Dec. 1, 1942. H. W. WASHBURN 2,303,413

SEISMOMETER

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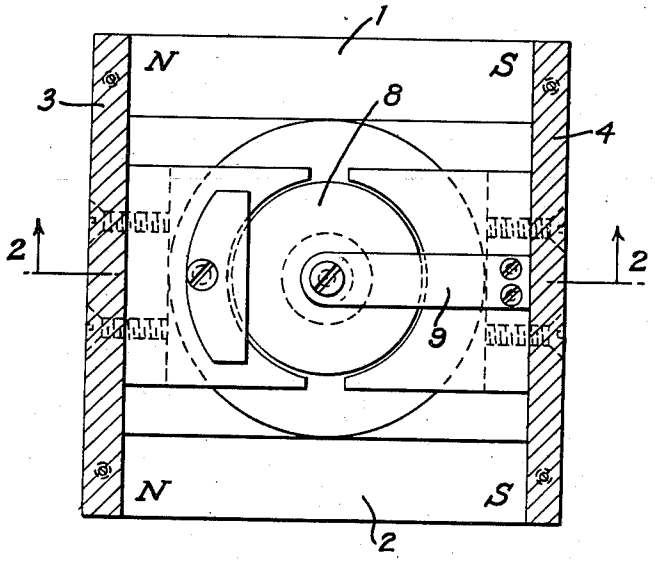


Fig. 1.

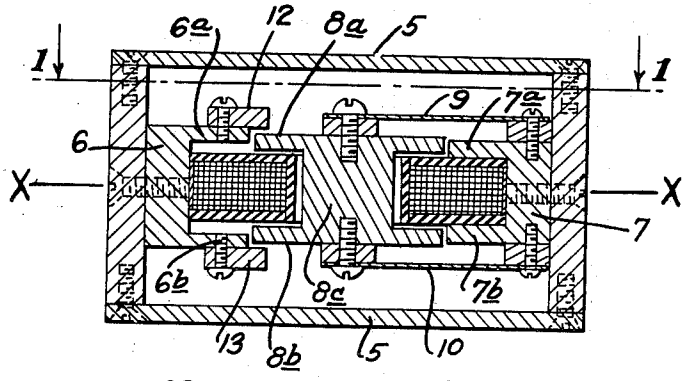


Fig. 2

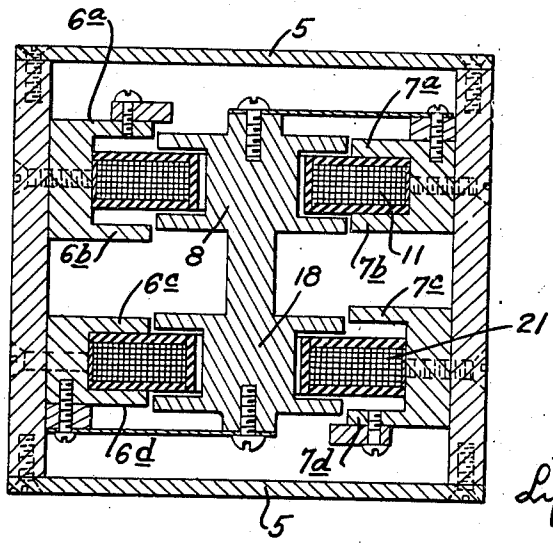


Fig. 3.

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SEISMOMETER

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9 Claims. (Cl. 177—352)

My invention relates to an instrument for detecting vibrations, particularly seismic waves.

One object of my invention is to provide a seismometer with a low resonant frequency.

Another object of my invention is to provide a means for controlling the relative effects that the magnetic and spring forces have in determining the frequency of a seismometer.

Another object of my invention is to provide a reluctance type seismometer in which the resonant frequency is affected only slightly by the magnetic circuit.

Another object is to provide a variable reluctance type seismometer.

Another object is to provide a seismometer having high sensitivity per unit weight.

Still another object is to provide a seismometer having substantially uniform response throughout the frequency range of interest in seismic surveying.

Other objects of my invention will be apparent or will be specifically pointed out in the description forming a part of this specification.

Referring to the drawing:

Fig. 1 is a plan view of the working parts of one preferred form of my invention taken on the line 1—1 of Fig. 2.

Fig. 2 is a vertical section of one form of my seismometer taken on the line 2—2 of Fig. 1.

Fig. 3 is a vertical section of another form of my invention also taken on the line 2—2 of Fig. 1.

Referring to Figs. 1 and 2 parallel permanent magnets 1, 2 have soft iron cross pieces 3, 4, butted against the ends thereof. Magnets 1, 2 and cross pieces 3, 4, are secured to brass end plates 5—5. Yoke type magnetic poles 6 and 7 are rigidly mounted on cross pieces 3, 4, respectively, facing inwardly and forming central air gaps. Each of said poles has a pair of pole tips symmetrically located but differently spaced with respect to a reference plane perpendicular to the plane of section drawn in Fig. 2 and passing through a center line X—X drawn through the poles. As shown, pole tips 6*a* and 6*b* of pole 6 are spaced further apart than pole tips 7*a* and 7*b* of pole 7. Thus, pole tips 7*a* and 7*b* opposite pole tips 6*a* and 6*b* respectively are symmetrically offset therefrom.

Flanges 8*a* and 8*b* of the bobbin type armature 8 are respectively located in the cylindrical shaped air gaps formed by pole tip pairs 6*a*, 7*a*, and 6*b*, 7*b*. Said armature is centrally supported by guide springs 9 and 10 secured to a frame formed by magnets 1 and 2 and cross-pieces 3 and 4 and end plates 5—5.

The fields of magnets 1 and 2 point in the same direction so that a high concentration of flux passes through the pole tips 6*a*, 6*b*, 7*a*, 7*b* and the armature 8. Said pole tips 6*a*, 6*b*, 7*a*, and 7*b* and said armature flanges 8*a* and 8*b* are dimensioned and positioned so that in the equilibrium position flux flows from pole tip 6*a* to pole tip 7*a* through flange 8*a* and a substantially equal amount of flux flows from pole tip 6*b* to pole tip 7*b* through flange 8*b*. Thus in the equilibrium position substantially no flux flows through the central core 8*c* of armature 8.

A coil 11 surrounding core 8*c* and secured to the frame is adapted to detect changes in flux through said core.

Whenever the frame moves with respect to the armature the flux through core 8*c* changes and a corresponding electromotive force is induced in coil 11. Thus vibrations reaching the frame produce corresponding electrical waves in coil 11.

My invention may be used as a seismometer to detect earth vibrations produced either spontaneously or artificially. In seismic prospecting earth waves lying in the range of frequencies from about 25 to 150 cycles are of particular interest.

My seismometer may be used to reproduce these waves faithfully at all the frequencies of interest. In order to achieve faithfulness of reproduction, I utilize a pickup coil 11 secured to the frame, a low resonant frequency for the moving armature 8, and a low inductance winding. By using a pickup coil so mounted I am able to use electromagnetic damping by short circuiting said coil with an appropriate damping resistor and I also attain a large ratio of the weight of the case to the weight of the armature.

Low inductance per unit turn is obtained by utilizing relatively thin pole tips 6*a*, 6*b*, 7*a*, and 7*b*. Such low inductance aids in producing uniform response at high frequencies.

To achieve a low resonant frequency, preferably lower than the frequency of any wave I desire to record I use an armature having low weight and a system in which the force constant of the moving armature is low.

The force constant affecting the resonant frequency of my seismometer is produced by springs 9 and 10 and magnetic forces between the pole tips and the armature. As is well known the resonant frequency of a vibrating system decreases as the force constant decreases.

To bring about a decrease in force constant, I use weak springs at 9 and 10 and I introduce auxiliary pole segments 12 and 13 which coact

with armature 8 to oppose magnetic forces produced between armature 8 and pole tips 6a, 6b, 7a and 7b when said armature is displaced from its equilibrium position.

As will be clear to those skilled in the art, when armature 8 is displaced upward or downward from its equilibrium position, the magnetic forces between the pole tips 6a, 6b, 7a, and 7b and said armature tend to restore said armature to its equilibrium position. Pole segments 12 and 13, however, attract armature 8 and consequently tend to draw the armature further from its equilibrium position. By properly proportioning these two counteracting forces the magnetic "stiffness" of the system may be made as small as desired. If the forces produced by segments 12 and 13, almost but not completely, counteract the forces produced by pole tips 6a, 6b, 7a, and 7b, the resonant frequency of the system depends almost entirely on the stiffness of springs 9 and 10.

The combination of variable area and variable gap characteristics and the attachment of the pickup coil to the frame instead of the moving part makes possible:

1. A low inductance winding compared with the necessary damping resistance;
2. Electromagnetic damping;
3. Light total mass;
4. Large ratio of moving mass to stationary mass; thus making possible flat steady state response over a wide frequency band and also a simple transient response.

To prevent stray pickup from affecting the system seriously, I use a system comprising four pole tips on each side and two armatures 8 and 8 secured together as in Fig. 3 and two pickup coils 11 and 21 connected in series. I utilize wide spacing between pole tip pairs 6a, 6b, and 7c, 7d and narrow spacing between pole tip pairs 6c, 6d and 7a, 7b, so that when the coils are connected to add effects of case vibration, any electromotive forces induced from external sources will be cancelled.

Basically my seismometer mechanism is a variable area type using opposed pairs of like pole tips symmetrically arranged about a central plane. In the preferred form of my invention, in which the magnetic stiffness is variable I combine effects of both variable area and variable gap type instruments. Obviously in outdoor use, an enclosing casing of convenient form may be utilized.

From the foregoing it is seen that I have provided a seismometer which is simple and rugged in construction, sensitive and adapted to reproduce seismic waves faithfully.

It is obvious that many modifications and variations of my invention, as hereinabove set forth, may be made without departing from the spirit of my invention. It is therefore to be understood that my invention is not to be limited to the specific details shown and described but only by the appended claims.

I claim:

1. In an electro-mechanical transducer having a magnetic system and a magnetic armature cooperating with said magnetic system to produce first magnetic forces acting on the armature and tending to restore the armature to a neutral position when displaced therefrom in a predetermined direction, a pickup coil surrounding said armature and responsive to flux changes through the armature, resilient means supporting said armature on said magnetic system also tending to restore said armature to said position after displacement therefrom in said direction, and additional magnetic means cooperating with said armature and said magnetic system and positioned to provide a second magnetic force to at least partially counteract said restoring forces.

2. In an electro-mechanical transducer having a magnetic system symmetrical about a reference plane and a magnetic armature symmetrical about a reference plane parallel to the first plane, said armature being displaceable along an axis perpendicular to the planes and positioned in magnetically self-centering relation to the magnetic system, resilient means supporting said armature in said magnetic system for restoring said armature to said position after displacement therefrom, and additional magnetic means positioned to at least partially counteract the restoring forces of said resilient means.

3. An electro-mechanical transducer of a type having an armature movable in a magnetic gap formed between pole pieces, characterized by an armature pole piece relationship effectively producing during armature movement a variable field intersection area in a surface parallel to the direction of armature movement resulting in a force tending to center said armature with respect to said pole pieces, and a gap of variable thickness along a line parallel to the direction of armature movement resulting in an alined force tending to counteract said centering force.

4. In an electro-magnetic transducer having one transducer element in the form of a magnetic system provided with a pair of north pole tips and a pair of south pole tips with airgaps therebetween and a second transducer element in the form of an armature resiliently suspended in the air gaps between pole tips of opposite polarity and displaceable in a direction parallel to the faces of the pole tips in variable field intersection area relationship to the pole tips, a pair of auxiliary magnetic pole tips secured to one of the elements and forming with the other element a structure having two air gaps of variable thickness in a direction parallel to the displacement direction and arranged so that one airgap thickness increases as the other decreases with displacement.

5. An electro-mechanical transducer comprising a magnetic system having a pair of spaced north pole tips and a pair of differently spaced south pole tips, both pairs being symmetrically disposed with respect to a common reference plane, an armature of soft magnetic material resiliently supported in the gaps between the pole tips and displaceable along an axis normal to said reference plane, said armature comprising a central core having an axis coinciding with the displacement axis, a pair of flanges on the ends of the core in planes normal to said axis and spaced apart a distance intermediate the spacing between the pairs of pole tips, each flange overlapping inner portions of the outer pole tips of the same polarity and outer portions of the other pairs of pole tips, the amounts of overlapping varying with the displacement, and a pickup coil surrounding said core.

6. An electro-mechanical transducer comprising a magnetic system having a pair of spaced north pole tips and a pair of differently spaced south pole tips, both pairs being symmetrically disposed with respect to a common reference plane, an armature of soft magnetic material resiliently supported in the gaps between the pole tips and displaceable along an axis normal to said reference plane, said armature comprising a

central core having an axis coinciding with the displacement axis, a pair of flanges on the ends of the core in planes normal to said axis and spaced apart a distance intermediate the spacing between the pairs of pole tips, each flange being positioned with respect to the pole tips to provide a magnetic flux path from a north pole tip to a south pole tip on the same side of said reference plane and also a magnetic flux path from said north pole tip to the other south pole tip through said core, the magnetic forces between said armature and said magnetic system tending to restore said armature to a neutral position in which the armature is symmetrically located with respect to said reference plane when the armature is displaced from said neutral position, auxiliary flux distribution means positioned in such relation to the armature and said magnetic system as to produce magnetic forces on the armature at least partly counteracting the aforesaid magnetic forces, and a pickup coil surrounding said core.

7. An electro-mechanical transducer comprising a magnetic system having a pair of spaced north pole tips and a pair of differently spaced south pole tips, each of the pairs being symmetrically disposed with respect to a common reference plane, an armature of soft magnetic material resiliently supported in the gaps between the pole tips and displaceable along an axis normal to said reference plane, said armature comprising a central core having an axis coinciding with the displacement axis, a pair of flanges on the ends of the core in planes normal to said axis and spaced apart a distance intermediate the spacing between the pairs of pole tips, each flange being positioned with respect to the pole tips to provide a magnetic flux path from a north pole tip to a south pole tip on the same side of said reference plane through the flange and another flux path through said armature core from a north pole tip on either side to the south pole tip on the other side of said reference plane, and a pickup coil surrounding said core.

8. In an electromechanical transducer having a magnetic system and a magnetic armature resiliently suspended therefrom and arranged so that flux density through the armature and parallel to the displacement axis changes in response to displacements along the displacement axis, and means for detecting changes in said flux density, the improvement which comprises flux distribution means cooperating with said system and armature to produce a force acting on the armature, and tending to force the armature farther away from a neutral position when displaced therefrom.

9. In an electromechanical transducer including a magnetic system having poles on opposite sides of a reference plane, an armature also having flux bearing sections on opposite sides of said reference plane, resilient means supporting said armature on said magnetic system and constraining the armature movement to a direction perpendicular to said reference plane, said poles and said armature cooperating to produce a magnetic force tending to restore the armature to a neutral position when displaced therefrom, and auxiliary flux distribution means positioned on opposite sides of said plane and cooperating with said armature to produce a magnetic force on the armature in an opposite direction to said aforesaid magnetic force during armature displacement.

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