Feb. 19, 1963 M. BRUENIG 3,078,035

PENDULUM CENTRIFUGE

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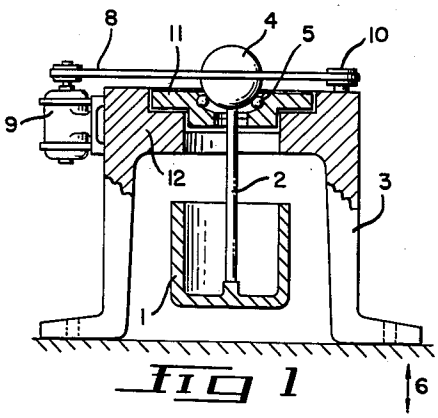


FIG 1

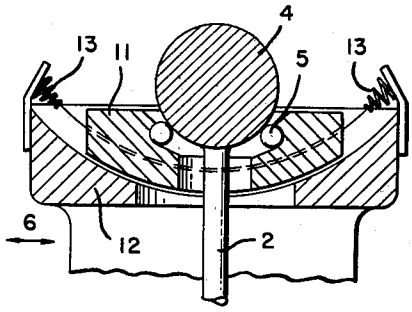


FIG 3

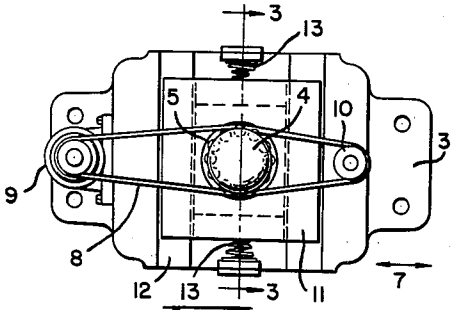


FIG 2

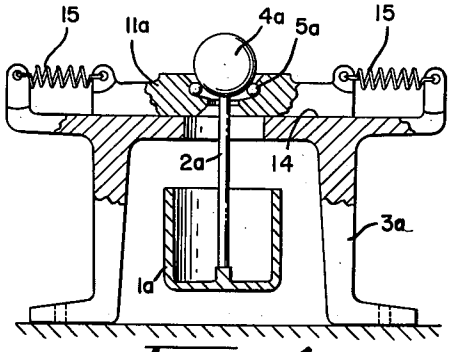


FIG 4

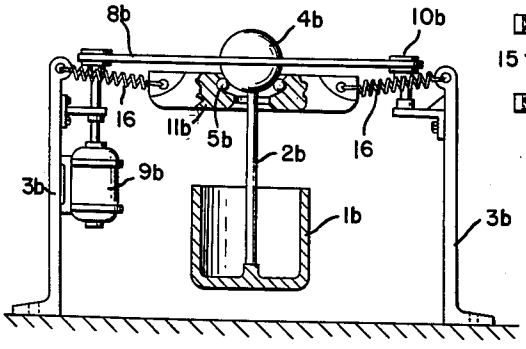


FIG 6

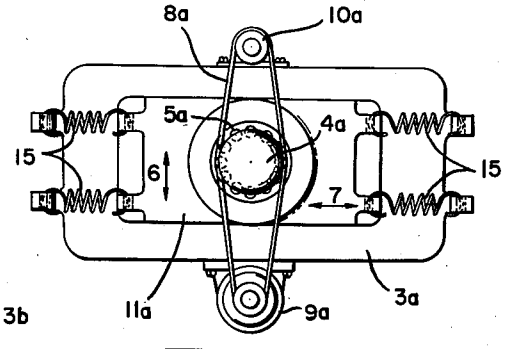


FIG 5

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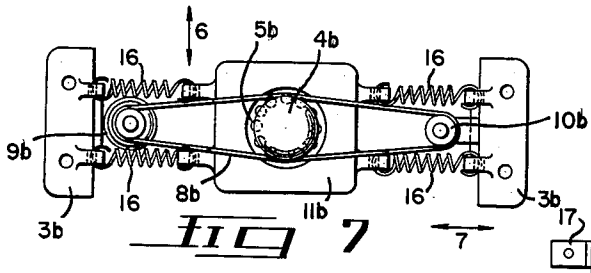


Fig 7

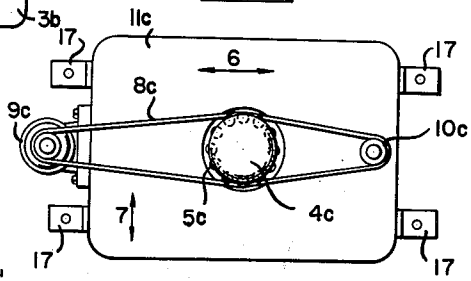


Fig 9

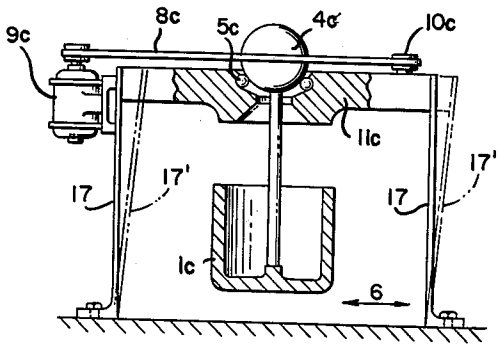


Fig 8

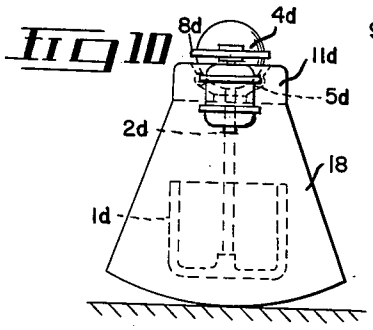


Fig 10

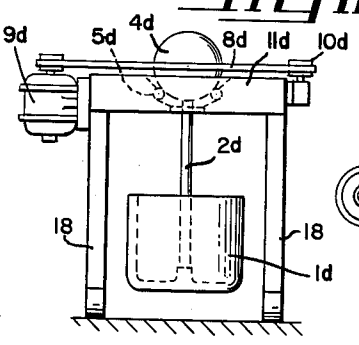


Fig 11

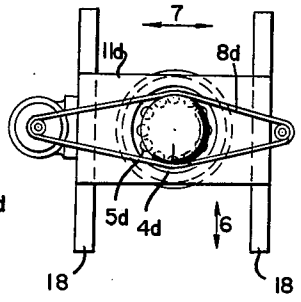


Fig 12

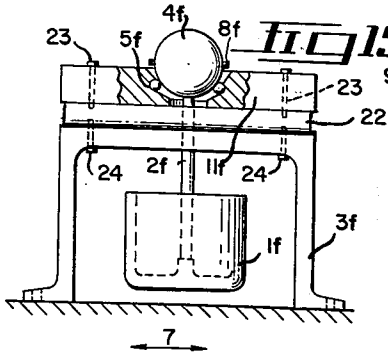


Fig 15

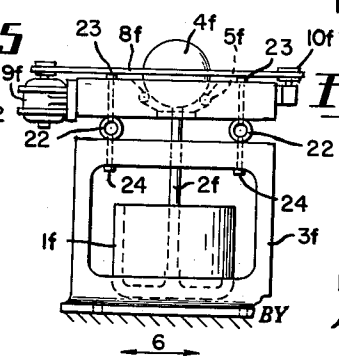


Fig 16

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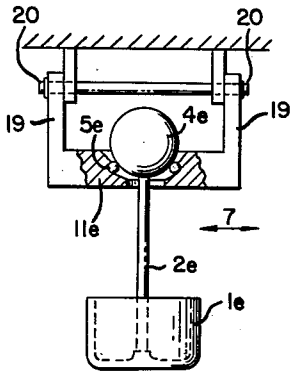


FIG 13

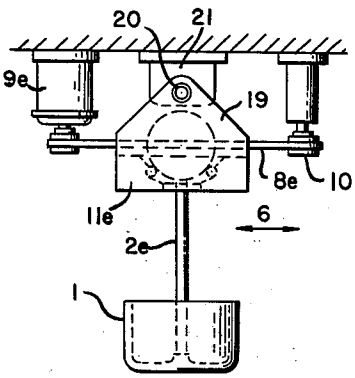
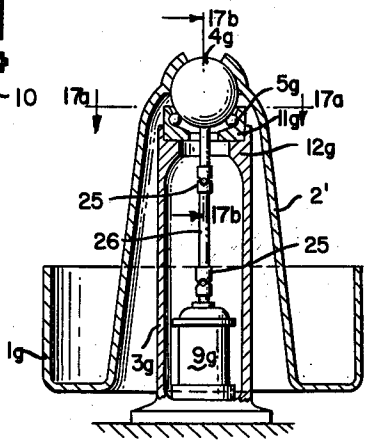


FIG 14

FIG 17



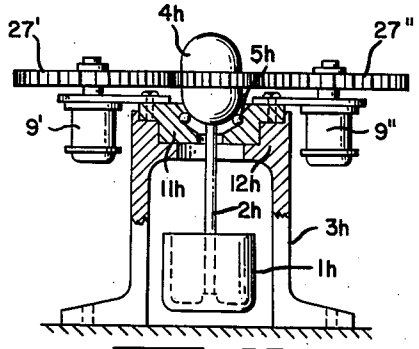


FIG 18

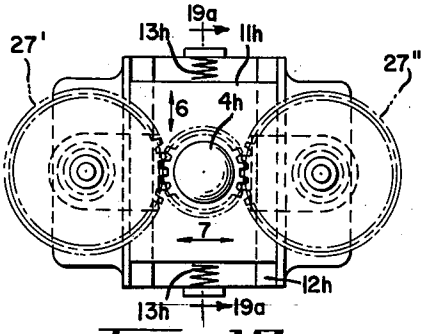


FIG 19

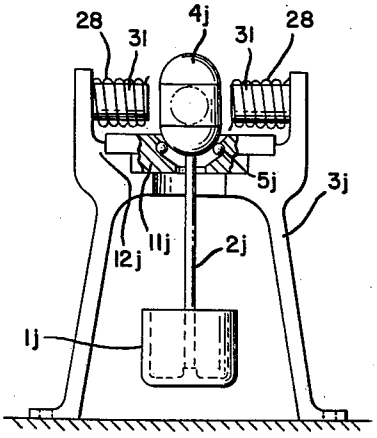


FIG 20

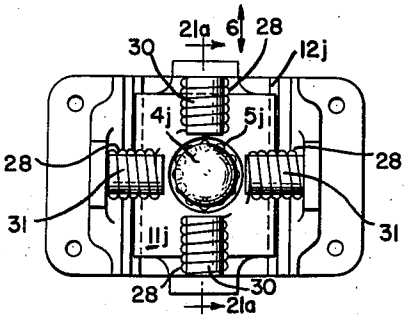


FIG 21

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FIG. 17a

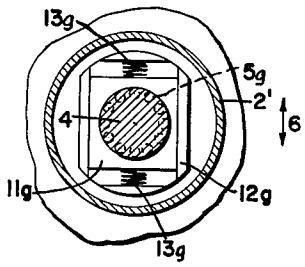


FIG. 17b

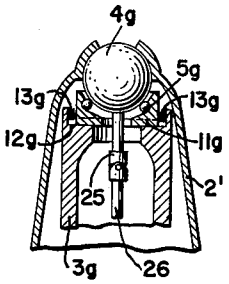


FIG. 19a

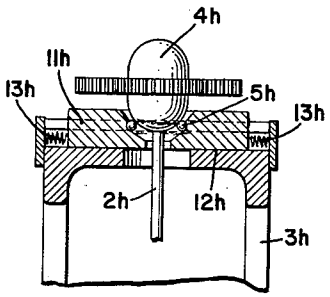
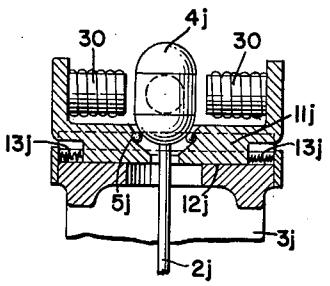


FIG. 21a



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United States Patent Office

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Patented Feb. 19, 1963

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PENDULUM CENTRIFUGE

Matthias Bruenig 23 Parchimerstrasse, Hamburg-Rahlstedt 24a, Germany

Filed Jan. 8, 1958, Ser. No. 707,772
Claims priority, application Germany Nov. 5, 1957
19 Claims. (Cl. 233—24)

This invention relates generally to centrifuges and more particularly to centrifuges of the pendulous type in which the rotary centrifuge body is pendulously suspended from a supporting member of the centrifuge frame.

Centrifuge construction and operation present a problem in that the rotary body or container including the material to be centrifuged must be balanced to a relatively high degree, otherwise the centrifuge will cause violent vibration such as to impart a heavy burden on bearings and the entire centrifuge structure including the foundation and even the building in which the centrifuge is installed. Such vibration caused by centrifuges, particularly of the heavy type, results in wear and tear not only on the structure of the centrifuge itself, but also on foundation and building and is also annoying in other respects.

In order to counteract wear and vibration it has been the practice in the prior art to provide centrifuges with oversize bearings, heavy frames and rugged foundations. Such practice, however, is costly and does not present a satisfactory solution of the problem. Perfect balancing of the rotary body is in most cases impossible since the material to be centrifuged can generally not be kept in equilibrium.

The pendulous type of centrifuge in which the rotary centrifuge body, mostly in the form of a container, is hung from a point of suspension and is free to align itself with its center of gravity vertically below its point of suspension, has some advantage in that it prevents disturbing vibration and excessive strain on the structure of the centrifuge. Such pendulum centrifuge, however, has another drawback which becomes evident particularly during starting and stopping when the suspended pendulous body, to which spinning motion is imparted, tends to perform an additional movement in that it swings outwardly in such a manner that the axis of rotation traces a cone in space with the point of suspension being the apex of the cone. Such swing-out motion can assume magnitudes that are dangerous and may lead to destruction of the centrifuge.

Therefore it is the primary object of this invention to provide means for stabilizing the rotary body of a pendulum centrifuge and thus to prevent the dangerous swing-out action described above.

It is another object of this invention to take advantage of the lower strains on the centrifuge structure achieved by such stabilizing means and provide improved centrifuges which are of lighter construction and thus cheaper to manufacture, but which in spit of inexpensiveness do not vibrate, have long life, and are reliable in service.

Still another object of this invention is to provide a rotary centrifuge body serving as a container for the material to be centrifuged, which can readily be removed from frame and drive of the centrifuge to serve also for transporting the material and thus save time in loading and unloading.

Stabilizing of the rotary, pendulous centrifuge body, in accordance with this invention, is achieved by limiting or preventing the swing-out action of this body. The swing-out action during which the axis joining the point of suspension and the center of gravity of the rotary body deviates from the vertical, is identical, as will be recalled, to the precession of a gyroscope in which the gyro is suspended by means of a friction bearing. Experiments with a gyro in connection with this invention, whereby the gyro body was suspended in ball bearings, have revealed that during the swing-out action the movement of the body axis takes a direction that is opposite to the direction of precession. This additional motion cannot be fully explained by physical laws but it can be assumed that it is due to friction on the carrying ball surface.

The present invention takes advantage of the recognition that a pendulously suspended, spinning gyro body is prevented from swinging out at its lower free end when a force is applied that acts on the body axis beneath the point of suspension and has a direction opposing such motion. The couple resulting from such force and the corresponding counter-force at the point of suspension effect a righting action on the gyro.

The force beneath the point of suspension, according to the present invention in which the gyro is represented by the rotary centrifuge body, is applied intermittently in that the bearing member, upon which the point of suspension in the form of a ball race or the like is located, is mounted to give it free lateral movement in both substantially horizontal directions of one vertical plane but to prevent substantial lateral movement of it in the vertical plane at right angles thereto. The pendulously suspended centrifuge body, besides having freedom to spin about its vertical axis and to swing in all radial directions, gains thereby the addtional freedom to escape with its point of suspension in the two opposite directions of one vertical plane. This freedom to escape in said directions, reduces twice during each revolution temporarily to practically zero the horizontal component of the force acting on the suspension means, and thereby effects a righting action or stabilizing of the pendulum, which fact prevents any dangerous swing-out of its rotational orbit and leaves enough latitude of movement to avoid vibration and excessive forces on the supporting structure, thus allowing lighter and less expensive construction of the centrifuge. On the other hand, advantages of the pendulous arrangement are retained, for instance, the rotary body including its contents may be considerably out of balance without causing trouble by vibration.

The means for stabilizing the rotary pendulous body in a manner as set forth above can take various forms. The supporting bearing member, carrying the ball race upon which a member for suspending the pendulous body rests, can be arranged in slides which in turn are secured to the stationary frame of the machine. In these slides the bearing member can move in the direction of the slides but is prevented from movement in the direction at right angle thereto. Many other mechanical forms are possible in which the principle of the invention is employed and in which the supporting bearing member beneath the point of suspension of the pendulous body is mounted to have substantial freedom of movement in substantially horizontal directions of one vertical plane, but is substantially restricted from movement in substantially horizontal directions of the vertical plane at right angle thereto. The vertical planes referred to are planes that contain or pass through the spin or rotary axis of the centrifuge body and are sometimes called meridian planes. Other mounting means for the supporting bearing member which make it possible to achieve the same end are springs, rollers, pivoted links, rockers and so forth. A limited number of examples of mounting is described in the detailed description to follow, but the invention is not limited to any specific form of mounting construction and others will occur to those skilled in the art, which fall within the scope of the limitations as defined in the claims.

The means for driving the rotary pendulous body must

be adapted for that purpose in order not to interfere with the desired freedom of movement as explained above. A belt drive, acting on the rotary body above its point of suspension from two opposite sides so as not to exert any push or pull thereon, or a shaft with a universal joint attached substantially in alignment with the axis of rotation at the upper end of the pendulum is suitable. Moreover, when fashioning the extension of the rotary body above its point of suspension in the form of a rotor and arranging a suitable magnetic field structure thereabout, a revolving magnetic field may be employed as a drive in a manner well known in the art.

The novel features as provided by this invention can be incorporated in centrifuges designed for most diversified purposes and are adaptable to improve centrifuges to such extent that they find acceptance in fields where the centrifuging process was not generally employed up to now. The features can be incorporated, for example, in milk, oil, laboratory and drying centrifuges, in centrifuges as employed in the sugar and chocolate industries, in centrifugal casting and molding machines, in devices for centrifuging chips and galvanized goods, and in many other devices in which centrifugal force is utilized and particularly where unbalanced conditions in operation are encountered and mostly cannot be avoided, or wherever the auxiliary use of the centrifuge containers as means for transporting and handling the material offers greater economy.

Various preferred embodiments of the invention will now be described in detail with reference to the accompanying drawings in which:

FIG. 1 is a side elevational view, partly in section, of a pendulum centrifuge in which the desired restricted freedom of motion according to the invention is achieved by application of slides;

FIG. 2 is a plan view of the embodiment depicted in FIG. 1;

FIG. 3 is an enlarged fragmentary cross-section on the line 3—3 of FIG. 2;

FIG. 4 is a side elevational view, partly in section, of an embodiment in which the slidable bearing member is guided by springs;

FIG. 5 is a fragmentary plan view of the embodiment shown in FIG. 4;

FIG. 6 is a side elevational view of an arrangement in which the bearing member, above which the point of suspension of the pendulous body is located, is secured and restricted in its freedom of movement by springs alone;

FIG. 7 is a plan view of the arrangement shown in FIG. 6;

FIG. 8 is a side elevational view of a modification in which for obtaining restricted freedom of motion, the supporting bearing member is secured by brackets or feet which are resilient in one vertical plane, but are relatively rigid in the vertical plane at right angle thereto;

FIG. 9 is a plan view of the construction shown in FIG. 8;

FIG. 10 is a side elevation of an embodiment in which the supporting bearing member is mounted on rockers which allow rocking movement in one vertical plane, but are rigid in the vertical plane at right angle thereto;

FIG. 11 is an end elevational view of the embodiment depicted in FIG. 10;

FIG. 12 is a partial plan view of the embodiment shown in FIG. 10;

FIG. 13 is a side and FIG. 14 an end elevational view of an embodiment wherein the supporting bearing member is suspended by arms pivotally connected to a frame structure above;

FIG. 15 is a side and FIG. 16 an end elevational view, partly in section, of an embodiment wherein the supporting bearing member is arranged on rollers;

FIG. 17 shows an elevation of a modification in which the supporting bearing member is arranged inside of the hollow, conical pendulous centrifuge body;

FIG. 17*a* is a horizontal section on line 17*a*—17*a* of FIG. 17, showing particularly the slidable arrangement of the bearing member;

FIG. 17*b* is a fragmentary vertical sectional view on the line 17*b*—17*b* of FIG. 17 showing the straight substantially horizontal sliding construction of this device;

FIGS. 18 and 19 are side elevational and plan views respectively, partly in section, of an arrangement for driving the pendulous centrifuge body by gearing;

FIG. 19*a* is a fragmentary vertical sectional view on the line 19*a*—19*a* of FIG. 19 showing the straight substantially horizontal sliding engagement of the bearing member;

FIGS. 20 and 21 are side elevational and plan views respectively, partly in section, of an arrangement for driving the pendulous centrifuge body by means of a revolving magnetic field; and

FIG. 21*a* is a fragmentary vertical sectional view on the line 21*a*—21*a* of FIG. 21 showing the sliding engagement of the bearing member in this embodiment.

Referring next to FIGS. 1 to 3 of the drawings, there is shown the rotary pendulous centrifuge body **1** in the form of a container secured to the pendulum rod **2** which in turn is suspended in a housing or frame **3**. As a means of suspension there is secured to the upper end of rod **2** a head **4** which is illustrated in all of the figures as a sphere but can take other suitable shapes particularly in its upper portion whereas the lower surface is preferably spherical as will become apparent shortly. This sphere **4** is resting on a ball race **5** which is arranged in a substantially horizontal plane on supporting bearing member **11**. There is substantial clearance between ball race **5** and rod **2** so that the pendulous body **1** is not only free to rotate but is also able to swing owing to the spherical surface of head **4**. Head **4** forms actually the point of suspension of the pendulum **1**, **2** as theoretically such point is located within head **4** at the focus of the curvature of the spherical surface resting on ball race **5**. The supporting bearing member **11**, according to this invention, is so mounted that it has substantial freedom to move in substantially horizontal directions of one vertical plane, but is restrained from practically all movement in horizontal directions of a vertical plane at right angles thereto. This freedom of movement may amount to only a few millimeters, but it can be considerably more, up to a few centimeters. In the example shown in FIGS. 1 to 3, restricted freedom of movement as specified above is achieved by arranging bearing member **11** in slides **12** which are fixedly secured to frame **3** or form an integral part thereof. It can readily be seen that in this arrangement bearing member **11** can slide in substantially horizontal directions of a vertical plane indicated by the two directions of the arrow **6** but is prevented from movement in the directions indicated by the arrow **7** and lying in a vertical plane normal to the first plane. To be better adapted to the pendulous motion of the system, slides **12** and the bottom of bearing member **11** are preferably curved as shown in section FIG. 3, but this curvature is not absolutely necessary and straight slides will serve as well to practice the invention. Moreover, ball race **5** can be replaced by a sliding surface. To limit movement in the directions **6** within a desirable degree, stops can be provided which are preferably elastic, and springs **13** are indicated in FIGS. 2 and 3 to serve that purpose.

The driving means for imparting spinning motion to pendulous centrifuge body **1** is preferably applied at its point of suspension so as not to cause any disturbing forces in the system. A belt drive is indicated in FIGS. 1, 2, and others, whereby the belt **8** engages head **4** on two opposite sides and extends between an idler pulley **10** and the driving pulley with motor **9**. It may appear that the belt, when arranged as shown in FIGS. 1 and 2, with its direction substantially at right angles to the direction

of freedom of movement of bearing member 11, interferes with such operational movement, but experience has shown that belt flexibility is generally sufficient to allow for necessary movement, which, as stated above, may amount to only a few millimeters. The drive as such forms no part of this invention and other driving means well known in the art can be employed, for instance, a flexible shaft or a universal joint can be attached to top or bottom of sphere 4 to transmit rotation. Also gear or friction wheel drives are possible and a preferred form of such a drive will be described hereinafter.

A modified embodiment of the invention is shown in FIGS. 4 and 5, wherein bearing member 11*a* is provided with a plane bottom surface sliding on a horizontal surface 14 secured to or forming an integral part of frame 3*a*. To obtain the desired degree of freedom of motion of bearing member 11*a* in accordance with this invention, tension springs 15 are fastened each with one end to this bearing member and with the other end to a projection of frame 3*a*. Four such springs are illustrated in the figures and all are parallel to one another and arranged two on one side and two on the other side of bearing member 11*a*. It will be understood that with these springs under sufficient tension, bearing member 11*a* is substantially restricted from moving in horizontal directions of a vertical plane lying parallel to the axes of the springs as indicated by arrow 7, but will have substantial freedom to move transversely thereto, i.e., in horizontal directions of the vertical plane indicated by arrow 6. Or, in other words, a revolving radial force acting on bearing member 11*a* will deflect the springs 15 less in their axial direction than at right angles thereto. Such relationship of deflection is particularly true within the range of the very small movements taking place in operation of the present centrifuge.

Springs of suitable strength may serve simultaneously to carry centrifuge body 1*b*, and such an arrangement is shown in FIGS. 6 and 7. In this arrangement the sliding surface 14 as shown in FIGS. 4 and 5 is, of course, omitted and bearing member 11*b* is held in position by springs 16 only. The action of these springs with respect to the desired freedom of motion is the same as described with reference to FIGS. 4 and 5, i.e., there is restriction of movement in the directions of arrow 7, but there is substantially less restriction to movement in the directions of arrow 6. The belt 8*b* of the drive for this embodiment is, for convenience of mounting, arranged at right angles to the directions of arrow 6, that is to the directions of freedom for movement of bearing member 11*b*, but as mentioned hereinbefore, belt flexibility provides a sufficient degree of freedom for the purpose set forth.

In another embodiment shown in FIGS. 8 and 9, freedom of motion as prescribed by this invention is obtained by mounting bearing member 11*c* on feet or brackets which are resilient in horizontal directions parallel to one vertical plane but are substantially rigid in horizontal directions parallel to a vertical plane at right angle thereto. In the construction shown the feet 17, for example, are illustrated as flat springs which can be considerably deflected in the directions indicated by arrow 6, where they can take the position 17', but are rigid in the directions indicated by arrow 7. Other sections of material which give similar results can, of course, be used for the mounting feet. Bearing member 11*c* in this case is of larger size and as shown carries also drive motor with pulley 9*c* and idler pulley 10*c*. It is, however, also possible to secure bearing member 11*c* on a table which in turn is provided with resilient feet 17. The feet are preferably mounted on the floor as shown.

The FIGS. 10, 11 and 12 illustrate an embodiment in which bearing member 11*d* is secured to a pair of rockers 18 which lend the system the restricted freedom of movement in accordance with this invention. It will be noted that in this modification bearing member 11*d* is free to move in substantially horizontal directions of a vertical plane parallel to the rocking directions as indicated by arrow 6 but is rigid in the horizontal directions of a vertical plane at right angle thereto as indicated by arrow 7.

It is furthermore possible to suspend bearing member 11*e*, which carries sphere 4*e* and pendulous centrifuge body 1*e*, 2*e*, by means of a pair of arms 19 as is shown in FIGS. 13 and 14. These arms are rigidly secured to bearing member 11*e* or form an integral part thereof and are pivoted with their free ends at 20 to a suspension structure 21 above. It is obvious that this structure need not be mounted on the ceiling as shown, but can be a part of a frame standing on the floor. The pivotal connection allows movement of bearing member 11*e* in substantially horizontal direction parallel to a vertical plane at right angle to the axis of the pivots but prevents movement in horizontal directions of the vertical plane coinciding with this axis.

In places where practically noiseless operation of the centrifuge is desirable, a construction as disclosed in FIGS. 15 and 16 is recommended. Here bearing member 11*f* is arranged on rollers 22 which can be in the form of solid or tubular members of rubber or plastic material. Rollers 22 in turn are carried on a plane horizontal surface of frame 3*f*. To limit or prevent rolling motion of members 22, they are engaged by suitable pins 23 projecting from bearing member 11*f* on their top and by similar pins 24 projecting from the frame surface at their bottom. Other means which are able to limit rotation of rollers 22 can of course be employed, and various such means will occur to those skilled in the art. In case rollers 22 are sufficiently flexible, they need practically no freedom for rolling motion, but when acted on by centrifuge body 1*f* through bearing member 11*f*, deflection will be considerable in directions at right angle to the axes of members 22, whereas such deflection is practically absent in opposite directions parallel with these axes. Thus the desired restricted freedom of movement in accordance with this invention is achieved. Rollers 22, when solid, can be reenforced by inserts of steel, or, when tubular, can be filled with liquid or compressed air if desirable.

Similar conventional drive means as shown in the constructions of FIGS. 1 to 7 can be employed for driving the devices depicted in FIGS. 8 to 16 and corresponding belt, pulley and motor arrangements are illustrated in all of these figures.

A different and actually reversed form of construction in which frame 3*g* of the centrifuge is arranged inside the hollow pendulum rod 2' of centrifuge body 1*g* is shown in FIGS. 17 and 17*a* and 17*b*. As this figure depicts, the pendulum rod 2' is conical in shape and rests with the inner wall of its upper portion upon sphere 4*g*. It may be fastened thereto or, particularly when suitable surface material is used, frictional engagement will be sufficient to drive pendulum 1*g*, 2' through sphere 4*g* to whose bottom in this case the drive in the form of a shaft 26 with universal joints 25 is connected. A flexible shaft connection will of course serve as well. The drive motor is indicated at 9*g*. Stabilization of the pendulous centrifuge body 1*g* in accordance with this invention by restricted freedom of movement of bearing member 11*g* is obtained in this arrangement in a similar manner as described with reference to FIGS. 1 to 3, i.e., by means of sliding engagement of bearing member 11*g* with slides 12*g* secured to frame 3g or forming an integral part thereof. The bearing member engaging slides 12*g* at the top of frame 3*g* can best be seen in FIG. 17*a*. From this illustration it is clear that sliding movement of bearing member 11*g* is possible in the direction of the slides indicated by double arrow 6.

FIGS. 18 and 19 illustrate by way of example how spherical head 4*h* can be driven by gears 27', 27''. These gears engage sphere 4*h* at its equator. As shown, an individual motor is employed for each gear, whereby gear

27' is driven by motor 9' and gear 27'' by motor 9''. Restricted freedom of movement of bearing member 11*h* in a manner as required by this invention is again obtained by slides 12*h* as set forth in the description to FIGS. 1 to 3. The sliding motion of bearing member 11*h* in slides 12*h* is limited in a similar manner as shown in FIG. 3 by resilient stops as indicated by springs 13*h* in FIG. 19. The drive motors 9' and 9'' with gears 27' and 27'' are preferably mounted on bearing member 11*h* so that the gears remain in proper engagement with sphere 4*h* in spite of sliding motion between parts 11*h* and 12*h*. It will be understood that other drive means such as friction wheels or the like are possible and that, for instance, gears 27' and 27'' can be driven from a single motor when suitable intermediate drive members are interposed. Owing to the stabilizing effect achieved by the means of this invention, actual pendulous swing of the centrifuge body during operation of the centrifuge is so small that a gear drive having sufficient clearance in gear teeth mesh, or a friction wheel drive having sufficiently resilient contact surfaces, when employed in a manner set forth above, is practically possible.

It is also possible to drive the pendulous centrifuge body 1*j* by a revolving magnetic field when spherical head 4*j* is constructed as a rotor. Such an arrangement is illustrated in FIGS. 20 and 21. The coils or windings 28 for producing a magnetic field are arranged on field poles 30, 31, and four such poles are indicated in FIG. 21, which when properly energized can produce the revolving field as desired. Restricted freedom of movement of bearing member 11*j*, as provided by this invention, is here also obtained by slides 12*j* in which this member is slidably mounted. This sliding engagement of bearing member 11*j* and slides 12*j* can best be seen in the plan view FIG. 21. In fact, this arrangement is similar to that shown in FIG. 19 and the bearing members 11*h* and 11*j* are substantially similar elements. The sliding motion in both cases is possible in the directions of the slides as indicated by the double arrows 6. At least one pair of poles 30, 30, whose axis lies in the vertical plane in which sliding motion of bearing member 11*j* is possible, is preferably mounted on said bearing member in order that a uniform air gap can be maintained in spit of such motion. The other pair of poles 31, 31 is shown mounted on the frame 3*j*, but also these poles can, of course, be mounted on bearing member 11*j*. On the other hand, all poles can be mounted on frame 3j when sufficient air gap clearance is provided to allow for sufficient movement of member 11*j* within this clearance range.

It will be remembered that with reference to FIG. 3 it has been stated that curved or arcuate slides are a preferred form but that straight slides can be employed without departing from the principle of this invention. To substantiate this statement, straight horizontal slides are illustrated in the examples of FIGS. 17 to 21.

From the description up to this point it will become apparent that many modifications within the scope of this invention can be made. Aside from the examples described above, it is, for instance, possible to dispose ball race 5 in an oblong recess provided in bearing member 11, which recess allows this race with its balls, a certain movement in directions of the horizontal longitudinal axis of said recess, whereas movement crosswise to this axis is impossible. In such a construction, ball race 5 actually takes the place of bearing member 11 in that it provides the restricted freedom of movement necessary for practicing this invention. The part in which such "slidable" ball race is disposed can of course be fixedly secured to or form an integral part of frame 3. Such construction as just pointed out obviously falls within the scope of this invention.

Moreover, spherical head 4 is shown in all figures of the drawings as a true sphere. Such shape, however, is only a preferred form and, as already stated in the opening paragraph of the detailed description of this specification, is not mandatory so that it can take other forms whenever convenient, provided the lower portion coming in contact with ball race 5 allows to a certain degree pendulous motion of centrifuge body 1 in order that when at rest it can adjust itself with its center of gravity vertically below its point of suspension.

Since, as mentioned before, many apparently widely different embodiments of this invention can be made without departing from the scope thereof, it is to be understood that the examples described and shown in the drawings are to be taken as illustrative only and not to be construed in a limiting sense.

What is claimed is:

1. A pendulum centrifuge including a stationary structure, a rotary centrifuge body having an upper end extension, suspension means engaging said end extension and providing for said centrifuge body freedom for rotary movement and freedom for unrestrained pendulous swing in all directions, mounting means for said suspension means interposed between the latter and said stationary structure and providing substantial freedom of movement for said suspension means in substantially horizontal directions of one vertical plane and offering substantial resistance to any movement in substantially horizontal directions of a vertical plane at right angles to the first-named plane, and means engaging said end extension above said suspension means for imparting rotary motion to said centrifuge body.

2. A pendulum centrifuge including a stationary structure, a centrifuge body adapted for suspension in said structure, suspension means for said centrifuge body including a pendulum rod to whose lower end said centrifuge body is attached, a head portion with a spherical surface portion at the upper end of said rod, a bearing member supporting said head portion at its spherical surface portion and providing for said centrifuge body freedom of rotary movement and unrestrained pendulous swing in all directions, means securing said bearing member in said stationary structure and providing for substantial movement thereof in substantially horizontal directions of one vertical plane and restricting such movement in horizontal directions of a vertical plane at right angles to the first-named plane, and means engaging said head portion for imparting rotary motion to said centrifuge body.

3. A pendulum centrifuge comprising a stationary frame provided with at least one substantially horizontal slide, a rotary centrifuge body, a pendulum rod attached to said body and pendulously suspended in said frame by suspension means which include a bearing member, a ball race disposed on said bearing member, a head having a spherical surface portion forming the upper end of said pendulum rod, said head engaging with its spherical surface portion said ball race and is being carried thereon to provide for said centrifuge body freedom for rotational and all-directionally unrestrained pendulous movement, said bearing member engaging the slide of said frame for slidable movement therein in substantially horizontal directions of a vertical plane, and means engaging said head for imparting rotary motion to said centrifuge body.

4. In a pendulum centrifuge, a stationary structure, a pendulum rod having a centrifuge body attached to its lower end and a head to its upper end, said pendulum rod with centrifuge body and head forming in combination a gyro system, said head having a spherical surface at least at its bottom portion, a bearing member engaging the spherical surface of said head to suspend said gyro system and to provide for rotary and all-directionally unrestrained pendulous motion thereof, mounting means interposed between said bearing member and said structure allowing said bearing member under the influence of said gyro system when operating to make movements in substantially horizontal directions of one vertical plane only, and means engaging said head for imparting rotary motion to said gyro system.

5. The structure as claimed in claim 4 in which said means for imparting rotary motion to said gyro system include an electric motor with pulley mounted at one side of said head and an idler pulley diametrically opposite therefrom, and a belt encircling both said pulleys and engaging said head at opposite sides.

6. In a pendulum centrifuge, a stationary structure having at least one substantially horizontal slide, a bearing member having a vertical bore and engaging said structure for slidable movement therein in substantially horizontal directions of one vertical plane, a ball race disposed around said bore, a pendulum rod extending through said bore and having a centrifuge body secured to its lower end and a head portion with a spherical surface portion to its upper end, said head portion engaging said ball race with its spherical surface portion to be carried thereby and thus forming the point of suspension of said centrifuge body and providing for rotational and all-directionally unrestrained pendulous movement of the latter, and means engaging said head portion for imparting rotary motion to said centrifuge body.

7. In a pendulum centrifuge having a rotary centrifuge body, the suspension means for said centrifuge body which consist of a suspension member engaging said centrifuge body for rotary and all-directionally unrestrained pendulous movement thereon, mounting means for said suspension member characterized by the fact that it provides for said suspension member considerably more freedom of movement in horizontal directions of one vertical plane than in horizontal directions of a vertical plane at right angles to the first-named plane, and means acting on said centrifuge body at said suspension member to impart rotary motion thereto.

8. In a centrifuge of the pendulous type having a centrifuge body adapted for rotation about a vertical axis, suspension means for said centrifuge body which comprise a bearing member engaging the latter for suspension therefrom and providing therefor freedom for rotational and unrestrained pendulous motion in all directions, mounting means for said bearing member characterized by the fact that it provides for the latter substantial freedom of movement in substantially horizontal directions of one plane through the rotation axis of said centrifuge body and restrains substantially all horizontal movement in a vertical plane normal to said first-named plane, and means acting on said centrifuge body substantially adjacent to said bearing member to impart rotary motion thereto.

9. In a centrifuge of the pendulous type having a rotary centrifuge body with a spherical head portion, the combination with a suspension member engaging said spherical head portion of said centrifuge body and providing therefor freedom of unrestrained pendulous swing in all directions and freedom of rotary motion about a vertical axis, of mounting means for said suspension member providing for the latter substantial freedom of movement in substantially horizontal directions of one vertical plane through said vertical axis and offering substantial resistance to movement in substantially horizontal directions of a vertical plane at right angles to the first-named plane, and means acting at said head portion for imparting rotary motion to said centrifuge body.

10. A pendulum centrifuge comprising a stationary frame, a rotary centrifuge body, a pendulum rod attached to said body and pendulously suspended in said frame by suspension means that include a bearing member, a ball race disposed on said bearing member, a head forming the upper end of said pendulum rod and having a spherical surface engaging therewith said ball race to be carried thereon for rotational and pendulous movement, said bearing member being secured to said frame by a plurality of tension springs arranged substantially in a horizontal plane and with their axes parallel to one another, said springs thereby providing for said bearing member considerably more freedom of movement in horizontal directions of a vertical plane normal to the axes of said springs than in horizontal directions of a vertical plane parallel to the axes thereof, and means engaging said head for imparting rotary motion to said centrifuge body.

11. A pendulum centrifuge comprising a stationary structure, a rotary centrifuge body in the form of an annular container surrounding the bottom portion of said structure, a hollow pendulum rod secured to said centrifuge body and surrounding the top portion of said structure, a substantially horizontal slide forming the top of said structure, a bearing member engaging said slide for slidable movement in substantially horizontal directions of one vertical plane only, a ball race carried by said bearing member, a spherical head frictionally engaging said hollow pendulum rod and being carried by said ball race for rotational and pendulous movement thereon, and means engaging the bottom portion of said spherical head to impart rotary motion thereto, whereby to drive said centrifuge body through said frictional engagement and said pendulum rod.

12. A pendulum centrifuge comprising a stationary base having a substantially horizontal plane surface, a bearing member, a pair of rockers fixedly secured to said bearing member and arranged on said plane surface for rocking movement thereon, a ball race disposed on said bearing member, a rotary centrifuge body, a pendulum rod attached to said body and having a head portion with a spherical surface engaging said ball race which carries said head portion to provide for rotational and all-directionally unrestrained pendulous movement of said centrifuge body, said rockers being free to rock under the influence of said centrifuge body when the latter is rotating, and means engaging said head portion for imparting rotary motion to said centrifuge body.

13. In a pendulum centrifuge, a bearing member having a vertical bore, at least one oblong mounting bracket having one end fixed in space and having its other end fixedly secured to said bearing member, a ball race disposed on said bearing member around said bore, a rotary centrifuge body, a pendulum rod attached with its lower end to said body and projecting with its upper end through said bore, a head portion secured to said upper end and having spherical surface portions engaging therewith said ball race to provide for rotary and all-directionally unrestrained pendulous movement of said centrifuge body, said bracket being flexible in one vertical plane, but being rigid in a vertical plane at right angle to the first-named plane, whereby said bearing member is free to make vibrational movements in horizontal directions parallel to said first-named plane, but is substantially restrained from movement in substantially horizontal directions parallel to said last-named plane, and means engaging said head portion for imparting rotary motion to said centrifuge body.

14. In a pendulum centrifuge, a rotary centrifuge body, a pendulum rod to whose lower end said centrifuge body is attached, a head having spherical surface portions forming the upper end portion of said rod, a bearing member having a ball race on which said head is disposed by engaging with its spherical surface portions said ball race to provide for rotary and all-directionally unrestrained pendulous motion of the centrifuge body and pendulum rod combination, a suspension structure, at least one arm fixedly secured to said bearing member and pivotally attached to said suspension structure with the pivotal axis lying substantially vertically above said bearing member, whereby said bearing member is free to oscillate about said axis under the influence of said centrifuge body when rotating, but is restrained from any movement in directions parallel to said pivotal axis, and means engaging said head for imparting rotary motion to said centrifuge body.

15. In a pendulum centrifuge, a base having at least one substantially horizontal plane surface, a bearing member having a vertical bore and a plane bottom a

ball race disposed on said bearing member, at least one pair of rollers in parallel arrangement interposed between said plane surface of said base and said bottom of said bearing member, means for limiting rolling motion of said rollers, a rotary centrifuge body having an upper extension projecting through the bore in said bearing member, a head having a spherical surface portion secured to said extension and engaging said ball race to provide for rotary and all-directionally unrestrained pendulous motion of said centrifuge body, whereby in reaction to rotary motion of said centrifuge body said bearing member is free for substantial movements on said rollers in horizontal directions at right angles to the axes of said rollers and is restrained from substantial movements in horizontal directions parallel to said axes, and means engaging said head for imparting rotary motion to said centrifuge body.

16. The structure as claimed in claim 15, wherein said rollers constitute an elastic resilient material.

17. A pendulum centrifuge comprising a stationary structure having slides for guidance in substantially horizontal directions of one vertical plane, a rotary centrifuge body having an upper extension with a spherical head portion, a bearing member engaging said slides and being engaged by said head portion for suspending said centrifuge body therefrom, drive means secured to said bearing member and acting at the equator of said spherical head portion to impart rotary motion to said centrifuge body, said bearing member engaging said slides being capable under the influence of said centrifuge body when rotating to perform movements in the guidance directions of said slides and being incapable of substantial movement in horizontal directions at right angles to said slides.

18. A pendulum centrifuge comprising a stationary structure having slides for guidance in substantially horizontal directions of one vertical plane, a rotary centrifuge body having an upper extension, a head portion in the form of an electric rotor secured to said extension a spherical surface portion on said head portion at the bottom of said rotor, a bearing member engaging said slides and being engaged by said spherical surface portion of said head portion for suspending said centrifuge body therefrom, a plurality of magnetic poles arranged around said rotor, a winding for energizing said poles to produce a revolving magnetic field to cause said rotor to rotate and drive said centrifuge body, said bearing member engaging said slides being capable under the influence of said centrifuge body when rotating to perform movements in the guidance directions of said slides and being incapable of substantial movement in horizontal directions at right angles to said slides.

19. The structure as claimed in claim 18, in which said plurality of magnetic poles is fixedly secured partly to said stationary structure and partly to said bearing member.

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