United States Patent

Mercier

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[54] **HIGH FREQUENCY GALVANOMETER**

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[52] **U.S. Cl.** ....**324/154 R,** 324/96

[51] **Int. Cl.** **G01r 1/00,** G01r 31/00

[58] **Field of Search** 324/154, 96

[56] **References Cited**

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[57] **ABSTRACT**

There is disclosed a high frequency galvanometer with minimal interia about the vibratory axis resulting from a circular suspension bobbinless and distributed coil construction.

8 Claims, 6 Drawing Figures

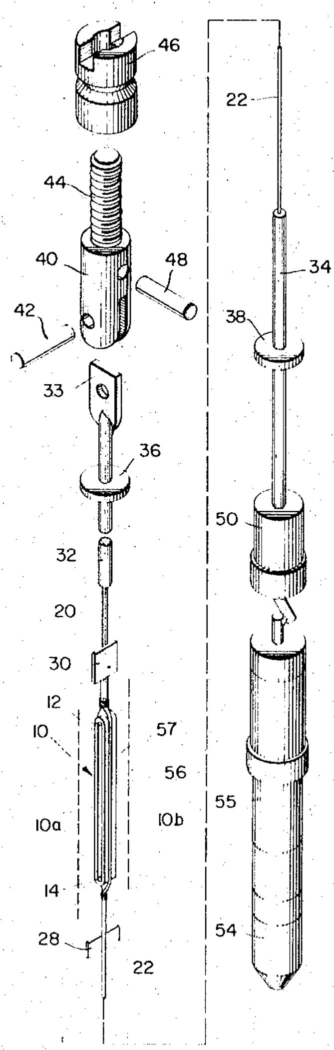

FIG. 3

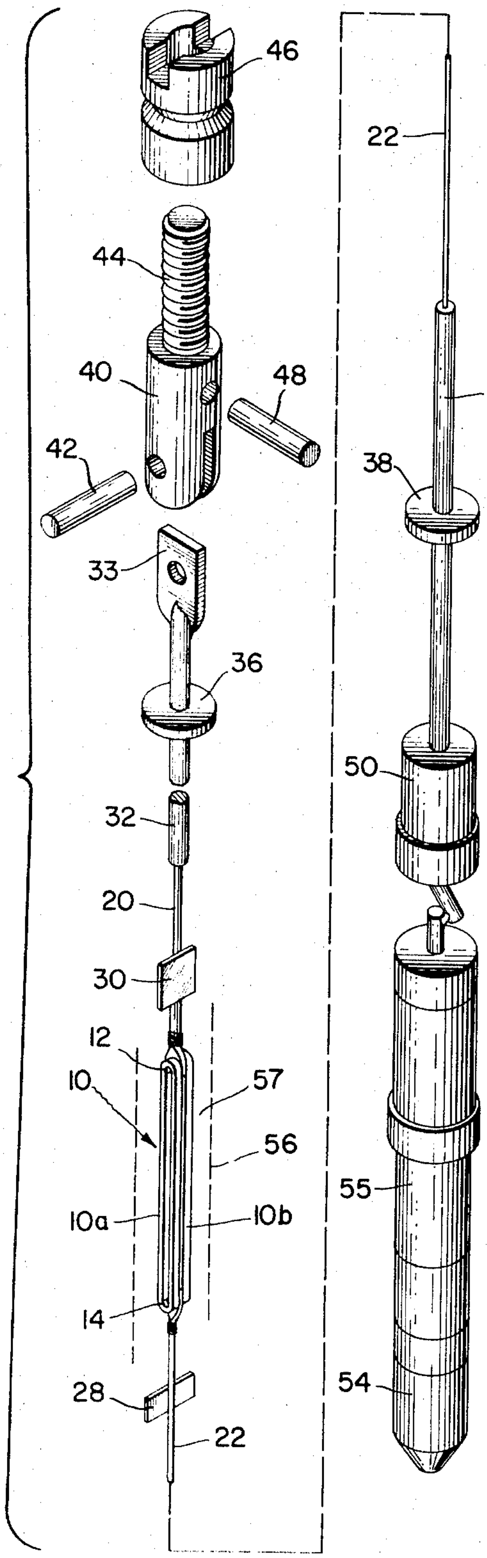

FIG. 1

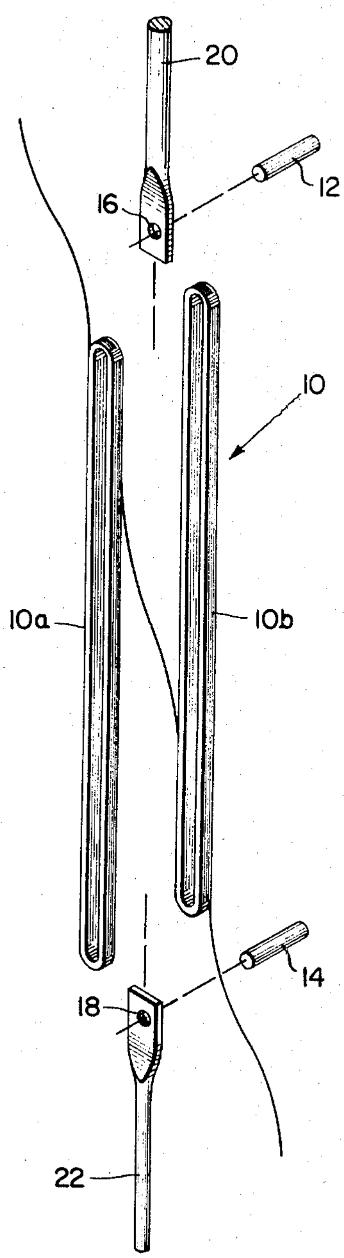

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FIG. 4

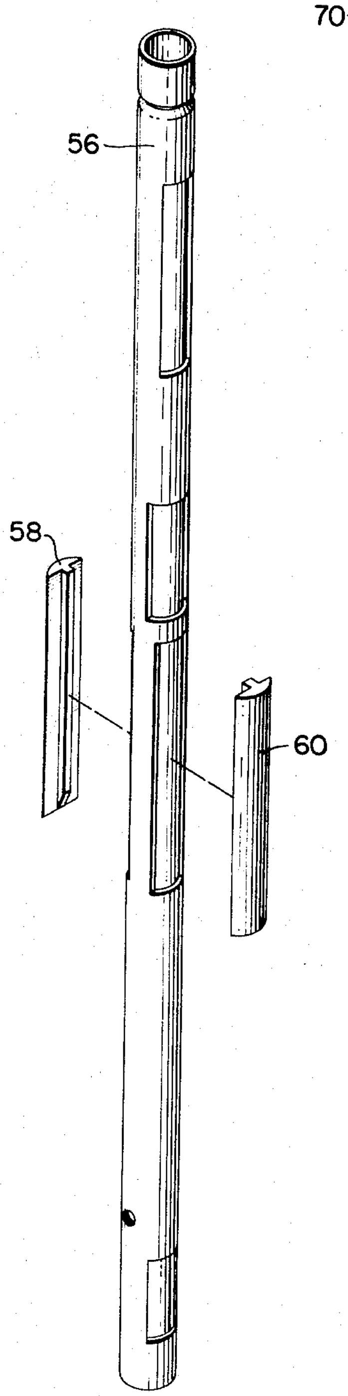


FIG. 5

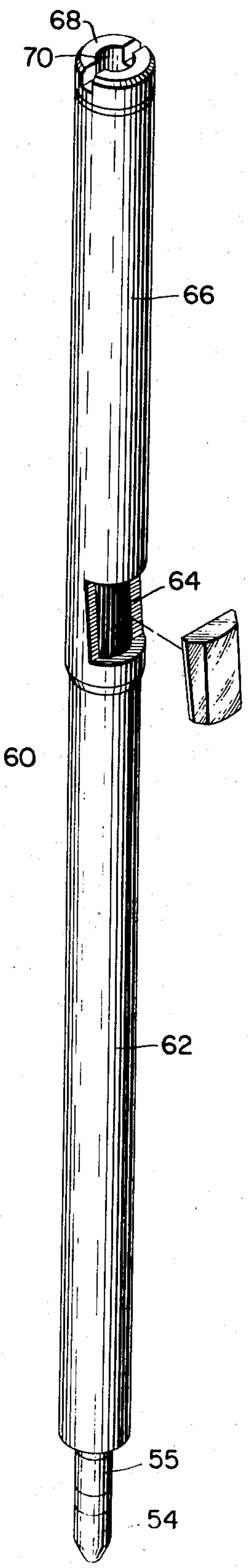


FIG. 2

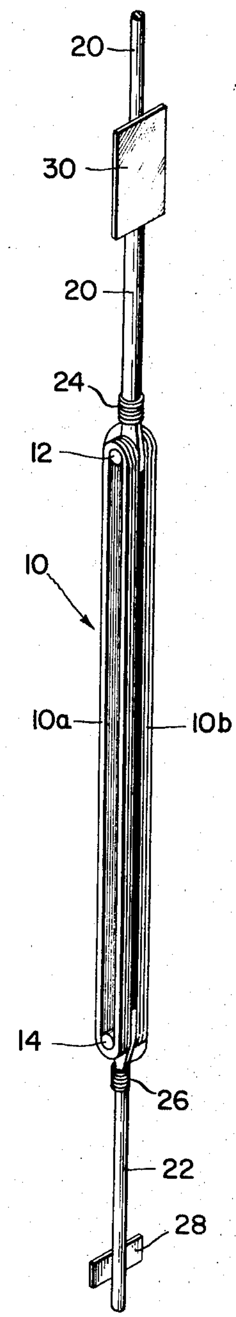
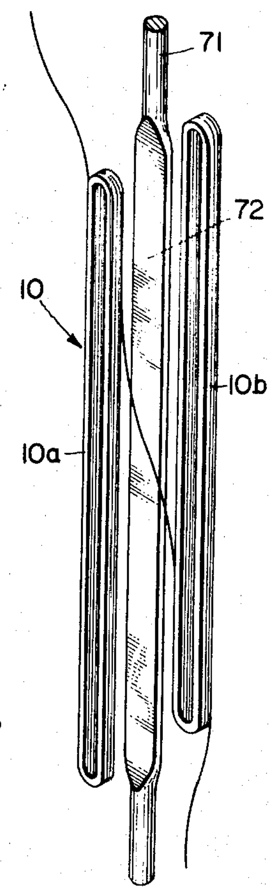


FIG. 6



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HIGH FREQUENCY GALVANOMETER

This invention relates to improvements in high frequency galvanometers. More particularly, the invention relates to a galvanometer with a frequency response operable to at least 25,000 Hz.

A principle failure of prior art galvanometers is their inability to operate at high frequencies in the order of 25,000 Hz. The draw-backs of the prior art invention is due to the relatively large moment of inertia of the movement assembly. The polar moment of inertia taken about the longitudinal axis of the galvanometer has been great due to, among other reasons, the use of unitary coils, bulky bobbins and long, flat ribbons as suspension means.

A flat ribbon does not have an optimum or minimal polar moment of inertia about its central longitudinal symmetrical axis. Therefore, a flat ribbon's inertial resistance to angular acceleration is high relative to a circular ribbon. Since the moment of inertia of a flat ribbon is not optimal from the standpoint of the moment of inertia for a constant cross-sectional area, flat ribbons do not lend themselves to high frequency applications. Another limitation on performance of galvanometers in the prior art is the bobbin itself on which the coil is wound. The entire coil assembly, with the bobbin, a part thereof, is mounted within the galvanometer. The miniaturization with respect to the mass, size and shape of the bobbin is restricted because of the great difficulty in assembling very small components. The mass, size and shape of the bobbin which holds the coil contributes substantially to the total moment of inertia about the longitudinal axis of the galvanometer. In the prior art in order to hold the moment of inertia to a reasonable value, only one bobbin has been used. A single bobbin necessitates the use of a closely wound unitary coil. A unitary coil because of its low ratio of surface area to volume has poor heat transfer characteristics. Hot spots develop readily in such a closely wound coil. Such hot spots tend to make galvanometers burn out.

Another disadvantage of the flat ribbon type suspension, of the prior art, results in a high spring constant due to the high stresses building up at the edges of the ribbon. A high spring constant reduces the current sensitivity of the galvanometer. The current sensitivity is defined as the ratio of the coil deflection to the input current. For a predetermined deflection, obviously, the greater the spring constant of the suspension the greater will be the required current flow through the coil. A long flat ribbon type suspension reduces the resonant frequency of the galvanometer. Obviously, the longer the suspension member happens to be, the lower the resonant frequency of this member and, therefore, the lower the resonant frequency of the galvanometer.

It is accordingly an object of the present invention to provide an improved galvanometer which obviates the foregoing deficiences of the prior art apparatus.

It is another object of the present invention to provide an improved galvanometer which has a very high frequency response.

It is a further object of the present invention to provide an improved galvanometer which has a minimal moment of inertia about its longitudinal axis.

It is yet another object of the present invention to provide an improved galvanometer which has high current sensitivity as well as very high frequency response.

It is still another object of the present invention to provide an improved galvanometer, as set forth, which is resistant to hot spots and subsequent burnouts.

In accomplishing these and other objects, there has been provided, in accordance with the present invention, an improved galvanometer structure which features circular suspension ribbons, a coil wound in two sections attached to the flattened portions of the circular suspension ribbon. The circular suspension ribbons receive the coil, which has a bobbinless structure, against the flattened portions thereby resulting in a galvanometer with a very low moment of inertia about its vibratory axis.

A better understanding of the invention may be had from the following detailed description when read in connection with the accompanying drawings, in which;

FIG. **1** is an exploded perspective view of the coil assembly of the galvanometer.

FIG. **2** is a perspective diagram of the vibratory assembly.

FIG. **3** is a perspective diagram of the galvanometer assembly and suspension.

FIG. **4** is an exploded view of the magnetic structure of the galvanometer assembly.

FIG. **5** is a perspective diagram of the complete assembly.

FIG. **6** is an exploded perspective view of the galvanometer and showing a different embodiment of the present invention.

Referring now to the drawings in more detail, there is shown in FIG. **1**, an exploded view of a coil assembly according to the present invention. A moving coil **10** of fine wire is wound in two distributed sections **10A** and **10B** although together they comprise one continuous coil. An upper suspension wire **20** is formed of circular wire. The lower end of the wire suspension member **20** is flattened; a small hold **16** is formed therein and a pin or peg **12** is inserted in the hole **16** with a portion of the pin extending beyond the flattened end of the wire on opposite sides thereof. A similar lower suspension wire **22**, also formed of circular wire, is provided. The upper end of the wire **22** is flattened; and the pin or peg **14** is inserted through the hole **18**, with a portion thereof extending from opposite sides of the flattened end of the wire **22**.

Referring now to FIG. **2**, an end **24** of the coil **10** is wrapped around and soldered to the upper circular suspension wire or ribbon **20**. The other end **26** of the coil **10** is similarly wrapped around and soldered to the lower circular suspension wire **22**. Thereby, a mechanical and electrical bond is formed between the ends **24** and **26** of the coil **10** and the circular suspension wires **20** and **22**, respectively. The upper portion of the circular suspension **20** has a mirror **30** affixed thereto. The circular suspension wire **20** to which the mirror **30** is attached is permanently affixed to a rod **32**, of FIG. **3**, by a suitable method, such as soldering or welding. This upper suspension rod **32** is provided with an enlarged flattened end **33** and is connected to an adjustable yoke **40** by a pin **42** made of an insulating material. The adjustable yoke **40** is provided with a threaded shaft **44** which engages an adjusting nut **46**. A guide pin **48** prevents rotation of the assembly with respect to the housing to be described later. The lower circular suspension wire **22** is provided with a similar means for permanently being affixed to a lower suspension rod **34** by a suitable method such as soldering or welding. To the lower suspension wire 22 a paddle 28 is affixed which provided damping for the vibratory assembly of the galvanometer. The lower rod 34 is centered in a bushing 50. On the upper rod 32 a locating disc 36 is provided which surrounds part of the shank of said rod 34. Symmetrically, a locating disc 38 is similarly provided for centering the lower rod 34. In addition, the lower rod 38 is centered in a bushing 50.

A wire, not shown, connects the lower rod 34 to a slip ring 54 which, as shown, is suitably mounted on an insulating member 55.

Referring now to FIG. 4, the oscillitory assembly is encased within an inner tubular body 56 in coaxial arrangement therewith. The inner tubular body 56 is constructed from nonmetallic material such as glass tubing, having an inner bore of capillary dimensions. In a preferred embodiment of the present invention, the inner tubular body 56 is utilized for allowing the outer tubular body 62, FIG. 5, to be fabricated with openings therethrough for reasons which will become obvious hereinbelow. The inner tubular body 56 is filled with a damping fluid 57 to a level position to totally immerse the coil while avoiding contact with the mirror 30. The damping fluid 57 is retained within the inner tubular body 56 by capillary action. The fluid 57, which totally immerses the coil 10 should have a high thermal capacity for removing sufficient thermal energy from the coil, thereby preventing coil hot spots. The damping fluid 57 may be one of many desirable types, such as silicon oil, which may be inserted into the inner body by a conventional hypodermic syringe, not shown. Permanent magnet pole pieces 58 and 60 are inserted into respective openings in the tubular body 56 and are shaped to provide a magnetic field having lines of flux transverse to the longitudinal axis of the coil assembly 10 located within the tubular housing 56. The outer surfaces of the permanent magnets 58 and 60 are also characterized to provide a smooth extension of the outer surface of the tubular housing 56 while providing a fluid type seal with the tubular housing 56 to retain the damping fluid 57 therein.

The galvanometer assembly is completed by sliding the protective outer casing 62 over the inner tubular body 56 and aligning a rectangular opening 64 within the protective outer casing 12 for communicating with the mirror 30. An upper cap 66 is then pressed into the top position of the projected outer casing 62 for closing the casing. An aperature 68 within the cap 66 allows the adjustment of the end adjusting nut 46. A kerf 70 is provided in the upper end of the cap 66 for providing a holding point from which rotational adjustment of the entire galvanometer assembly, about its longitudinal axis, may be obtained.

In accordance with the present invention, a wire suspension 20 and 22 of circular cross section is utilized to reduce the polar moment of inertia about the longitudinal axis of the galvanometer to an absolute theoretical minimum. The minimum value of inertia thereby increases the frequency response as a function of this factor to its absolute maximum value. The bobbins of the prior art have been eliminated completely in accordance with the present invention by winding the coil 10 on very small diameter pins 12 and 14 which protrude through the flatten ends of the circular suspension ribbons 20 and 22. The pins 12 and 14 add only very insignificantly to the moment of inertia of the assembly. The flattened ends of the suspension ribbons 20 and 22 allow the coil 10 to be mounted as close to the longitudinal symmetrical axis as is possible. Mounting the coil 10 in this fashion reduces its contribution to the total moment of inertia to a very minimum value. On the small diameter pins 12 and 14, the coil 10 is wound in two sections symmetrically spaced on opposite sides of the circular suspension wires 20 and 22, thereby dispensing with the use of a bobbin. By distributing the coil 10 on both sides of the suspension ribbons 20 and 22, the symmetry of the structure is preserved and the moment of inertia which the coil 10 contributes to the total moment of inertia is kept to a minimum. Another advantage of a distributed coil as opposed to a unitary coil, of the same wire size, wire length and number of turns, is that the ratio of the surface area to the volume is greater in a distributed coil thereby improving the cooling properties of the distributed coil and reducing the occurrence of hotspots.

An alternative construction for the galvanometer, in accordance with the present invention is shown in FIG. 6. The structure there shown is similar to that shown in FIG. 1 with the exception that suspension wire is formed of a single piece. Whereas the suspension wire means in FIG. 1 includes an upper and a lower suspension wire 20 and 22, respectively, with flattened ends; in FIG. 6, the suspension is shown as a single continuous wire 70. The wire 70, as before, is essentially a round wire. However, the middle portion 72 thereof is flattened to provide a pair of planar surfaces. Whereas in FIG. 1 the coils 10*a* and 10*b* were attached to the suspension wire means 20 and 22 by small pins which extend through the flattened ends of the suspension wires, in the construction illustrated in FIG. 6, the coils 10*a* and 10*b* may be cemented, respectively, to opposite sides of the flattened portion 72 of the suspension wire 70.

The present invention has a low spring constant since the suspension wires 20 and 22 are circular in cross-section. For a spring line member with a constant cross-sectional area and made of a specific material the spring constant will be a minimum for a circular cross section area. The moments taken about the longitudinal central axis of the spring like member will be at a minimum. Therefore, the length of the ribbon suspensions 20 and 22 can be reduced with respect to prior art suspensions while retaining the low spring constant which is very desirable from a current sensitivity standpoint. The current sensitivity is defined again as the ratio of the coil deflection to the input current. Since the resonant frequency of a long slender member is inversely proportional to its length, the shorting of the ribbon suspensions 20 and 22 produces the results of a much higher resonant frequency for the galvanometer assembly than for a long ribbon. This factor, too, increases the frequency response characteristic of the galvanometer.

Therefore the circular cross section of the circular suspension ribbons 20 and 22, contributes to the high frequency response in two ways, one, by reducing the moment of inertia and, two, by reducing the spring constant and thereby the length of the suspension required.

Thus, it may be seen that there has been provided, in accordance with the present invention, an improved galvanometer structure which is characterized by a very high frequency response, which exhibits a high current sensitivity and which is resistant to so called hot spots.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A galvanometer structure comprising
a coil of fine wire,
a suspension ribbon means including a first and a second wire suspension member,
said wire suspension members each being circular in cross section and having one flattened end,
said flattened end each having a small aperture formed therein,
pin suspension means inserted through each of said apertures in said flattened ends and protruding from both sides thereof,
said coil of fine wire being formed in two equal but electrically continuous parts,
said parts of said coil being mounted on and supported between said pins and on opposite sides, respectively, of said flattened ends,
opposite ends of said fine wire of said coil being electrically connected to said suspension members, respectively,
means for producing a magnetic field with lines of flux transverse to the longitudinal axis of said coil, and support means connected to said suspension means for supporting said coil in said magnetic field.

2. The invention as set forth in claim 1 and including rod means fastened to said suspension ribbon means whereby said suspension ribbon is mechanically short and exhibits a high resonant frequency.

3. A galvanometer structure as set forth in claim 2 and further including galvanometer mirror means fastened to said rod means.

4. The invention as set forth in claim 1 wherein said means for producing a magnetic field includes a first and second shaped magnetic pole piece located on respective sides of said coil.

5. A galvanometer structure comprising
a coil of fine wire,
a suspension ribbon means including a first and a second suspension member,
said first and second suspension members each being circular in cross section and having one flattened end,
said flattened end of each of said suspension members having a small aperture formed therein, and
pin suspension means inserted through each of said apertures in said flattened ends and protruding from both sides thereof,
said coil of fine wire being formed into substantially equal and electrically continuous parts,
said parts of said coil being mounted on and supported between said pins and on opposite sides, respectively, of said flattened ends, with opposite ends of said fine wire of said coil being electrically connected to said first and second suspension members, respectively.

6. A galvanometer structure as set forth in clam 5 and including rod means fastened to said suspension ribbon means whereby said suspension ribbon means is mechanically short and exhibits a high resonant frequency.

7. A galvanometer structure as set forth in claim 5 and including means for producing a magnetic field with lines of flux transverse to the longitudinal axis of said coil, and
support means connected to said suspension ribbon means for supporting said coil in said magnetic field.

8. A galvanometer structure as set forth in claim 6 and including galvanometer mirror means fastened to said rod means.

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