

[54] **CIRCULAR CONNECTION BANDS FOR A SUSPENDED BODY**

[75] Inventors: **Darryl K. Bergstrom**, Pacific Palisades; **David C. Clark**, Los Angeles, both of Calif.

[73] Assignee: **Lear Siegler, Inc.**, Santa Monica, Calif.

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[52] U.S. Cl. **267/160**

[51] Int. Cl. **F16f 1/10**

[58] Field of Search..... 267/160, 134, 150

[56] **References Cited**

UNITED STATES PATENTS

3,126,746	3/1964	Blitzer et al.	267/160
3,545,286	12/1970	Stenstrom	267/160
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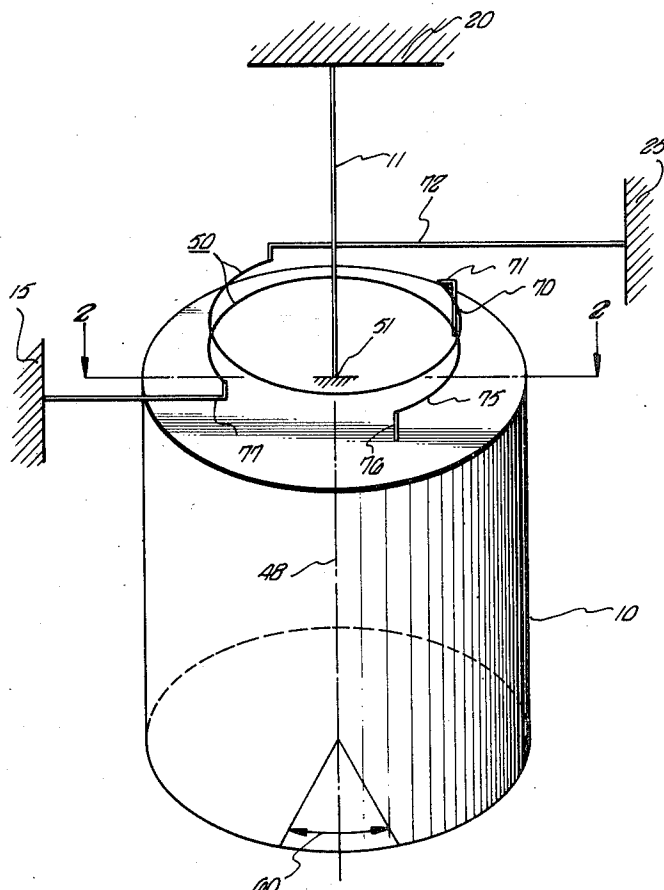
Primary Examiner—James B. Marbert

Attorney, Agent, or Firm—Jackson & Jones Law Corporation

[57] **ABSTRACT**

A connection band configuration having a minimum spring constant for a suspended body capable of rotating back and forth is disclosed. The connection band configuration comprises at least a pair of circular bands which are positioned in a horizontal plane transverse to the vertical plane which contains an axis of rotation about which the suspended body rotates. At least one pair of connection bands are employed with both bands of the pair having their centers substantially coaxial with the vertical rotational axis. One end of one band of the pair is mounted at a predetermined point on the suspended body and the other end of that band is mounted at a second point which is fixed relative to a rotational movement of the body. The other band and its mountings are a mirror image of the first band. The mountings are arranged in such a manner that when the suspended body is at its rest position, both bands of the pair are in an initial circular configuration. As the body rotates about the vertical axis, each band of the pair moves in opposition to the movement of the other band. The movement of each band takes the form of expanded and contracted circular arcs, respectively.

9 Claims, 3 Drawing Figures



SHEET 1 OF 2

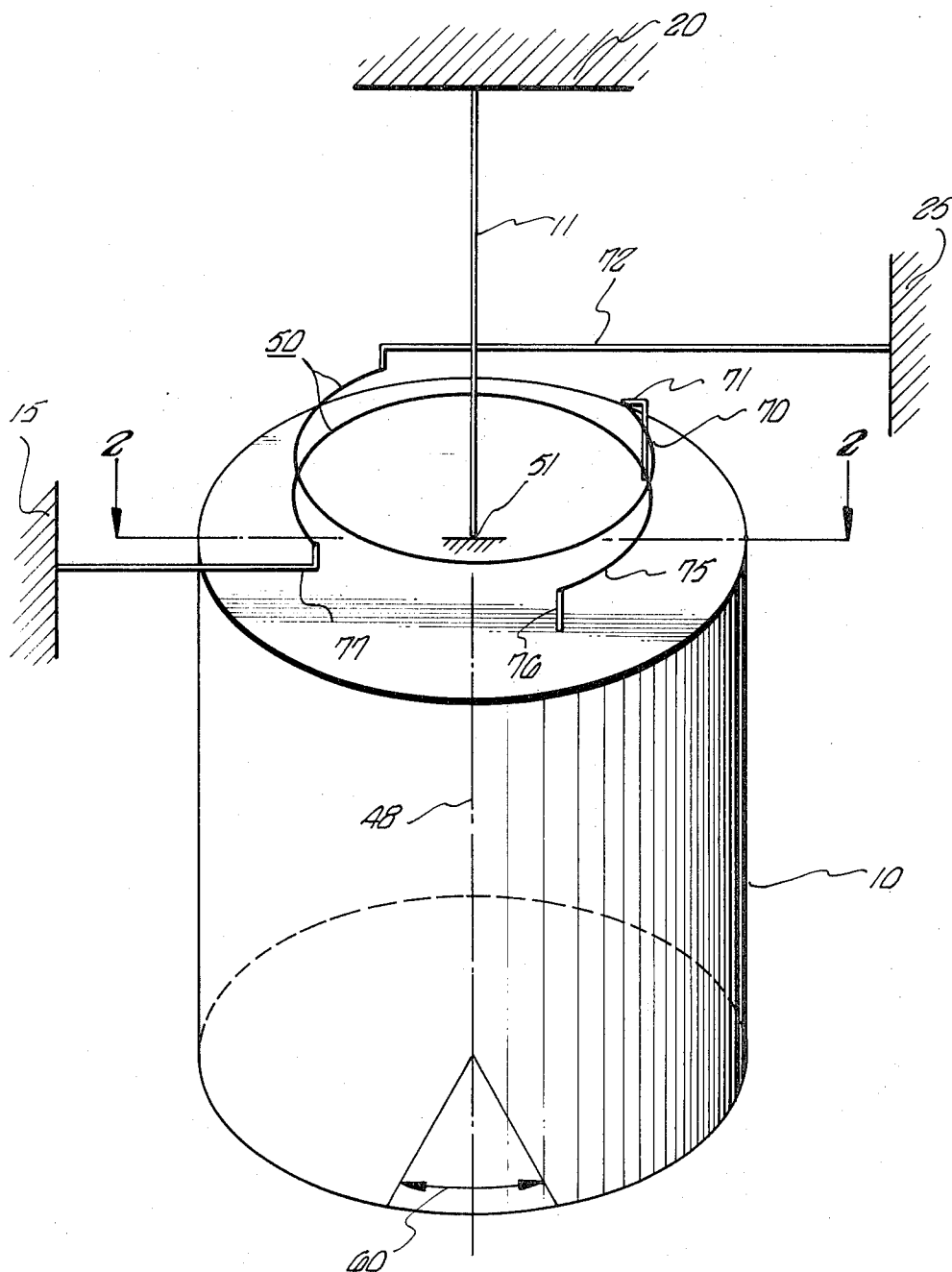


FIG. 1

FIG. 2.

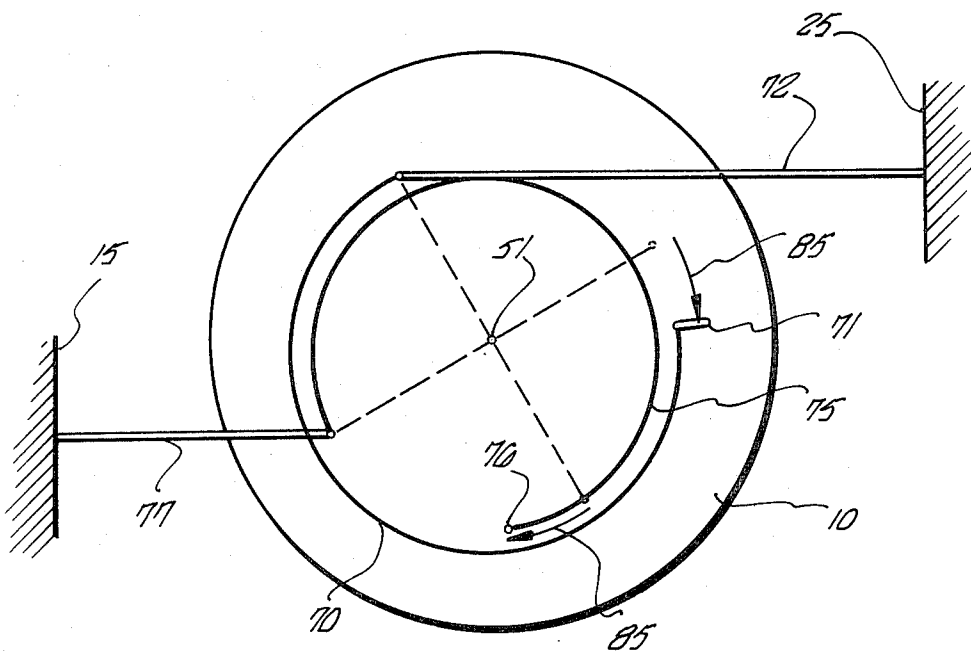
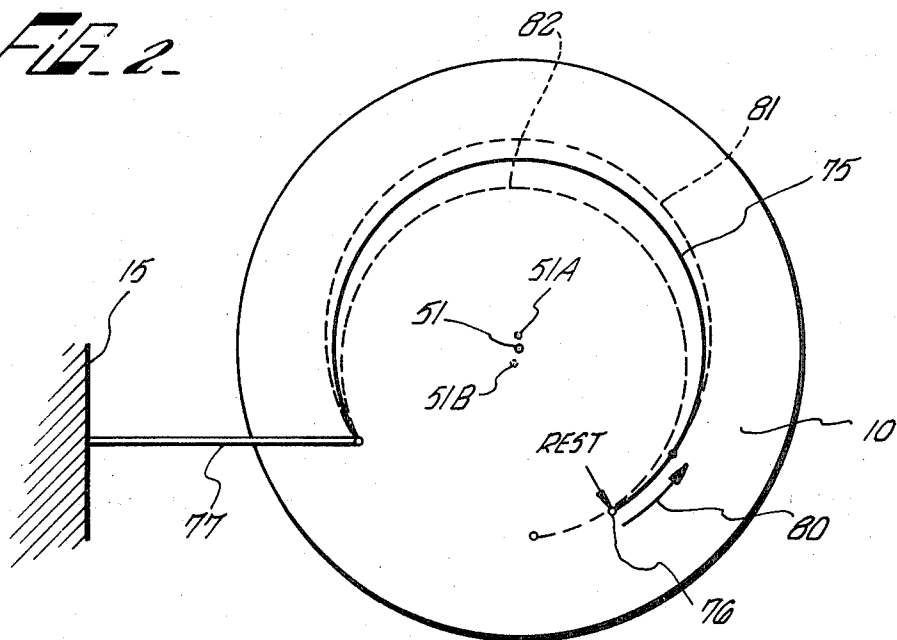


FIG. 3.

CIRCULAR CONNECTION BANDS FOR A SUSPENDED BODY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The field of this invention pertains to connection bands for suspended bodies which are adapted to exhibit rotational movements. More particularly, the field of this invention pertains to gyroscopic instruments and in particular to such gyroscopic instruments known in the art as north seeking instruments.

2. Description of the Prior Art

A suspended body, rotating back and forth, does so about an axis of rotation and relative to some fixed position. Such rotating bodies often require connection bands for various reasons. For example, such bands are often employed to conduct electrical signals between the fixed position and electrical equipment which may be located within the rotating body. In north seeking gyroscopes, the rotatable body houses a small electrically driven rotor. The rotor requires electrical power to spin at desired high speeds. In such an instrument, the spin axis of the rotor tends to align with the horizontal component of the earth's spin velocity. Such alignment designates the true north/south meridian of the earth. Irrespective of the suspension technique for suspending a precessing body, it is of prime significance that the connection bands present the lowest possible spring constant. Such a low spring constant avoids affecting the bodies normal period of rotation, and does not disturb its normal rest position.

Many configurations of connection bands are known to the prior art. One highly successful connection band assembly is described and claimed in U.S. Pat. No. 3,512,264, issued May 19, 1970, to the present assignee. In that particular meridian-seeking instrument, the connection bands are co-planar with the vertical axis of the meridian seeking gyroscope and are curved in the form of semi-circles in the longitudinal plane with the openings of the pair of semi-circular bands facing away from each other.

As the gyroscope of the above-mentioned patent precesses back and forth, the curved connection bands assume the form of semi-helical loops. Each band of the pair of semi-helical loops develops forces which are in opposition to a pre-conditioned spring force applied between both ends of each of the connection bands. Further, the unique configuration of the referenced bands exhibits an opposed configuration in the longitudinal plane of the north seeking instrument which configuration produces canceling forces with respect to each other as the gyroscopic unit precesses back and forth. It was considered that this particular connection band configuration was nearly optimum in that any paracitic torques normally resulting from such connection bands were eliminated. For a given set of conditions, (as defined further hereinafter) the spring constant of this connection band assembly was in the order of 16 dyne cm. per radian.

Another prior art patent dealing with connection bands is U.S. Pat. No. 2,930,240 issued Mar. 29, 1960 to O. Rellensmann et al. In the Rellensmann patent as shown, for example, in FIG. 2, three connection bands are employed for conducting electrical signals from an external source to a rotor within the gyroscope body. Each of the connection strips are shaped somewhat like

a helicon. The connection bands are located in a plane horizontal to the suspension band which partially suspends the gyroscopic unit. The shape of the Rellensmann connection bands together with the unequal number and their mounting configuration, results in unavoidable spring constants which were unfavorable. These unfavorable spring constants were recognized as such and thus Rellensmann mathematically calculated a compensation equation which attempted to correct for the unavoidable unbalanced torques produced by his connection band assembly.

The foregoing disadvantages of the prior art are avoided by the present invention in which a minimum spring constant is exhibited by a pair of circular connection bands which are positioned one above the other in horizontal planes located transversely to the vertical plane coincident with a vertical axis about which a suspended body rotates. The ends of the connection bands are mounted between the suspended body and a relatively fixed point. The circular bands of this invention are coaxial in that they share a substantially common center point, which center point is located at the vertical axis of the suspended body.

SUMMARY OF THE INVENTION

Our invention comprises at least one pair of circular connection bands concentrically mounted with their center points located at the vertical axis of a suspended body which is adapted for rotation about the vertical axis. Each band of the pair of bands, at one given starting position, is a circle of a given diameter with a circular segment substantially between 270° and 360°. A pair of mounting posts are provided for each band. One end of one band is mounted on a post positioned at a predetermined point on the suspended body, and the other end of the band is mounted on a post located at a fixed position relative to the suspended body. The other band is also provided with a pair of mounting posts and its mounting arrangement is a mirror image of the first band. Consequently, as the suspended body rotates about its vertical axis, the mounting posts of one band of the pair move towards one another, whereas the mounting posts of the other band move away from one another. In the instance wherein the mounting posts move toward one another, the band mounted thereon forms a circular arc of slightly larger diameter, referred to as an expanded circular arc. In the same instant in counteraction to the movement of the first band, the second band forms a circular segment of slightly smaller diameter, hereinafter referred to as a contracted circular arc. These counteracting movements effectively cancel each other over the normally minute degrees of arc through which the suspended body rotates. The spring constant of the bands remains a substantially fixed value throughout the rotational movement of the body. The equations presented in the detailed description substantiate that the spring constant for the band configuration of this invention is in the order of 1 dyne cm. per radian for a pair of bands. This extremely low spring constant provides a highly advantageous and unique connection band assembly suitable for use in many delicate instruments.

BRIEF DESCRIPTION OF THE DRAWINGS:

FIG. 1 is a perspective view of a suspended body employing the band suspension system of this invention;

FIG. 2 is a top view taken along 2—2 in FIG. 1 to show the lower connection band;

FIG. 3 is a top view which depicts the opposing movements of both connection bands as the suspended body rotates in one direction.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 is a perspective view in diagrammatic form of a band suspended pendulum 10. In the view of FIG. 1, positions 15, 20 and 25 symbolically indicate fixed mounting positions. A thin suspension band 11 is connected between fixed position 20 and the suspended pendulum 10. It should be clearly understood that the view of FIG. 1 is symbolic and is simplified for the sake or teaching the principles of this invention. Thus, the points 15, 20, and 25, although shown as fixed positions, may or may not be fixed depending upon a given use for our invention. For example, if one makes reference to the issued U.S. Pat. No. 3,512,264 assigned to the same assignee as the present invention, it will be clearly understood that the position 20 is often driven electrically so that it follows the rotation of the pendulum 10 in the manner therein described. Movement of position 20 removes any tendency of the suspension band 11 to develop a set amount of twist. In a like manner, the positions 15 and 25, as described in the above-referenced patent, may also be movable under command of an electrical follow-up system such that as the pendulum 10 rotates, positions 15 and 25 follow the movement of the pendulum. Such movements counteract any tendency of mechanical unbalance due to imbalance of the connection bands. In a similar manner, it should be understood that the pendulum 10 although in the form of an elongated cylinder, may assume other configurations which are suitable for employment of this invention. In addition, the band 11 is not necessary. For example, the pendulum 10 may assume the form of a sphere which is fully suspended in a liquid much in the manner of the sphere depicted in the aforementioned Rellensmann patent. With the foregoing background in mind in connection with the scope of this invention, the principles of the connection band and its unique ability to exhibit an extremely low spring constant will now be described.

A pair of connection bands 50 are depicted in FIG. 1 with both bands sharing a common center point 51. The center point 51 is the point of connection for suspension band 11 to pendulum 10. Point 51 lies on the vertical axis 48 (shown in dashed lines) about which the pendulum 10 rotates back and forth through an arc 60 (shown highly exaggerated) in FIG. 1. The upper band 70 is connected to the pendulum 10 by any suitable mounting means, or post, 71. Band 70 comprises a circular segment about center point 51 of approximately a minimum of 270° to a maximum of approximately 360° for optimum results in our invention.

The circular segment, as depicted in FIG. 1, is 270° and the other end of the circular band 70 is connected to a fixed (or relatively fixed) point 25 by a second mounting post 72. The lower band 75 is also provided with a pair of mounting posts 76 and 77. This lower band 75 is virtually a mirror image of the upper band 70 and it also therefore comprises a circular segment having approximately a 270° arc.

The bands 70 and 75 of the pair of bands, as depicted in FIG. 1, are mounted in opposition. This manner of

band configuration including mounting each band for movements in opposition to each other, stacking one band above the other, and having both bands share a common center point provides many advantages. One advantage of this configuration is that the initial torque which either band may produce substantially cancels itself out by an equal and opposite torque which is present in the opposite band of the pair. Furthermore, ambient temperature changes will generally affect both bands in the same manner due to their proximity and location. Again, these temperature changes will occur in opposing directions in the band pair and tend to cancel each other out. In certain instances such as power bands one of the bands may be subjected to a higher current carrying capacity than the other band; and in such an instance, it may develop a higher temperature than the other band. Such an event would indeed cause the band having the higher temperature to expand and exhibit a spurious torque to the pendulum 10. To minimize and compensate for this temperature imbalance, one makes sure that the other band of the pair also carries the same amount of current so that each band is at the same temperature.

As mentioned hereinbefore, the spring constant for the connection band configuration 50 of this invention is extremely low. This is particularly important because it allows the suspended body to rotate back and forth through its normal period without any unbalanced or parastic torque being present. Such torques would adversely affect the normal periodicity of the rotational movement.

When pendulum 10 is suspended by band 11, the suspended body has a suspension spring constant. That suspension spring constant is arbitrarily designated as K_s . It is known that the total K_t spring constant for the system is the suspension spring constant K_s plus the connection band spring constant which is designated as K_{cb} . In order to calculate the spring constant for the connection bands alone, one need only calculate the total spring constant, K_t , and subtract from the total spring constant the spring constant K_s , or the spring constant for the suspension band. For explanation purposes, and in order to mathematically derive the extremely low spring constant in equation form for the connection band configuration of this invention, a given exemplative set of values will be arbitrarily selected. Any suspended body exhibits a center of gravity and a known moment of inertia of a given mass through a selected axis of rotation. For example, a right circular cylinder 10, as depicted in FIG. 1, has a moment of inertia about the axis 48 which is defined as $\frac{1}{2}mr^2$ where r is the radius of the cylinder and m is the mass of a homogeneous solid for cylinder 10. Assume that the moment of inertia I_y — y for the cylinder 10 is $(6.39 \cdot 10^3 \text{ gram} \cdot \text{cm}^2)$. If one subjects body 10 to an initial rotational movement away from its rest position, body 10 will rotate back and forth about that rest position in accordance with a given period that is measurable in time. The period, for example, in our test was shown to be approximately 96 seconds for a period designated P . It is known that the total spring constant K_t is equal to $\omega^2 I_y$ — y wherein ω is equal to $(2\pi/P)$. Assuming that the period P is 96 seconds then:

$$Kt = (2\pi/P)^2 \cdot I_y - y : \text{or}$$

$$Kt = (2\pi/96)^2 \cdot (6.39 \cdot 10^3 \text{ gram cm}^2) : \text{or}$$

$$Kt = 27.3 \text{ dyne} - \text{cm per radian}$$

Next the period is measured without any connection band present, at all, i.e., snipped and removed. Our tests have shown (all other given conditions the same) that the period without our connection bands was 98 seconds. The constant for the suspension system alone applying the same moment of inertia, calculated as above, is 26.2 dyne — cm per radian. The difference between the two, i.e., between 27.3 dyne — cm per radian and 26.2 dyne — cm per radian is equal to 1.1 dyne — cm per radian. Thus, the spring constant for a pair of suspension bands configured in accordance with the principles of this invention is approximately 1 dyne—cm per radian. This is over an order of magnitude less than any spring constant for any other known connection band configuration. As a relative figure of merit, for example, under similar test conditions, the spring constant for the suspension band assembly shown in the aforementioned U.S. Pat. No. 3,512,264 is approximately 16 dyne — cm per radian with connection bands in both instances comprising 0.0005 inch by 0.010 inch, 85% Ag — 15% Cu hard drawn.

Reference is now made to FIG. 2 which depicts a top view of the lower band 75 of the band pair 50 of FIG. 1. The solid line in FIG. 2 is the normal circular configuration for band 75. The two dashed lines represent the circular changes in band 75 through its entire length as the suspended body rotates back and forth past an initial rest position. For example, as body 10 is moved in a counter-clockwise direction as shown by the arrow 80, the mounting post 76 moves further away from post 77 and the band forms an expanded circular segment with a center point located approximately at 51A (shown by dashed line 81). On the other hand as the suspended body 10 moves back past the rest position, the mounting post 76 moves closer toward post 77. Band 75, throughout its length, forms a contracted circular segment shown, for example, by the inner dashed lines 82 with a center point 51B.

Referring back to FIG. 1, it should be noted that the two bands of band pair 50 are mounted in opposition. The mounting posts of both bands thus always move in opposite directions. As the mounting posts of band 75 move closer together, the mounting posts for band 70, FIG. 1, move farther apart. The configuration depicted in FIG. 2 for band 75 occurs simultaneously and in a mirror image opposing relationship for band 70. The important point to be noted is that for any given arc of rotation, each band is bent initially an equal amount throughout its entire length. Both bands of the pair of bands move in opposition in such a manner that the torques exhibited by each on the body cancel each other out. The canceling movement of the band pair 50 is shown in FIG. 3 which depicts both bands 75 and 70 at a moment when the suspended body has rotated in a clockwise direction an amount shown by the arrows 85. Of course at rest position as shown in FIG. 1, then the bands of FIG. 3 would be two coaxial circular segments of approximately 270°. Dashed lines 95 show the two equal and vertical 90° angles at which the mounting means 71, 72, and 76, 77 meet the rest circular segments. In the description, for simplicity purposes and sake of clearness, very large arcs of rotation have been assumed. In many instances such as in north seeking gy-

roscopes, as is well known, such arcs are very minute, amounting only in the order of a few seconds of a degree. In either event however the connection bands of our invention provides an extremely low spring constant that helps maintain the suspended body at its normal rest position and operates to cancel out any unbalanced torques as the body rotates.

It is to be understood that the foregoing features and principles of this invention are merely descriptive, and that many departures and variations thereof are possible by those skilled in the art, without departing from the spirit and scope of this invention.

What is claimed is:

1. A connection band assembly for a suspended body having a vertical axis about which it rotates back and forth, said assembly comprising:

means suspending said body for rotational movements about said vertical axis;

a pair of circular electrically conductive connection bands of an electrically conductive material lying in two parallel planes that are both transverse to said vertical axis, with each band comprising a circular segment with a portion of a full circle removed so as each band comprises less than a full circle and more than a semi-circle;

means connecting one end of each band of said pair to said body with the circle of the pair of bands concentric with the vertical axis and the missing portions of said pair of bands defining circular arcs at opposed vertical angles drawn through said center when said body is in an initial rest position; and

means connecting the other end of each band of said pair of bands to a position located other than on said body whereby the bands move in opposition to each other as the body rotates.

2. A connection band assembly in accordance with claim 1 and further comprising for each band, circular segments, substantially between 270° to 360°.

3. A connection band assembly in accordance with claim 1 and further characterized in that as said body rotates one of said bands assumes the shape of an expanded circular arc and the other band of said pair assumes the shape of a contracted circular arc.

4. A connection band assembly in accordance with claim 4 wherein said expanded circular arc has a slightly larger diameter than said concentric circle and said contracted circular arc has a slightly smaller diameter than said concentric circle.

5. A connection band assembly for a suspended body having a vertical axis through its center of gravity about which it may rotate back and forth relative to fixed positions, said assembly comprising:

means suspending said body for rotational movements about said vertical axis;

at least a pair of circular connection bands (of an electrically conductive material) concentrically mounted one above the other in planes transverse to the vertical axis and having a common center point located substantially at the vertical axis of the suspended body;

means for mounting one end of each band of the pair to the body and mounting the other end to a relative fixed point with the mounting positions being at spaced points on a circle in one plane and mounting one end of the other band to the body and mounting the other end of the other band to a

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relative fixed position, with these mountings also being at spaced points on a concentric circle in the other plane, whereby the bands move in opposition to each other as the body rotates.

6. A connection band assembly in accordance with claim 5 and further comprising means for suspending said body including a suspension band fastened above the body at one end and fastened at its other end to the body at said center point.

7. A connection band assembly in accordance with claim 5 and further comprising circular segments for each band of substantially 270° to 360°.

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8. A connection band assembly in accordance with claim 5 and further characterized in that as said body rotates one of said bands assumes the shape of an expanded circular arc and the other band of said pair assumes the shape of a contracted circular arc.

9. A connection band assembly in accordance with claim 5 wherein said expanded circular arc has a slightly larger diameter than said concentric circle and said contracted circular arc has a slightly smaller diameter than said concentric circle.

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