

[54] **SEISMOMETER WITH SPRING SPIDER SUSPENSION**

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[51] Int. Cl. **G01v 1/16, F16f 1/34**

[58] Field of Search **340/17; 267/161**

[56] **References Cited**

UNITED STATES PATENTS

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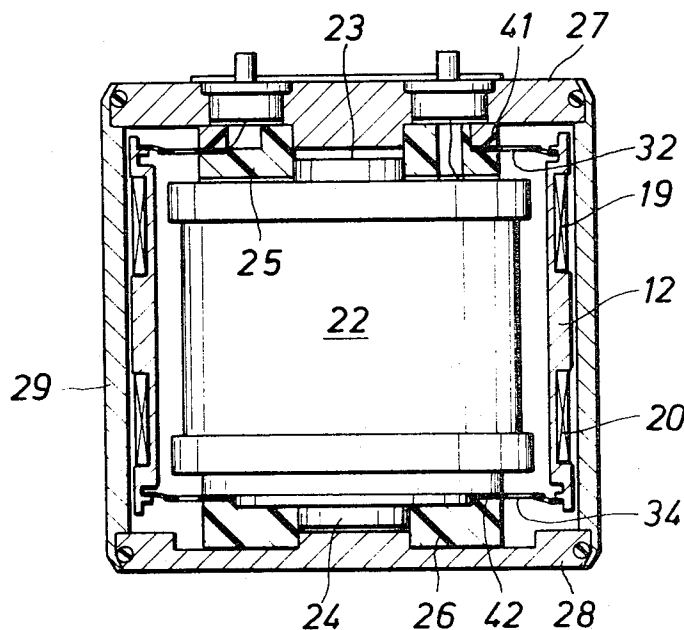
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[57] **ABSTRACT**

Spring spiders support one element of a seismometer, the coil-mass assembly, for movement relative to another element, the magnet assembly. The outer portion of each of the spring spiders is connected to the coil-mass assembly by outwardly extending tabs integrally connected to the outer portion. The outer portion and tabs are bent up and down to position the tabs successively on opposite sides of an annular flange on the coil-mass assembly. This type of connection allows the elements to rotate relatively around their central concentric axes and also reduces substantially the transverse bending of the outer portion of the spiders as the spring arms of the spiders flex, thereby substantially reducing the distortion in the output signal due to such bending.

8 Claims, 5 Drawing Figures



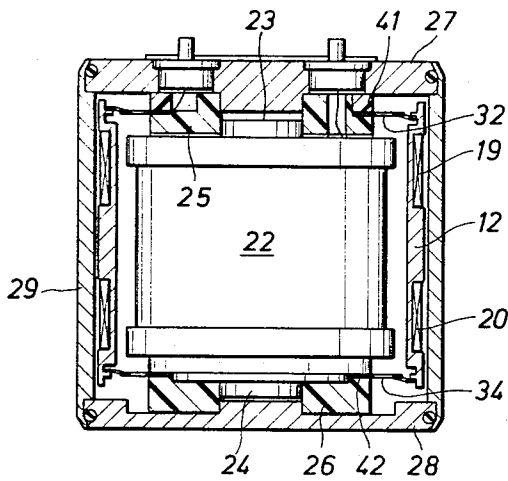


FIG. 1

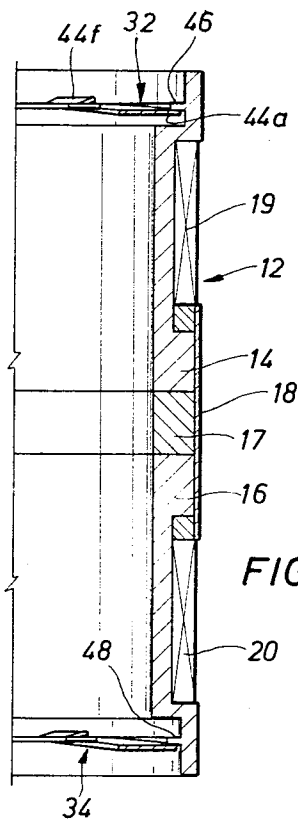


FIG. 4

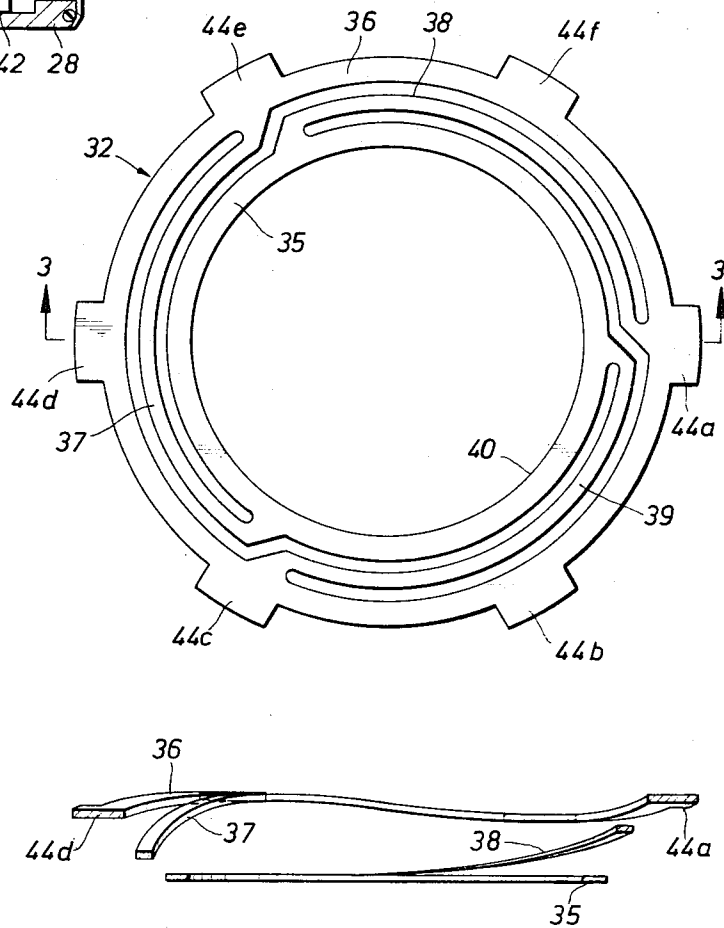


FIG. 2

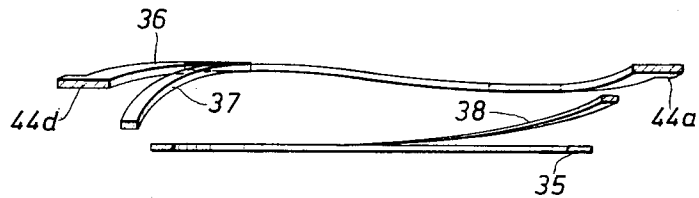


FIG. 3

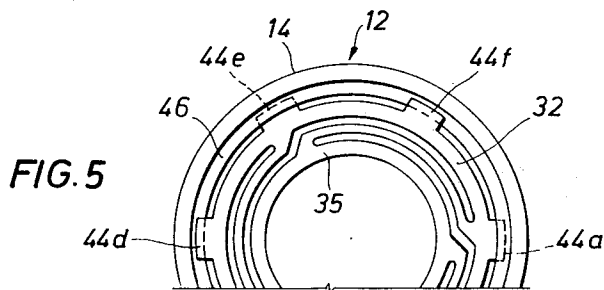


FIG. 5

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SEISMOMETER WITH SPRING SPIDER SUSPENSION

This invention relates to spring spiders generally, and in particular, to spring spiders for seismometers and the like.

This invention has particular utility in connection with electromagnetic seismometers. Designers and manufacturers of electromagnetic seismometers, or geophones, as they are often called, work to reduce to a minimum or eliminate distortion of the output signal. It has been determined that one source of distortion is the mounting of the springs, usually circular and usually called spring spiders, that support the two elements of the geophone that move relative to each other to produce the output signal. These springs are usually etched from a sheet of material of generally uniform thickness and have outer and inner or central portions connected by spring arms. Heretofore, either the inner or outer portions of the spring spiders were connected to one of the elements by positioning the portion, which is usually annular in configuration, in an annular groove formed by an annular shoulder on the element and a snap ring spaced therefrom. Clearance was provided between the spring and the sides of the groove to allow for ease of assembly and this also allowed for relative rotation of the element and the spring. If the outer or inner portions were completely free to bend transversely at all times, there would be no particular problem. These portions, however, are not always free to do this because their edges move into and out of contact with the bottom of the grooves, since the springs also serve to guide the relative movement of the two elements. The normal force between the edges and the bottom of the grooves vary from time to time and from geophone to geophone. Therefore, the transverse bending allowed varied also, and this distorts the output signal in varying amounts which cannot be anticipated and therefore cannot be compensated for.

This transverse bending or flexing of the central or outer portions of the spring spider can be eliminated by clamping these portions securely between two annular shoulders. This, however, would also eliminate, or at least limit, the ability of the spring and elements to rotate relative to each other.

Therefore, it is an object of this invention to provide a seismometer of the spring spider type described above that has substantially no distortion of its output signal due to varying and unpredictable amounts of transverse bending of the outer and central portions of the spring spiders and yet allows relatively free rotation between at least one of the relatively movable elements and the spring spiders.

It is another object of this invention to provide apparatus having two relatively movable elements such as an electromagnetic seismometer wherein one of the elements is suspended by spring spiders to allow relative movement between the two elements and wherein the spring spiders are connected to the element in such a manner that the transverse bending portions thereof connected to said element, when the spring arms of the spider are flexed, is substantially reduced, while allowing the element to rotate relative to the spiders in the desired manner.

It is another object of this invention to provide a spring spider for apparatus having two relatively movable elements whose relative movement produces an

output signal, such as a seismometer, that can be connected to one of the elements in such a way that the element can freely rotate relative to the spider and yet the distortion of the output signal due to variations in the amount of transverse bending of the portion of the spider connected to the element is greatly reduced.

It is another object of this invention to provide a seismometer wherein the spring spiders are connected to one of the elements of the seismometer by integrally connected tabs on the spider that are alternately positioned on opposite sides of an annular flange on the element whereby the portion of the spring to which the tabs are attached is bent in opposite directions, thereby providing this portion of the spring with a configuration that resists transverse bending when the spring arms of the spring spider are flexed and yet is so connected to the element to allow relative rotation between the element and the spring spider.

These and other objects, advantages, and features of this invention will be apparent to those skilled in the art from a consideration of this specification, including the attached drawings and appended claims.

In the drawings:

FIG. 1 is a vertical sectional view through the preferred embodiment of the electromagnetic seismometer or geophone of this invention;

FIG. 2 is a plan view of one of the spring spiders used with the seismometer of FIG. 1;

FIG. 3 is a cross sectional view of the spring spider of FIG. 2 taken along line 3—3;

FIG. 4 is a partial sectional view on an enlarged scale of the coil-mass assembly of the seismometer of FIG. 1 with the two supporting spring spiders assembled therewith; and

FIG. 5 is a partial top view of the coil-mass and spring spider assembly of FIG. 4.

Electromagnetic seismometers, or geophones, of the type to which this invention relates, have two elements that move relative to each other due to earth tremors. One element is in engagement with and moved by the earth. The second is supported by springs and lags behind the movement of the first due to its inertia. The relative movement between the two elements produces an output signal that is proportional to the relative movement imparted.

In the seismometer shown in the drawings, the inertial element is coil-mass assembly 12. As shown in FIG. 4, it includes coaxial cylindrical members or spools 14 and 16. These members are spaced apart by insulation ring 17. Annular outer shell 18 holds the spools and insulation ring in assembled condition. Spools 14 and 16 have annular grooves on the exterior thereof in which are wound coils 19 and 20, respectively.

Positioned inside annular coil-mass assembly 12, and in axial alignment with the opening therethrough, is the other element of the seismometer, permanent magnet assembly 22. This assembly includes a permanent magnet, having pole pieces 23 and 24 that provide a magnetic field within which coils 19 and 20 are located. The permanent magnet assembly is held against movement relative to the housing of the seismometer by spacer rings 25 and 26, which are positioned at opposite ends of the permanent magnet assembly and between end plates 27 and 28 of the housing. These end plates combine with cylindrical housing member

29 to completely enclose the permanent magnet assembly and the coil-mass assembly of the seismometer, which are the two relatively moving elements thereof.

The movement of the coils 19 and 20, relative to the magnetic field of permanent magnet assembly 22, produces an electric current that is used to indicate the intensity of the earth tremor, in the well-known manner.

The coil-mass assembly is resiliently supported on spring spiders 32 and 34. These spiders allow the permanent magnet assembly to move along its longitudinal axis relative to the coil-mass assembly, which tends to not so move due to its inertia. The longitudinal axis of the coil-mass assembly and that of the permanent magnet assembly coincide in this assembly, since the inside surface of the coil-mass assembly is equally spaced from the permanent magnet assembly. The spring spiders maintain this relationship.

Spring spiders 32 and 34 are identical in the embodiment shown. Therefore, only one will be described in detail. As shown in FIG. 2, spring spider 32 includes inner or central portion 35 and outer portion 36, both of which are annular. Arcuate spring arms 37, 38, and 39 connect the central and outer annular portions of the spring and allow the portions to move axially relative to each other, by bending the spring arms. Preferably, the spider is preformed with the outer and central annular portions of the spider displaced axially relative to each other before the spring is heat treated, as shown in FIG. 3. The distance these portions are axially displaced is determined by the spring rate of the spring and the weight of the coil-mass assembly. Preferably, when the weight of the coil-mass assembly is placed on the outer annular portion of the springs, whether there be two or more, it will deflect the springs until they are all substantially flat again.

These spring spiders are etched out of sheet material, usually, and then trimmed by punch presses to the desired outer and inner configuration. The spring is connected to permanent magnet assembly 22 by clamping central annular portion 35 of the spring between spacer ring 25 and clamping ring 41 (FIG. 1). These two rings are forced together to clamp this portion of the spring between them by end plates 27 and 28. In the same manner, central portion 42 of spring spider 34 is clamped between spacer ring 26 and the lower surface of permanent magnet assembly 22. The surfaces between which central portions 35 and 42 of the spring spiders are clamped are wide enough to effectively hold these portions of the springs from bending transversely as the spring arms are flexed.

As explained above, preferably one of the elements of the geophone can rotate relative to the other. The connection described above will effectively hold the central portions of the spiders from radial or transverse bending, but it will also create a substantial frictional force, one that will effectively eliminate any relative rotational movement between the permanent magnet assembly and the spiders.

In accordance with this invention, means are provided to connect at least one of the central and outer portions of the spiders to one of the elements to substantially reduce transverse bending, and thereby substantially reduce the unpredictably varying distortion in the output signal due to drag between the edge of the

spider and its mounting while allowing relative rotation of the elements.

In the embodiment shown, the outer portions of spring spiders 32 and 34 are connected to coil-mass assembly 12, so that the coil-mass assembly can freely rotate relative to the other element, permanent magnet 22, and yet effect a substantial reduction in the transverse bending of the outer portion of the spring spiders. As shown in FIGS. 2 and 5, a plurality of tabs 44a-44f are integrally connected to outer portion 36 of spring spider 32. It is understood that spring spider 34 is provided with a similar set of such tabs. In turn, coil-mass assembly 12 has inwardly extending annular flange 46 located adjacent its upper end. The inside diameter of the opening through the coil-mass assembly enlarges adjacent the ends thereof and flange 46 is positioned in this portion of enlarged diameter. The flange extends inwardly far enough to extend over the tabs connected to the outer portion of the spring. Thus, with the spring installed in the position shown in FIGS. 4 and 5, the tabs extend beyond the inner edge of flange 46, and in accordance with this invention, each successive tab is placed so that it extends over an opposite side of the flange. In other words, as shown in FIG. 5, tab 44d is on top of the flange, the next tab 44e is below it, the next 44f is above, and then 44a is below again. This effectively anchors the outer portion of the spring spider to flange 46 and the coil-mass assembly and allows the spring spider to support its portion of the weight of the coil-mass assembly. In addition, it has been determined that this type connection between the outer portion of the spring spider and flange 46 substantially reduces transverse bending of outer portion 36 as the spring arms are flexed by the moving of coil-mass assembly 12 relative to the permanent magnet assembly. This is probably due to the wavy configuration imposed on the outer portion of the spider by the alternately up and down position of the tabs.

Fewer tabs than what is shown can be used. Also, more can be used. With the increase in the number, the same effect can be obtained by locating adjacent groups of tabs on opposite sides of the flange. For example, tabs 44a-44f of FIG. 2 could each be divided into a pair of adjacent tabs and each adjacent pair would be located on opposite sides of flange 46.

These tabs can be formed when the springs are originally etched from the spring material and left in the same plane with the outer portion. Alternatively, outer portion 36 of the spring spider can be preformed to have a wavy configuration, as shown in FIG. 3, with every other tab located at a crest of a wave and the remaining tabs located at a wave trough. So shaped, when the spring is installed, the tabs on the wave crests can be forced downwardly to become the tabs engaging the underside of flange 46 and the tabs at the troughs of the waves can be forced upwardly by bending the outer portion of the spring until they engage the upper side of flange 46. This results in an increase in the resilient force exerted by the tabs on the flange, which could tend to cause a portion so preformed to resist transverse bending better than if the tabs and the outer portion of the spring remain substantially flat. This preforming of the outer portion into a wavy configuration, as described above, does not increase the frictional force between the tabs and the flange sufficiently

to affect to any great extent the ability of the coil-mass assembly to rotate relative the springs.

As stated above, spring spider 34 is equipped with tabs in the same manner as described above in connection with spring spider 32, and it is connected to the lower end of coil-mass assembly 12 by interlocking these tabs with inwardly extending annular flange 48.

From the foregoing description of one embodiment of this invention by way of example, it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the apparatus and structure.

The invention having been described, what is claimed is:

1. A seismometer comprising first and second relatively movable elements providing an output signal due to their relative movement, said first element being annular with said second element positioned in the opening therein, means yieldingly suspending one of said elements for movement relative to the other in a direction generally parallel to the longitudinal axis of the opening in said first member, said suspending means comprising a spring spider having a central portion and an outer portion connected together with a plurality of spring arms, means connecting the outer and central portions to the first and second elements, respectively, at least one of said connecting means including a plurality of circumferentially spaced tabs extending between one of said portions and said element to which said portion is connected, said tabs being positioned to alternately bend said portion in opposite directions to reduce the transverse bending that occurs in said portion as the spring arms attached thereto are flexed by the relative movement of the elements.

2. The seismometer of claim 1 in which the tabs bend the outer portion of the spring spider.

3. A seismometer comprising first and second relatively movable elements providing an output signal due to their relative movement, said first element being annular with said second element positioned in the opening therein, means yieldingly suspending one of said elements for movement relative to the other in a direction generally parallel to the longitudinal axis of the opening in said first member, said suspending means comprising a spring spider having a central portion and an outer portion connected together with a plurality of spring arms, means connecting the outer and central portions to the first and second elements, respectively, at least one of said connecting means including a plurality of tabs connected to one of said portions and circumferentially spaced therearound and an annular flange on said element to which said portion is connected, said flange having a diameter such that the tabs alternately engage opposite sides of the flange to connect the portion of the spring to which they are attached to the flange while allowing said spring portion and flange to rotate relatively as the elements rotate relatively around their axis.

4. The seismometer of claim 3 in which the spring

portion with the tabs is preformed to have a wavy configuration with every other tab located at a wave crest and the remainder located at a trough to increase the resilient force that the tabs exert against the flange by alternating the positions of the tabs when placed in engagement with the flange.

5. The seismometer of claim 3 in which the tabs are on the outer portion of the spring spider.

6. An electromagnetic seismometer comprising an annular coil-mass assembly, having a central opening therethrough, a permanent magnet assembly located in the central opening, and a spring suspension system for supporting the coil-mass assembly for movement relative to the permanent magnet assembly parallel to the longitudinal axis of the opening through the coil-mass assembly including two spaced flanges on the coil-mass assembly extending inwardly toward the permanent magnet assembly, two spring spiders extending transverse the opening in the annular coil-mass assembly and spaced apart along its longitudinal axis, each spider having a central portion connected to the permanent magnet assembly, an outer portion having a plurality of integrally connected tabs spaced circumferentially around said outer portion with each adjacent pair of tabs positioned adjacent opposite sides of one of the flanges to connect the spider to the coil-mass assembly so that the weight thereof is supported by the spring spiders while allowing the coil-mass assembly to rotate relative to the permanent magnet assembly around the longitudinal axis of the opening therethrough.

7. The seismometer of claim 6 in which the outer portions of the spring spiders have a wavy configuration with every other tab located at a wave crest and the other tabs located at wave troughs, said arrangement being reversed when the spider is connected to its associated flange on the coil-mass assembly to increase the force with which the tabs engage the flange.

8. A seismometer comprising first and second relatively movable elements providing an output signal due to their relative movement, said first element being annular with said second element positioned in the opening therein, means yieldingly suspending one of said elements for movement relative to the other in a direction generally parallel to the longitudinal axis of the opening in said first member, said suspending means comprising a spring spider having a central portion and an outer portion connected together with a plurality of spring arms, means connecting the outer and central portions to the first and second elements, respectively, at least one of said connecting means including a plurality of circumferentially spaced tab groups with each group comprising at least one tab extending between one of said portions and said element to which said portion is connected, said tab groups being positioned to alternately bend said portion in opposite directions to reduce the transverse bending that occurs in said portion as the spring arms attached thereto are flexed by the relative movement of the elements.

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