Nov. 11, 1947. E. F. McCLAIN, JR 2,430,476

PHONOGRAPH REPRODUCER

Filed Aug. 25, 1943 2 Sheets-Sheet 1

FIG. 1

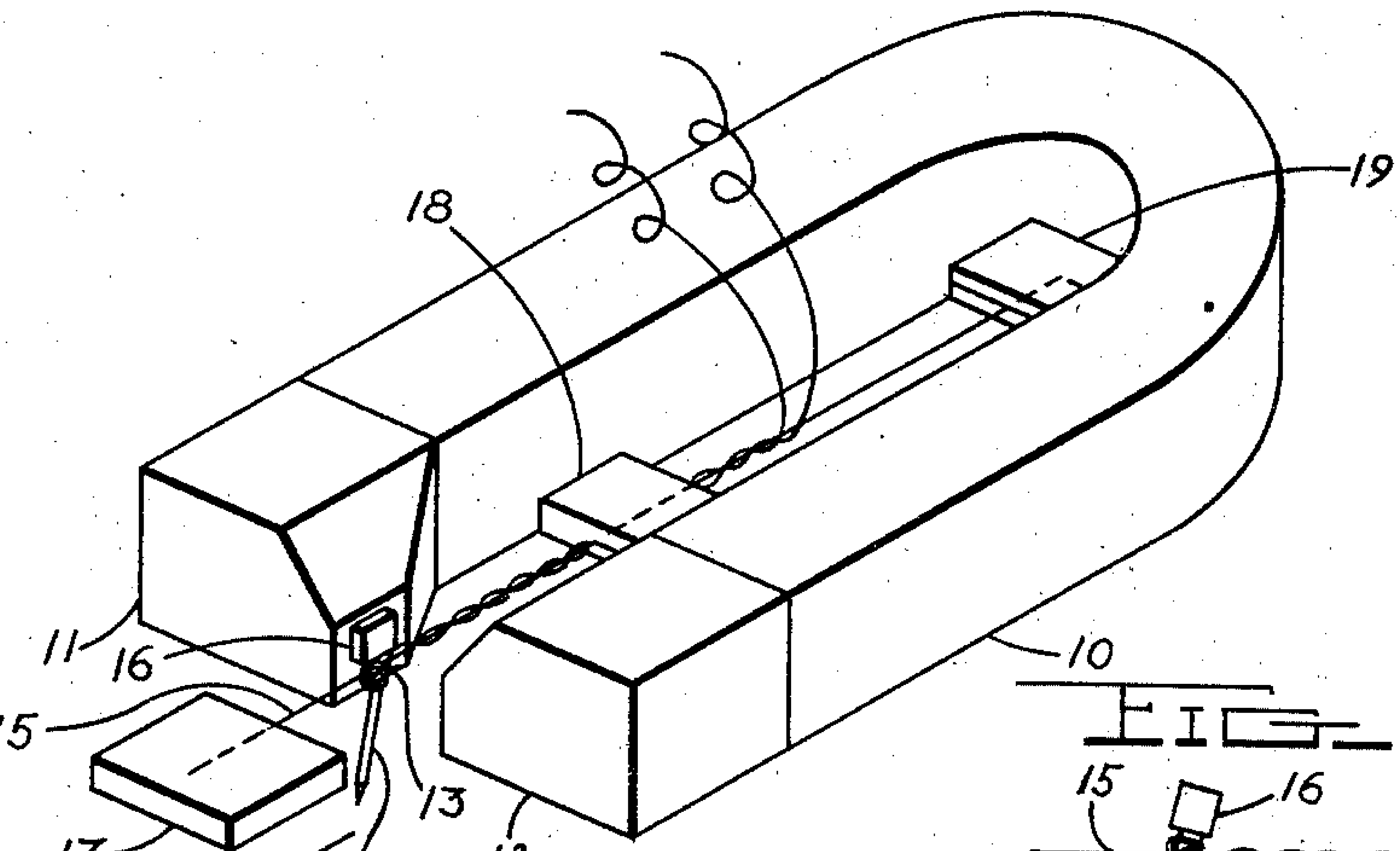

FIG. 2

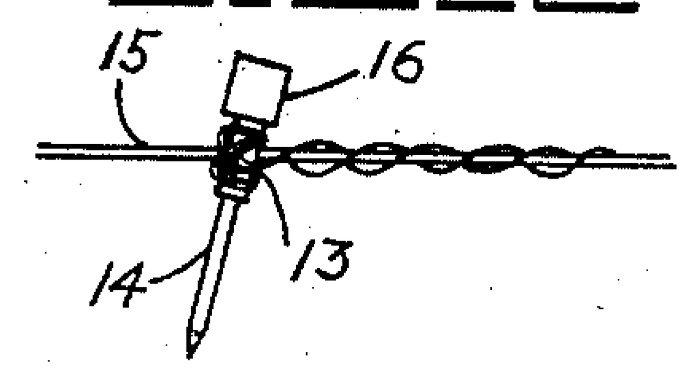

FIG. 3

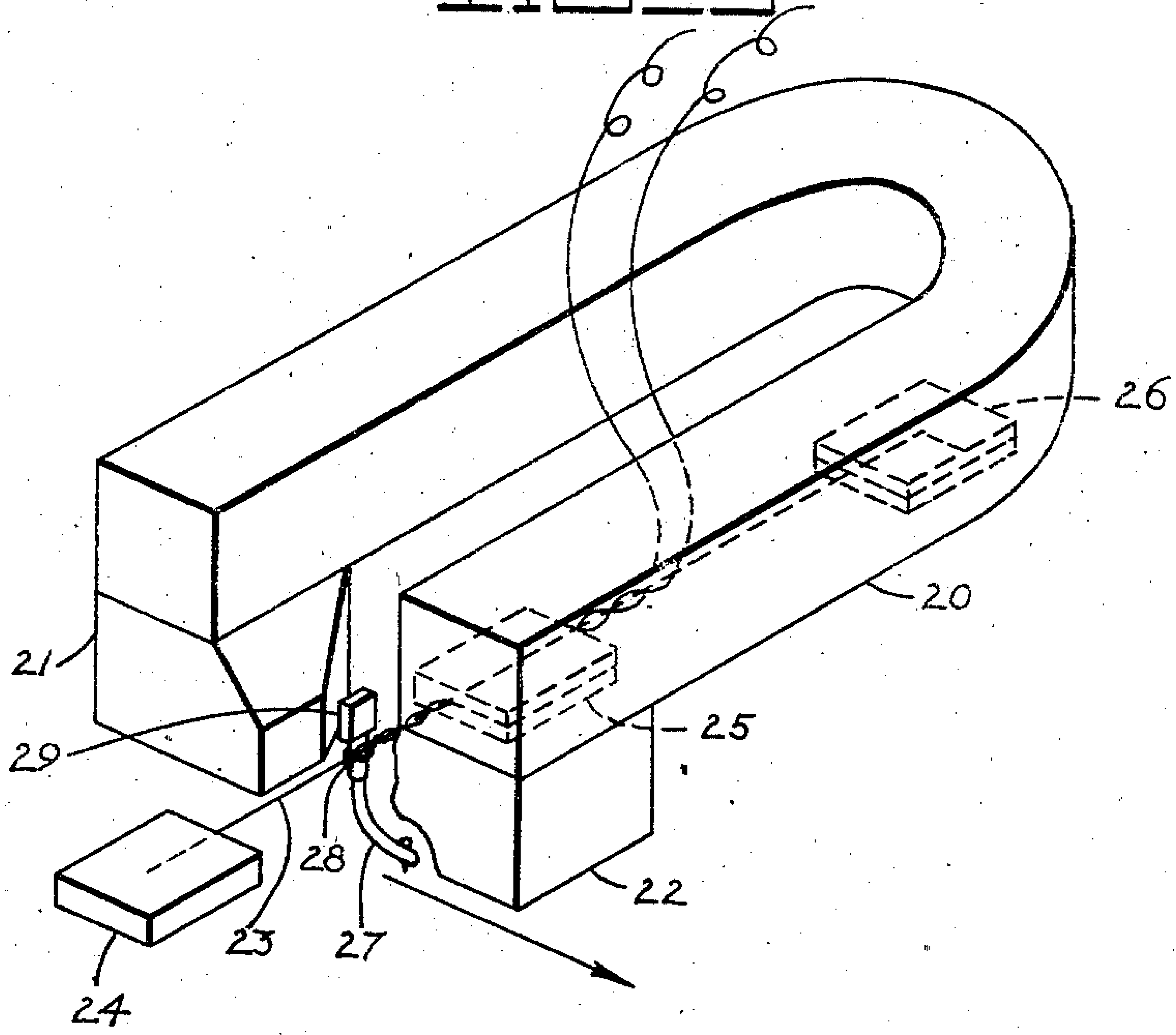

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FIG. 4

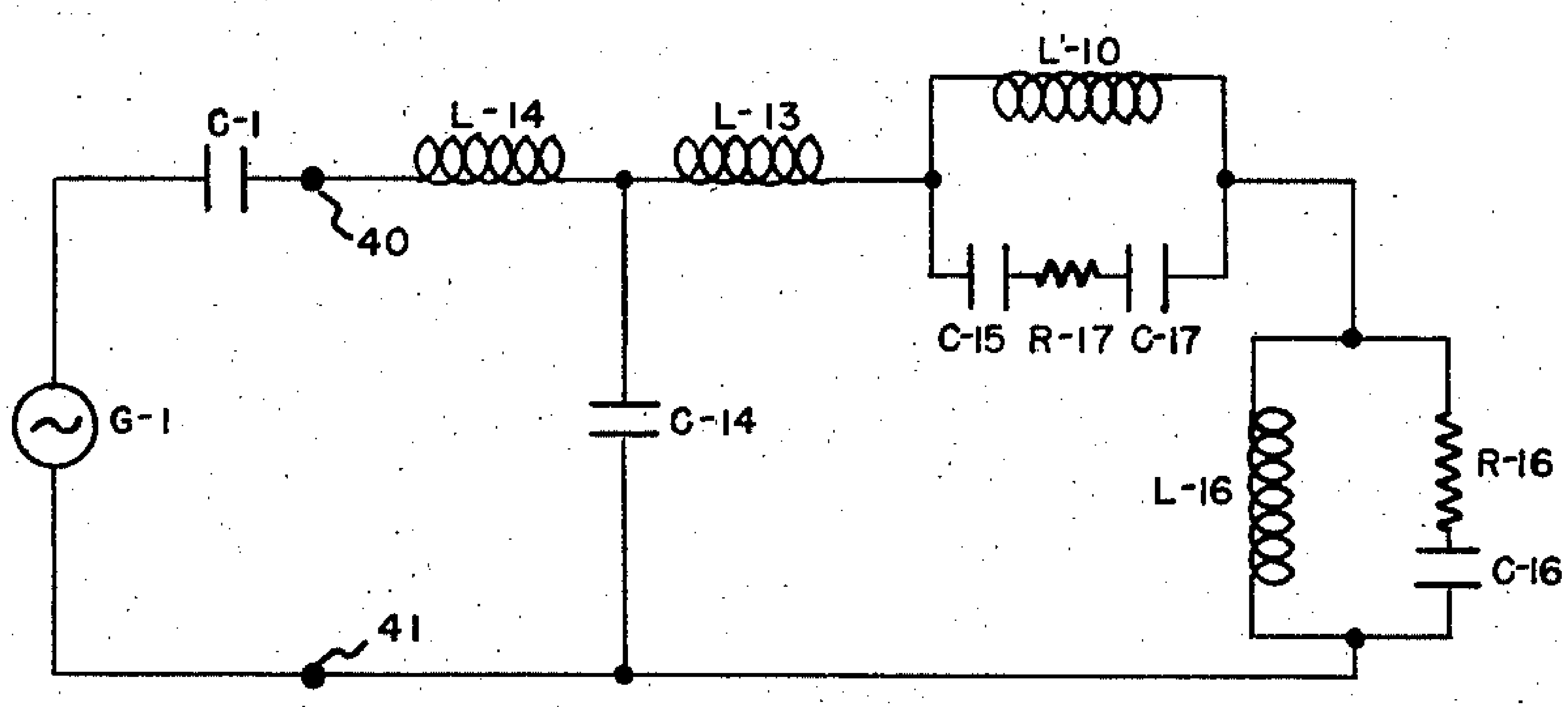
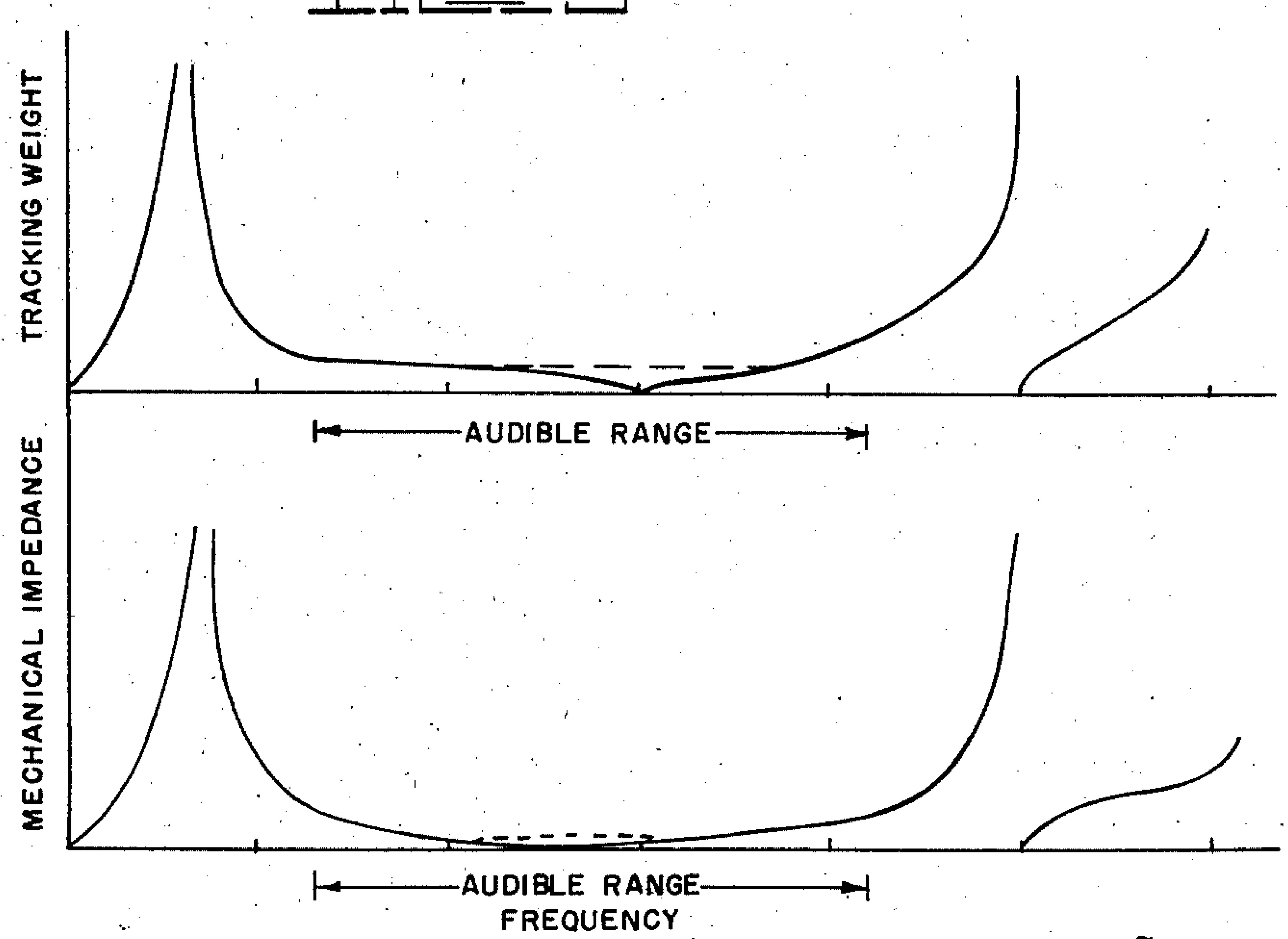


FIG. 5



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PHONOGRAPH REPRODUCER

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Application August 25, 1943, Serial No. 499,921

7 Claims. (Cl. 179—100.41)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

This invention relates to phonograph reproducers or pick-ups, and it is particularly directed to a new type of dynamic reproducer.

Dynamic type reproducers may be described as those which develop an E. M. F. corresponding to the variations in the recording being reproduced, by movement of a coil in a magnetic field. They all contain the fundamental elements consisting of a needle or stylus, one end of which "tracks" in the groove of the recording, a magnet for producing the necessary magnetic field, and a coil mechanically associated with the stylus and lying in the magnetic field. Usually the coil is directly fastened to a rigid member, or form, which, in turn, serves as a holder for the stylus. The arrangement is such that motion of the stylus ordinarily causes the coil to move back and forth across the magnetic field. The construction of high fidelity, rugged, dynamic reproducers requires a careful balancing of more or less opposing factors, with the result that elaborate and expensive designs have been developed for high quality reproduction.

The factors involved are essentially mechanical. It is necessary that the stylus have some kind of supporting system which will permit its deflection without too much reaction, or stiffness. Similarly, the moving parts should not be too massive or excessive record wear and poor reproduction results, and particularly the moving assembly must not have a resonance frequency within the audible range being reproduced. Since mechanical systems having resonant frequencies below the audible range are so massive as to be useless for reproduction of high frequencies, it is necessary to design the system so that any resonant frequencies fall outside the upper limit, or at least above 10,000 cycles per second, if high fidelity is desired. This generally requires small mass and a proportionately large restoring force, thus necessitating a relatively high stiffness "coefficient" or amount of restoring force per unit displacement of the stylus. As with a large moving mass, a high stiffness coefficient, or response, causes excessive record wear and increases the difficulty of having the stylus track properly in the groove.

It is an object of the invention to provide a reproducer of the dynamic, or moving coil, type which is of simple construction and yet rugged.

Another object includes the provision of a dynamic reproducer which is relatively inexpensive to build but which has unusual fidelity.

Another object is to provide a reproducer which has a substantially flat response curve over a wide frequency range coupled with low point pressure and a low stiffness response.

Another object is to provide a lateral reproducer, or one capable of responding to recordings of the lateral deflection type.

Another object is to provide a vertical reproducer, or one capable of responding to recordings of the vertical deflection type.

Other objects will be apparent from the following description, having reference to the accompanying drawing, in which:

Fig. 1 is a view of a lateral reproducer made in accordance with the invention;

Fig. 2 is a detailed view of the coil 13, stylus 14, wire 15, and damper 16 of Fig. 1;

Fig. 3 is a view of a vertical reproducer made in accordance with the invention;

Figure 4 is an explanatory diagram showing the electrical equivalent circuit of the reproducer shown in either Figure 1 or Figure 3; and

Figure 5 is an impedance diagram for the circuit of Figure 4 showing its response to frequencies in the audible range.

Briefly the reproducers of this invention comprise a magnet, a moving coil positioned in the field of the magnet and a thin, flexible wire which provides the support for the coil and the stylus.

Referring to Fig. 1, a permanent magnet 10, which may conveniently be made of Alnico or any hard steel, is provided with soft iron pole pieces 11 and 12 which are designed to concentrate the field around a pick-up coil 13. A stylus 14 is rigidly fastened to a wire 15, on top of which a rubber anti-resonant damper 16 may be fastened. The coil 13 is wound around the upper part of the stylus 14 where it is joined to the wire 15, and the damper 16 is cemented on top of the stylus and coil (see Fig. 2 for detail). The wire 15 is supported by means of elastic bearings 17 and 18 which may be of rubber and are perforated to receive the wire 15. The means for holding the rubber bearings is not shown in order to avoid confusion in the drawing, inasmuch as such means are obvious and conventional in style. The wire 15 extends through the bearing 18 and into an elastic clamp 19 where the wire 15 is bent at an angle so that the clamp 19 (which may also be of rubber) will prevent it from turning. Thus, lateral motion of the stylus 14 rotates the coil 13 in the magnetic field against the torsional reaction of the wire 15 as the latter is twisted. The leads from the coil 13 may be conveniently threaded through the bearing 18 before being removed for connection to the associated amplifying apparatus.

Since there is a practical limit to the minimum size that the stylus may be made and still possess sufficient stiffness to keep from bending, the moving or vibrating assembly consisting of the wire 15, stylus 14 and the coil 13 will have a high stiffness response if it is designed to have a natural resonant frequency above audibility. This problem is overcome in the present invention by designing the vibrating assembly to have a natural resonance at about 3000 cycles per second and to damp out the resonance by means of an anti-resonant damper, such as the elastic, or rubber, member 16. The assembly may be designed for resonance at other frequencies than about 3000 (with corresponding changes in the damper), but it has been found that optimum dimensions of the various parts determine the resonant frequency in the neighborhood of 3000 cycles per second. Convenient dimensions for such an assembly are: wire support, steel piano wire .018 to .021 inch diameter and 1.5 to 2.0 inches long exclusive of the right angle leg; stylus .035 to .045 inch in diameter and about 0.28 inch long. Best results are obtained when these dimensions are correlated to give a resonant frequency of about 3000 cycles per second, with which design a rubber damper consisting of a piece 0.94 x 0.94 x 0.063 inch may be used. The stylus is fastened, such as by soldering, about 0.25 inch from the free end of the wire. The coil may, for example, consist of about 30 turns of No. 40 silk covered wire. Although a steel piano wire is mentioned for the support, any spring metal or alloy may be used, such as brass or Phosphor bronze.

The lateral reproducer shown in Fig. 1 is easily converted to the vertical type, as is shown in Fig. 3. In Fig. 3 a magnet 20 has pole pieces 21 and 22 fastened to the sides thereof, although the construction shown in Fig. 1 can be used. A wire support 23 is mounted in rubber bearings 24 and 25 and clamped in a rubber clamp 26 all in the identical manner described with reference to Fig. 1. A stylus 27 is fastened to the wire 23, a coil 28 is wound around the end of the stylus 27 and a damper 29 is fastened on top similar to the arrangement of Fig. 2. However the damper 29 may be omitted except under the most exacting requirements because the weight of the reproducer is, at least in part, supported by the stylus 27, and this weight ordinarily causes sufficient torsional deflection of the wire 23 to damp out resonant vibrations in the audible range. The stylus 27 is curved at right angles to the wire 23 so that vertical motion of the end of the stylus as it follows the recording will cause the desired torsional displacement of the wire 23 and rotation of the coil 28, as already described.

In mounting, the lateral reproducer shown in Fig. 1 is positioned so that the wire 15 is parallel to a tangent to the record groove at the point of stylus contact, and the vertical reproducer is positioned so that the wire 23 is parallel to a normal to the record groove at the point of stylus contact (i. e., at right angles to the direction of record travel).

As already described, the best fidelity is obtained when the stylus, coil and wire assembly will not resonate within the audible range of frequencies, and that high stiffness response, which is present in those systems whose resonant frequencies are very high, is obviated in this invention by damping out the resonant frequency of a system which will otherwise resonate within the audible range. In the lateral reproducer shown in Fig. 1 the point pressure of the stylus was reduced as low as 10 grams and the stiffness response was as low as 0.5 gram per mil deflection, while maintaining high fidelity (e. g., substantially flat response from 30 to about 13,000 cycles per second). With the vertical reproducer shown in Fig. 3 the stylus pressure was approximately 20 grams and the stiffness response the same as in the lateral reproducer. The elastic damper and the clamp and bearings may be made of any elastic material in addition to rubber, such as synthetic rubbers, plasticized synthetic resins and the like. The point of the stylus should be of the long wearing type, such as sapphire or other hard substance, as is well known and practiced in the art.

In Figure 4 there is shown by way of further detailed explanation of the principle of my invention an electrical circuit which is the equivalent of the reproducers shown in Figures 1 and 3. Before pointing out the analogy between the electrical circuit shown in Figure 4 and the reproducers shown in Figures 1 and 3, appropriate analogies should be made between mechanical and electrical properties. It is accepted that in mechanics mass occupies the same status as does inductance in electricity; the reciprocal of stiffness in mechanics is similarly analogous to capacitance in electricity and, for many purposes, this reciprocal is called compliance; friction in mechanics is closely analogous to electrical resistance. A detailed discussion of such relationships can be found in the book "Dynamical Analogies," by Harry F. Olson published in 1943 by D. Van Nostrand Company, Inc.

The diagram constituting Figure 4 includes as circuit elements a current generator G—1 and compliance C—1 before the terminals 40 and 41 of the generator are reached. Generator G—1 is a "constant current generator" or one having a high internal impedance because C—1, the compliance of the record, is low. The network beyond terminals 40 and 41 is composed of circuit elements corresponding to the mechanical properties of the various parts of the reproducers shown in Figures 1 and 3. For purposes of clarity, the numeral designations of Figure 1 were adopted in Figure 4 to designate the circuit elements corresponding to the appropriate part. When the mechanical part is equivalent to an inductance the numeral is preceded by an L; when it corresponds to a capacitance (or compliance) it is preceded by a C; and when it corresponds to a resistance, it is preceded by an R. In most cases the mechanical parts have inductive, capacitive and resistive components.

Looking into the network from the terminals 40 and 41, a low impedance is seen inasmuch as the relative values of the circuit elements are set to produce such a response. Accordingly, L—14, the mass of the needle, is low; L—13, the mass of the coil, is low; L—10, the mass of the arm is high as compared with L—13 and L—14; L—16, the mass of the anti-resonant damper, has a value necessary to produce resonance in the parallel circuit of which it forms a part. The several compliances are likewise of various values, namely, C—1, the compliance of a record which the needle or stylus 14 traverses, is low; C—14, the compliance of the needle is very low; C—15, the compliance of the mounting wire is comparatively high; C—17, the compliance of the bearings is also comparatively high; C—16, the compliance of the anti-resonant damper, has a value necessary to produce resonance with the other circuit elements in the parallel circuit of which it is a part. The resistive components of the several impedances have values determined by the corresponding mechanical parts, namely, R—16, the resistive component of the impedance of the anti-resonant damper is not very high and depends to a considerable degree on the nature of the material used; R—17, the resistive component of the bearing impedance is also not very high and depends to a great extent on the nature of the material used.

The response of a record to a stylus and of this network to frequencies from 15 cycles per second to 25,000 cycles per second, a very generous audible range, is sketched in the explanatory graphs shown in Figure 5. In the upper portion of Figure 5, tracking weight is plotted against frequency. Tracking weight is the minimum weight necessary to insure that the ball tip of the stylus will at all times be in contact with the sidewalls of the record groove. Tracking weight is a direct function of the mechanical impedance of the reproducer. Since the sidewalls of a record groove are at an angle of approximately 45°, the stylus experiences a vertical component as well as a lateral component. The downward force due to tracking weight must be great enough to overcome this vertical component.

Referring to the lower portion of Figure 5 where the mechanical impedance of the reproducer of my invention is plotted against frequency, the rise in impedance at low frequencies is due to resonance between L—10, C—15 and C—17. The drop of the impedance at about 1000 cycles is due to resonance between L—13, L—14, C—15 and C—17. In order to prevent such an occurrence, the anti-resonant damper is made part of the system and its effect is shown in dotted lines in the graphs of Figure 5. In other words, the impedance of the network is kept from dropping to zero by resonance between L—16 and C—16 which resonance occurs at the same frequency as that between L—13, L—14, C—15 and C—17. At high frequencies, the sharp increase in impedance is due to resonance between L—13 and C—14. Immediately following this the impedance of the network drops to zero due to resonance between L—14 and C—14. Beyond this point, which is well above the audible range, the impedance increases due to reactance of L—14. Thus, it is evident from the above discussion that the reproducer of my invention presents a low, relatively uniform impedance throughout the audible range.

The record, owing to the small value of record compliance C—1 (mechanically, high stiffness), acts as a constant current generator. Speaking in mechanical terms, then, since the stiffness of the record is high the displacement of the pickup element will be constant. In terms of the electrical equivalent circuit, since the impedance looking into the pickup unit is low compared to the impedance of the generator, the output current of the generator will be constant.

Electrically, the record acts as a generator which would be damaged if the terminal voltage were allowed to rise. It is therefore apparent that the impedance looking into the load, i. e., the pickup, must be low if the goal of low generator wear, i. e., low record wear, is to be attained. The voltage developed across the terminals of the generator is analogous to the force acting on the wall of the record groove.

Many variations will be apparent to those skilled in the art, and the invention should not be limited other than as defined by the appended claims.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

I claim:

1. A phonograph reproducer of the dynamic type which comprises a magnet producing a constant magnetic field, a stylus, a thin, flexible supporting wire, means securing said stylus to said wire, a coil mounted on said stylus in symmetrical relation with respect to said wire, means mounting said wire to position said coil in said field and means securing one end of said wire against substantial rotational movement whereby deflection of said stylus produces torsional displacement of said wire and rotational displacement of said coil with respect to said field.

2. A phonograph reproducer of the dynamic type comprising a magnet, a stylus adapted to follow the groove of a recording, a coil mounted in such relation to said stylus that deflection of the stylus produces corresponding displacement of the coil, an anti-resonant damper with said coil proportioned to suppress mechanical resonance of parts in the audible frequency range, a torque-responsive supporting member forming a pivotal support for said stylus, damper and coil, said torque-responsive member being resiliently mounted in resilient bearings in such relation to said magnet that the coil is positioned in the field of said magnet and is rotationally displaced in said magnetic field by deflections of the stylus which produce torsional displacements of the supporting member which are quickly corrected by the elastic response of the resilient bearings.

3. A lateral phonograph reproducer of the dynamic type which comprises a magnet for producing a constant magnetic field, a stylus subject to lateral deflection, a thin, flexible wire, means securing said stylus to said wire, a coil mounted on said stylus in symmetrical relation with respect to said wire, means securing one end of said wire against substantial rotational movement and means mounting said wire with respect to said magnet to position said coil in said field whereby lateral deflection of said stylus produces torsional displacement of said wire and rotational displacement of said coil with respect to said field.

4. A lateral phonograph reproducer of the dynamic type which comprises a magnet, a stylus adapted to follow the groove of a recording, a coil mounted in such relation to said stylus that deflection of the stylus produces corresponding displacement of the coil, an anti-resonant damper mounted adjacent to said coil and of size to suppress resonance of said stylus and coil within the audible range of frequencies, a torque-responsive supporting member forming a pivotal support for said stylus, said supporting member being resiliently mounted in elastic bearings in such relation to said magnet that said coil lies within the field of said magnet and so that said support is substantially parallel to a tangent to the record groove at the point of contact of the record and stylus in order that lateral deflection of said stylus will produce rotational movement of said coil in said magnetic field and torsional displacement of said support.

5. A vertical phonograph reproducer of the dynamic type which comprises a magnet for producing a constant magnetic field, a stylus subject

to vertical deflection, a thin, flexible wire, means securing said stylus to said wire, a coil mounted on said stylus in symmetrical relation with respect to said wire, means securing one end of said wire against substantial rotational movement and means mounting said wire with respect to said magnet to position said coil in said field whereby vertical deflection of said stylus produces torsional displacement of said wire and rotational displacement of said coil with respect to said field.

6. A vertical phonograph reproducer of the dynamic type comprising a magnet, a stylus adapted to follow the groove of a recording, a coil mounted in such relation to said stylus that deflection of the stylus produces corresponding displacement of the coil, an anti-resonant damper mounted adjacent to said coil and of a size to suppress resonance of said stylus and coil within the range of reproduced frequencies, a torque responsive supporting member mounted in elastic bearings to form a pivotal support for said stylus, coil and damper, said support being positioned so that said coil lies within the field of said magnet and so that said support is substantially parallel to a normal to the record groove at the point of contact of the record and stylus so that deflection of said stylus produces torsional displacement of said

support and rotational displacement of said coil.

7. A vertical phonograph reproducer of the dynamic type comprising a magnet for producing a constant magnetic field, a stylus subject to vertical displacement, a torque-responsive member pivotally supporting said stylus, a coil mounted on said stylus in symmetrical relation with respect to said pivoted support, and resilient means mounting said torque-responsive support in such relation with respect to said magnet to position said coil within said magnetic field whereby vertical displacement of said stylus produces torsional displacement of said support and rotational displacement of said coil with respect to said field.

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