July 10, 1956 T. ONGARO 2,754,435

VOLTAGE GENERATING VIBRATORY PICK-UP DEVICES

Filed Sept. 29, 1952

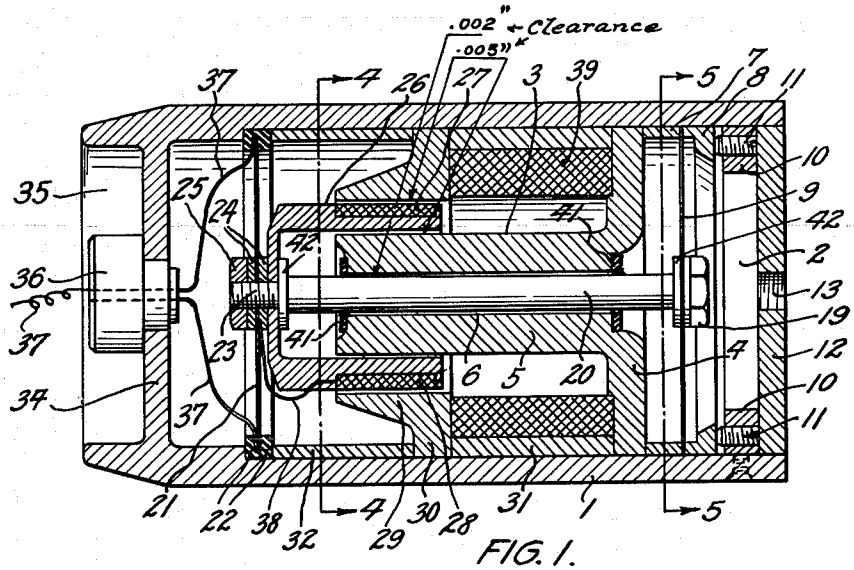


FIG. 1.

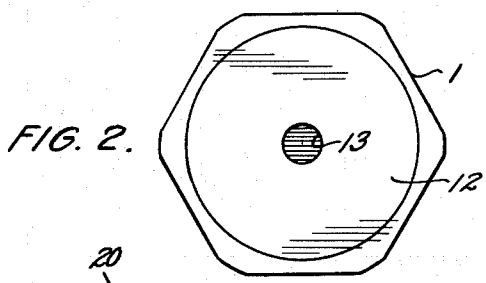


FIG. 2.

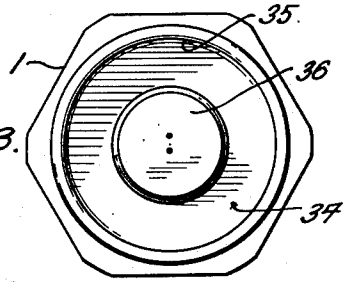


FIG. 3.

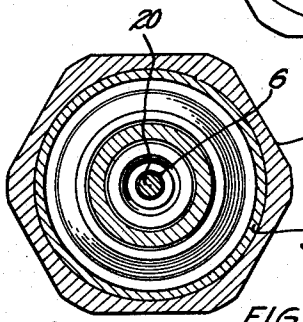


FIG. 4.

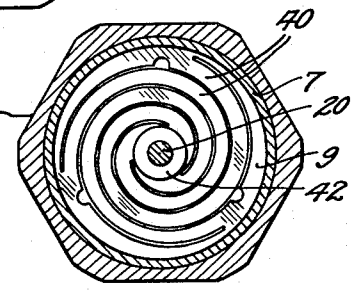


FIG. 5.

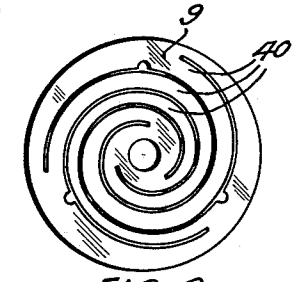


FIG. 6.

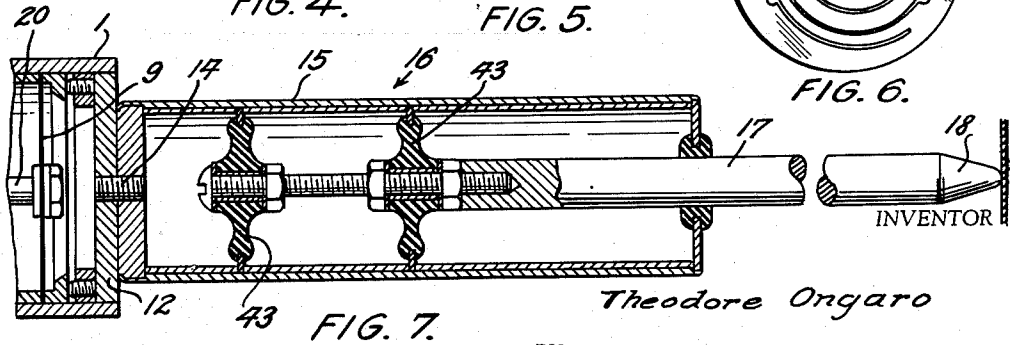


FIG. 7.

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VOLTAGE GENERATING VIBRATORY PICK-UP DEVICES

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8 Claims. (Cl. 310—27)

This invention relates to vibration detection apparatus, having specific reference to an improved pick-up device adapted to generate measurable electric current through the operation of internally positioned voltage-generating means responsive to vibratory forces imparted to the apparatus from extraneous sources.

A primary object of the invention is to provide such a pick-up which, while possessing high sensitivity to vibratory impulses applied thereto, is unusually strong and rugged from a mechanical standpoint, so that careful handling need not be exercised in the use and operation of the same, this being in contrast with the relatively delicate devices of comparable sensitivity hitherto used in analogous capacities.

It has been thought that the increased ability of a vibration pick-up device of this character to withstand shock and abuse of the kind commonly encountered in most industrial applications would, of necessity, result in a sharp decrease in the sensitivity of the instrument. Since sensitivity is an important factor in the accurate analysis or study of vibration, it became necessary, in producing the present invention, to provide a pick-up which would not only meet the requirements of mechanical or physical ruggedness, but, also, to include therein features of construction rendering the pick-up extremely sensitive to vibration imparted thereto.

In accordance with the present invention, a pick-up is provided consisting of a strongly constructed outer case having an internal chamber in which is mounted a pair of spaced diaphragms formed with flexible reed-supported centers, the latter having secured thereto the opposite ends of a longitudinal movable shaft forming the armature member of a bobbin coil of the induction type, the latter cooperating with a magnetic core stationarily positioned within the chamber to develop measurable electric current upon movement of the induction coil and its shaft relative to said magnetic core, means being provided for mechanically limiting the longitudinal movement of the bobbin coil and its supporting shaft and, also, movement thereof transversely across the longitudinal axis of the instrument.

A further feature of the invention resides in the specific construction of the diaphragms utilized in effecting the pulsating support of the bridging shaft of the bobbin coil, wherein each of said diaphragms comprises a thin sheet metal body formed with an unbroken continuous peripheral region and a center or hub region, the said regions being united by relatively spaced and elongated spiral reeds integrally formed with the diaphragm, the length of each of said reeds exceeding the effective diameter of the diaphragm in which the reeds are incorporated, whereby to provide a diaphragm for use in the capacity set forth and which is characterized by its high sensitivity in responding to vibration imparted to the outer case of the pick-up in which such diaphragms are mounted.

Other objects reside in vibration-determining apparatus of the character set forth in which the diaphragm and associated voltage-generating means, mounted within

an outer casing, are so constructed that, while strong and rugged in their mechanical design, and highly resistant to forces tending to impair their sensitive response to minute vibratory impulses imparted thereto, nevertheless does not necessitate the use of the customary body of a frequency-damping liquid within the casing; to provide a pick-up of this character in which mechanical friction in the seismic response of the current-generating mechanism is substantially eliminated; and to provide further improvements and advantages in apparatus of this kind which will be in part obvious and in part pointed out hereinafter.

For a further understanding of the invention, reference is to be had to the following description and the accompanying drawings, wherein:

Fig. 1 is a vertical longitudinal sectional view taken through my improved vibration pick-up instrument;

Fig. 2 is an end elevational view thereof;

Fig. 3 is a similar view of the opposite end of the instrument;

Fig. 4 is a vertical transverse sectional view taken through the instrument on the plane indicated by the line 4—4 of Fig. 1;

Fig. 5 is a similar view taken through the instrument on the line 5—5 of Fig. 1;

Fig. 6 is a detail perspective view of one of the diaphragms;

Fig. 7 is a fragmentary longitudinal sectional view disclosing the instrument of the present invention equipped with a vibration transmitting prod of the filter type.

Referring more particularly to the drawings, the numeral 1 designates a relatively thick-walled cylindrical metallic case utilized by the vibration pick-up instrument of the present invention. The case includes, in this example thereof, an internal longitudinally extending chamber 2 bounded by a cylindrical outer wall. Positioned in the chamber 2 is a first pole member 3, the latter being formed at one end with a circular head 4, and from the central portion of this head, and arranged in the longitudinal axis of the chamber, there extends an integral longitudinally projecting hub 5. The latter is formed with an elongated longitudinally extending bore 6 disposed in the longitudinal axis of the chamber.

Engaging the forward surface of the head 4 of the pole member 3 and arranged in contact with the cylindrical wall of the chamber 2 is a spacing ring 7. Cooperative with this ring is a complemental clamping ring 8, the latter being maintained in close-fitting engagement with the peripheral portion of a case-vibrated diaphragm 9.

To maintain the ring 8 in clamping contact with the circumferential edge of the diaphragm 9, the inner surface of the chamber 2 carries stationary ring 10 having threaded bores for the reception of clamping screws 11. These screws, upon being rotated, have their inner ends arranged to impinge the clamping ring 8, forcing the latter rearwardly into firm frictional and retaining contact with the outer peripheral portion of the diaphragm 9, clamping the same between the rings 7 and 8 in a manner enabling vibratory forces to be imparted to the diaphragm from the case 1.

Also engaging the ring 10 is a removable end plate 12. This plate may be tightly fitted in the forward end of the chamber 2, or may have threaded engagement with the wall of said chamber, as desired. The plate 12 includes an axial opening 13 which, if desired, may be threaded for the reception of a stud 14 carried by one end of the casing 15 of a filter cell or prod 16.

This prod, as shown in Fig. 7 includes a forwardly and longitudinally disposed rod 17 having a tapered forward end 18, which is adapted to be placed against a work surface, the vibratory characteristics of which are to be determined by the apparatus. As will be explained in detail hereinafter, vibration imparted to the rod 17 from

the surface or surfaces with which the forward end of the rod is brought into contact are transmitted to the casing 15 of the prod, and thence to the case of the vibration pick-up instrument. The latter may operate, if desired, with the prod removed, as by being placed directly on a vibratory surface.

The diaphragm 9 is formed from a sheet metal stamping, such as beryllium-copper or phosphorous bronze, steel or suitable material. The disk includes an unbroken continuous periphery and a center or hub, the same being resiliently united by the spirally arranged reeds, producing a flexible, freely vibratory body. To the center of this body there is clamped as at 19 one end of a seismic bridging shaft 20 which is mounted for pulsating movement in slightly spaced relation (.002 of an inch) from the bore 6 of the pole member 3. The shaft extends through the bore from one end thereof to the other, and is of greater length than the hub 5 of said pole member, so that one end of said shaft may be connected with the central portion of the diaphragm 9, while its other or opposite end is rigidly connected with the central portion of a second diaphragm 21, the latter being arranged stationarily in the chamber 2 toward the rear end of the case 1 and in circumferentially insulated relation thereto. Structurally, the diaphragm 21 is the same as the diaphragm 9. The second diaphragm 21 has its outer peripheral edge clamped between a pair of insulating clamping rings 22.

Centrally, the diaphragm 21 is formed with an opening in which is received the reduced threaded rear end 23 of the bridging shaft 20. The end 23 carries clamping washers 24 and a clamping nut 25 is employed and by which the central portion of the diaphragm 21 is securely gripped for movement in unison with the shaft 20 and, also, the central reed-supported portions of the first diaphragm 9.

Mounted on the reduced end 23 of the shaft 20 is a movable inductive coil bobbin 26. The latter includes a cylindrical body 27 on which is wound a coil 28. The coil 28 is movable in the hub bore of an outer or second pole member 29, the latter being formed with a circumferential flange 30 engaging the circular wall of the case 1 and confined between spacing sleeves shown at 31 and 32. The sleeve 31 is positioned between the head 4 of the first pole member 3 and the flange 30 of the second pole member 29, while the spacing sleeve 32 is positioned between the flange 30 and one of the insulated clamping rings 22. The rearward of these rings seats peripherally on an annular shoulder 33 formed in the chamber 3.

By tightening the screws 11 all the internal parts of the case may be forced longitudinally rearwardly to hold the same in definitely spaced and operatively located positions within the instrument. At its rear end the case includes a transversely extending web 34 which is inset inwardly of the case in a manner defining a shallow open-sided chamber 35. Carried by the web 34, and positioned in the chamber 35, is a connector 36 from which electrical conductors 37 may extend to current-amplifying and vibration registering or recording apparatus, not shown. The connector 36 also is electrically joined with the outer peripheral portions of the diaphragm 21 by means of portions of the conductors 37 which are flexibly arranged in the chamber 2. Likewise, the inductive coil 28 is joined by a conductor 38 with the central portion of the diaphragm 21 or the reduced rear end 23 of the bridging shaft 20.

As the device vibrates in response to vibrations applied thereto by placing the case 1 bodily on a vibratory surface, or through the use of the detachable prod or filter cell shown at 16, such extraneously applied vibratory forces are transmitted to the sensitive center of the diaphragm 9, and to the centers of both diaphragms by the bridging shaft 20 carrying the inductive coil 28. This coil is movable in the magnetic field of the primary core disclosed at 39, the latter being clamped between the head 4 of the pole member 3 and the adjoining face of the outer pole member 29. Through the vibration of the inductive coil, as a result of this arrangement of parts, voltage is developed in the conductor 38 leading from the coil 28 to the central portion of the diaphragm 21. This voltage passes through the insulated diaphragm 21 and is then transmitted by the conductors 37 to the connector 36, in order that the same may be delivered to suitable amplifying apparatus in a manner providing current flow or a voltage adequate to effect the actuation of various indicators or vibration-recording registers, not shown.

The construction of the diaphragms 9 and 21 is of importance. As previously stated, each of these diaphragms is stamped from thin sheet metal or other material having resilient properties. In its formation, each diaphragm includes a plurality of spirally arranged, relatively spaced, coextensive reeds, shown at 40 in Fig. 5. These reeds merge in the perforated central region of each diaphragm. Two or more of such reeds are used, each reed possessing a length greater than that of the effective diameter of the diaphragm body, whereby to provide high mechanical strength on the part of said diaphragms and resistance to injury but to allow the centers thereof to pulsate freely in response to applied vibratory forces.

It will be further noted that the bobbin inductive coil 28 and the seismic bridging shaft 20 are suspended by the centers of the diaphragms 9 and 21 from the case of the instrument. The transverse clearance between the outer wall surfaces of the bridging shaft 20 and the wall surfaces of the longitudinal bore 6 the pole member 3 is less, dimensionally considered, than the clearance which exists between the bobbin 26, the inner pole member 3 and the outer pole member 29. Thus any transverse motion of the seismically suspended portion of the pick-up is limited with respect to the two extremes by the clearance provided between the bridging shaft 20 and the center bore walls of the pole piece 3. This limited motion thus protects the bobbin from any damage due to extreme shock along the transverse axis of the instrument. Motion along the longitudinal axis of the instrument on the part of the seismically suspended members thereof is limited by the yieldable bumper elements 41 which are present in the center pole piece 3 and are acted upon by the two washers or shoulders 42 on the ends of the bridging shaft 20. Thus it will be apparent that both transverse motion and axial motion of the bobbin are limited in such manner as to protect both the sensitive diaphragms and the bobbin from any damage due to extreme conditions beyond those in which the pick-up is intended to operate.

To further disclose the sturdy construction of the instrument, it will be noted from the drawings that the outer case 1, although being rigid in itself, is more than adequately protected from deformation by the steel center pole piece 3 and the outer pole piece or member 29. No apparent damage has been caused the pick-up even after repeatedly dropping the same from a height of from 8 to 10 feet on a solid concrete base or floor.

With reference to the sensitivity of the instrument, it will be noted that the diaphragms 9 and 21 each is formed of a thin spring-like material in which the reeds 40 have been cut or stamped. This construction imparts extremely high strength and rigidity in directions transverse of the diaphragm, and yet provides a great degree of freedom for the central portion thereof for movement in an axial direction, since the only friction introduced into the diaphragms is that due to the molecular friction inherent in the diaphragms themselves. It has been pointed out that the diaphragms can not be readily damaged by transverse motion or shock, nor can their elastic limits be exceeded due to longitudinal motion along the axis of the pick-up, yet these diaphragms are extremely sensitive while being protected from forces normally producing damage to instruments of this character. A high degree of directional sensitivity is thus obtained from the

inherent construction of the diaphragms. It will be further noticed that with a large magnetic core, such as that indicated at 39, and an adequate wire cavity in the bobbin 26, it is possible to obtain a high output voltage for small bobbin displacement. The outer pole piece or member 29 forms a complete magnetic shunt around the entire wire cavity of the bobbin, thus protecting the pick-up from the undesired effects of stray magnetic fields. No output voltage from such a magnetic field has been encountered during the use of the pick-up in studies performed on electric motors and other equipment.

The electrical signal produced by the operation of the apparatus is carried out from the bobbin through the bridging shaft, and thence through the diaphragm 9 to a ground, while the other lead extends from the bobbin, through the second diaphragm 21, being led externally from the instrument through the connector 36 to associated amplifying and recording apparatus, not shown, and returned. There are no leads from the bobbin to the electrical output connector to break or to become damaged during hard usage, or which in other ways may impair the utility of the pick-up. The apparatus is simple, sensitive, rugged in construction and may be produced at a comparatively low cost. All the parts are readily accessible and can be conveniently replaced from time to time when necessary.

The prod device disclosed at 16 in Fig. 7 of the drawings has been set forth and claimed in my co-pending application executed of even date with the present application. Its construction is such as to make possible the study and analysis of relatively low-frequency vibrations of high amplitude that are often contaminated with other high-frequency components or harmonics of low amplitude; for example, those existing in the study and analysis of vibrations of electrical motors. The mechanical filtering cell provided by the prod is essentially a mechanical means for greatly increasing the attenuation ratio between the high and low-frequency component of an input signal or pulsation.

The stylus rod 17 of the prod is suspended from the casing 15 by means of the resilient diaphragms shown at 43. These diaphragms may be made of rubber, steel, or various resilient material having cushioning characteristics. In use the outer end of the transmitting rod or stylus 17 is placed in contact with the vibratory work piece such as an electric motor, and the vibration existing in the work piece is transmitted through the stylus rod to the resilient diaphragms 43. These diaphragms when properly designed, and with due consideration given to the time constant of the system, will act as a diminishing or suppressing means to the applied high-frequency component of the vibratory forces, while transmitting almost without loss the low-frequency components thereof. Thus the mechanical filtering cell provided by the prod makes possible the study and analysis of vibrations in a wide field of activity which has only been open before with the employment of large and relatively expensive electronic filters.

It will be understood that the prod may or may not be used in connection with my improved pick-up, although its use in many instances, as in the study and analysis of certain vibration frequencies, has been found to be advantageous.

While I have described what I consider to be the preferred form of the present invention, nevertheless it will be understood that the construction is subject to certain modifications or variation without departing from the spirit and scope of the invention as the same have been expressed in the following claims.

I claim:

1. A vibration pick-up instrument of the type set forth, comprising: a case having an internal chamber formed with an internal shoulder, said chamber being closed at one end by a transversely extending web constituting an end wall, a removable closure for the opposite end of said chamber, a diaphragm seated against said shoulder and electrically spaced from said case, a secondary pole member positioned in said case, said pole member being formed with an axial opening, a primary pole member positioned in said chamber, said primary pole member being formed with a longitudinally extending hub having an open ended bore disposed in the longitudinal axis of said case, a magnetic core positioned between said pole members and spaced from the hub of said primary pole member, a case-grounded diaphragm arranged in said chamber, a ring-type spacer positioned between said grounded diaphragm and said primary pole member, clamping means carried in the chamber of said case for holding said grounded diaphragm peripherally against movement, a bridging shaft connected at the ends thereof with the centers of said diaphragms, a bonnet positioned on said shaft for movement in unison therewith, said bonnet including a cavity, an inductive coil disposed in said cavity and shielded by the secondary pole member, stop devices resiliently mounted in the ends of said primary pole member, and spaced members on said shaft engageable with said resilient stop means to control the extent of longitudinal movement of said shaft.

2. Apparatus as specified in claim 1, and wherein said shaft and the hub opening of said primary pole member have a working clearance less than that existing between said bonnet and said secondary pole member, whereby to cause said primary pole member to limit movement of said shaft in a transverse direction, means for electrically grounding one of said diaphragms to said case, means for insulating the other of said diaphragms from said case, and conductor means leading from said insulated diaphragm exteriorly of said case.

3. A vibration pick-up instrument of the high inertia type, comprising: a case having an internal chamber closed at both ends, inner and outer stationary pole members arranged within said chamber, a pair of normally undistorted spaced diaphragms positioned in said chamber on opposite sides of said pole members, a bridging shaft carried by said diaphragms movable by vibration of the diaphragms longitudinally of said primary pole member and disposed in the longitudinal axis of said chamber, and a bonnet carrying an inductive coil connected with one end of said shaft, with the coil thereof movably positioned between said pole members, and a vibration transmitting and frequency damping prod device detachably connected in vibration imparting order with one end of said case.

4. Apparatus as specified in claim 3, and wherein the prod device includes an outer case having a rigid stylus projecting therefrom, and frequency-diminishing suspension means connecting said case and stylus.

5. A vibration pick-up instrument for electrically translating vibratory forces, comprising: a case having an internal chamber, a first pole member stationarily positioned in said chamber, said pole member including an elongated hub having an open-ended bore disposed in the longitudinal axis of the chamber, a second pole member stationarily arranged in said chamber, said second pole member being formed with a hub having an axial opening arranged to receive one end of the hub of the first pole member, a pair of diaphragms stationarily mounted in said chamber on opposite sides of said pole member, said diaphragms including vibratory central regions, a bridging shaft passing through the bore of said first pole member and having its ends directly clamped to the central portions of said diaphragms, a bonnet fixed on one end of said shaft and disposed in part in the hub opening of the second pole member, said bonnet carrying an inductive coil, a primary magnetic core arranged between said pole members in spaced relation from the hub of the primary member to provide for pulsating movement on the part of said bonnet within said core, and spaced stop means cooperative with said shaft and the first pole member for mechanically limiting the extent

of longitudinal pulsating movement of said shaft in response to diaphragm vibration, one of said diaphragms being united electrically in direct vibration-transmitting engagement to said case and the other of said diaphragms being stationarily mounted in but electrically insulated from said case, and current conductor means joined with the insulated diaphragm and leading exteriorly of the case.

6. A pick-up instrument of the seismic type comprising: a case having an internal chamber; a first pole member stationarily positioned in said chamber; said member being provided at one end with a head from which a tubular hub extends in the axis of the chamber; a second pole member stationarily positioned in said chamber; said second pole member including a hub spaced from and concentrically surrounding a portion of the hub of the first pole member; a magnetic core stationarily positioned between said pole members and radially spaced from the hub of the first pole member; a pair of diaphragms stationarily mounted in said chamber on opposite sides of said pole members; a high inertia armature assembly supported by said diaphragms; said armature assembly including a shaft connected at the ends thereof with central portions of said diaphragms and passing through the hub of said first pole member, and a bonnet on one end of said shaft carrying a coil; the coil being normally located in the hub portion of the second or outer pole member so as to be magnetically shielded by the latter; the clearance between said coil and said hubs of said first and second pole members being greater than the clearance between another portion of said armature assembly and another portion of the stationary members of said pick-up.

7. A pick-up instrument of the seismic type comprising: a case having an internal chamber; a first pole member stationarily positioned in said chamber; said member being provided at one end with a tubular hub which extends along the axis of the chamber; a second pole member stationarily positioned in said chamber; said second pole member including a portion spaced from and concentrically surrounding a portion of the hub of the first pole member; a magnetic core stationarily positioned between said pole members and radially spaced from the hub of the first pole member; a pair of diaphragms stationarily mounted in said chamber on opposite sides of said pole members; a high inertia armature assembly supported by said diaphragms; said armature assembly including a shaft connected at the ends thereof with central portions of said diaphragms and passing through the hub of said first pole member, and a bonnet on one end of said shaft carrying a coil located in said portion of said second pole member surrounding said hub, said portion of said second pole member having an axial length at least equal to the axial length of said coil so as to magnetically shield said coil.

8. A vibration pick-up instrument comprising: a case having an internal chamber, a first magnetic member stationarily positioned in said chamber, a second annular shaped magnetic member stationarily positioned in said chamber, said first magnetic member having a portion thereof extending along the axis of said chamber into said annular shaped magnetic member to define an annular space between said portion and said annular shaped magnetic member, a pair of longitudinally spaced diaphragms stationarily mounted in said chamber on opposite longitudinal sides of said annular space, said portion of said first magnetic member having a bore therethrough concentric with said annular space, a bridging shaft connected at the ends thereof with central portions of said diaphragms and passing through said bore in said portion of said first magnetic member, and a bonnet on one end of said shaft carrying a coil positioned in said annular space between said annular magnetic member and said portion of said first magnetic member, the radial clearance between said shaft and said bore in said portion of said first magnetic member being less than the clearance between said coil and said annular magnetic member and between said coil and said portion of said first magnetic member.

References Cited in the file of this patent

UNITED STATES PATENTS

2,067,803	Thearle	Jan. 17, 1937
2,348,225	Petty	May 9, 1944
2,533,249	Henson	Dec. 12, 1950
2,596,048	Severs	May 6, 1952
2,657,374	Bardeen	Oct. 27, 1953