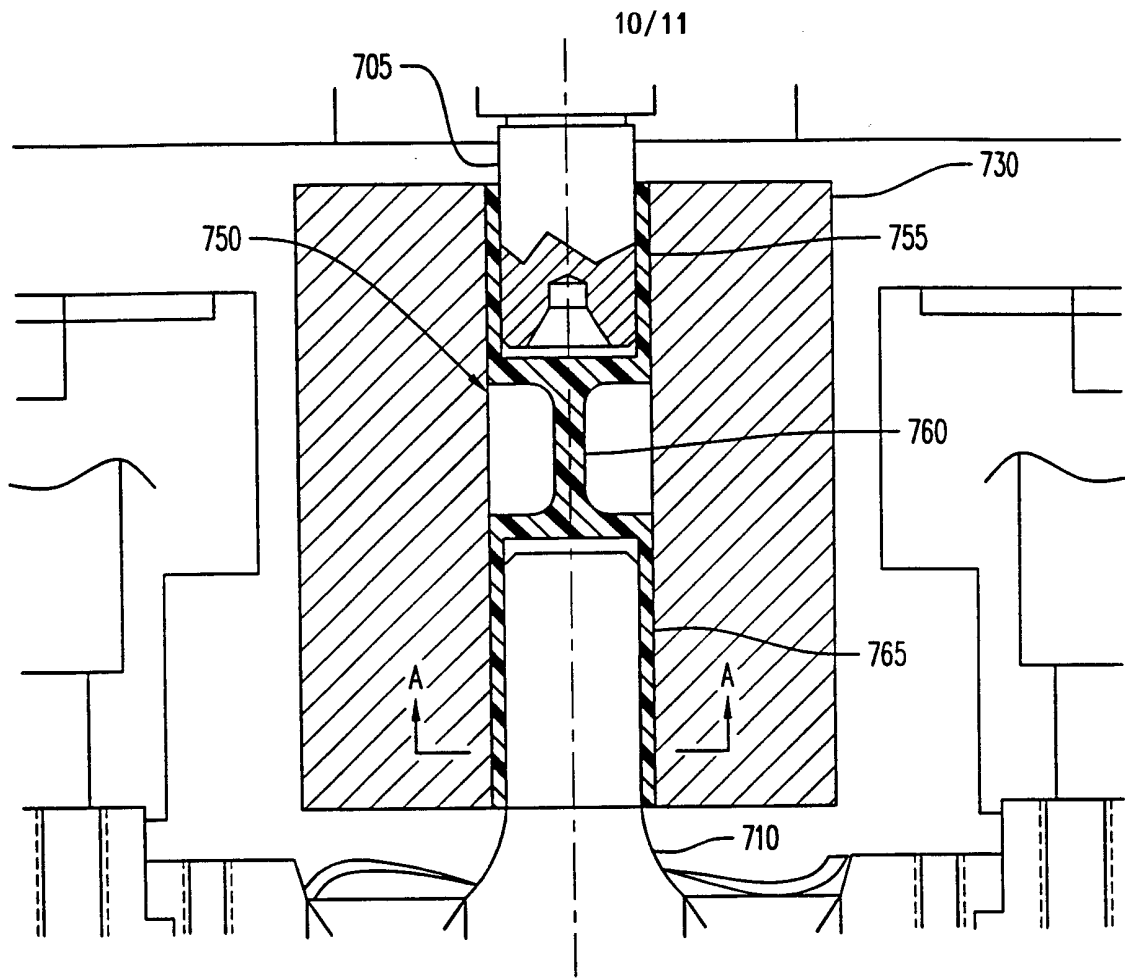


FIG. 11A

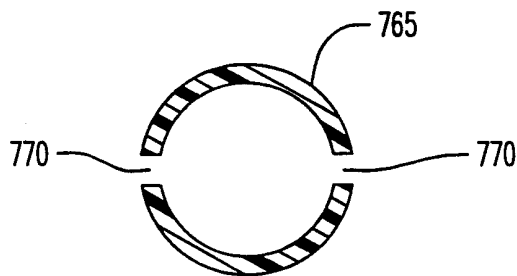


FIG. 11B

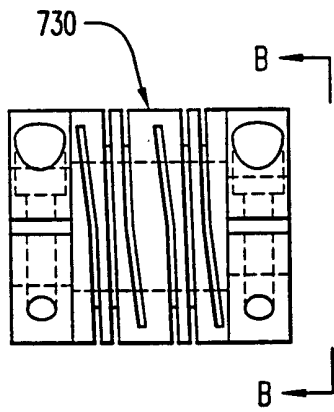


FIG. 12A

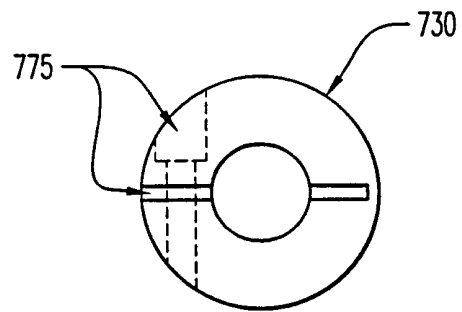



FIG. 12B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/16619

A. CLASSIFICATION OF SUBJECT MATTER		
IPC(7) :B04B 9/14 US CL :494/82, 84; 464/180; 74/574 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) U.S. : 494/1, 7, 9, 10, 12, 16, 20, 46, 82, 84; 464/180; 74/572, 574; 68/23.1, 23.3; 210/144, 363		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched NONE		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) NONE		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,827,168 A (HOWELL) 27 October 1998, see Figures 2-3.	1-6, 11, 15, 17, 19, and 22
X	US 3,770,191 A (BLUM) 06 November 1973, see Figures 1, 2, 5, and 6.	1, 2, 4-6, and 11-13
X	US 5,026,341 A (GIEBELER) 25 June 1991, see Figures 1 and 3A.	1, 2, 4-6, and 11
X	US 5,342,282 A (LETOURNEUR) 30 August 1994, see Figures 1-2.	1, 2, 4-6, 11, 15-18, and 22
X	US 4,334,718 A (HIRT et al.) 15 June 1982, see Figures 1-3.	1, 5, and 11-13
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means		
"P" document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search 05 SEPTEMBER 2000	Date of mailing of the international search report 02 OCT 2000	
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer  CHARLES E. COOLEY Telephone No. (703) 308-0651	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/16619

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,511,350 A (ROMANAUSKAS) 16 April 1985, see Figure 1.	15 and 22
X	US 847,009 A (KNUDSEN) 12 March 1907, see Figures 1-4.	15 and 22
X	US 4,910,502 A (SERVEAU et al.) 20 March 1990, see Figures 1 and 3.	1, 5, and 7
A	US 3,779,451 A (LEHMAN) 18 December 1973, see Figure 1.	15-22
A	US 4,411,637 A (RAUCH) 25 October 1983, see the Figure.	1-14