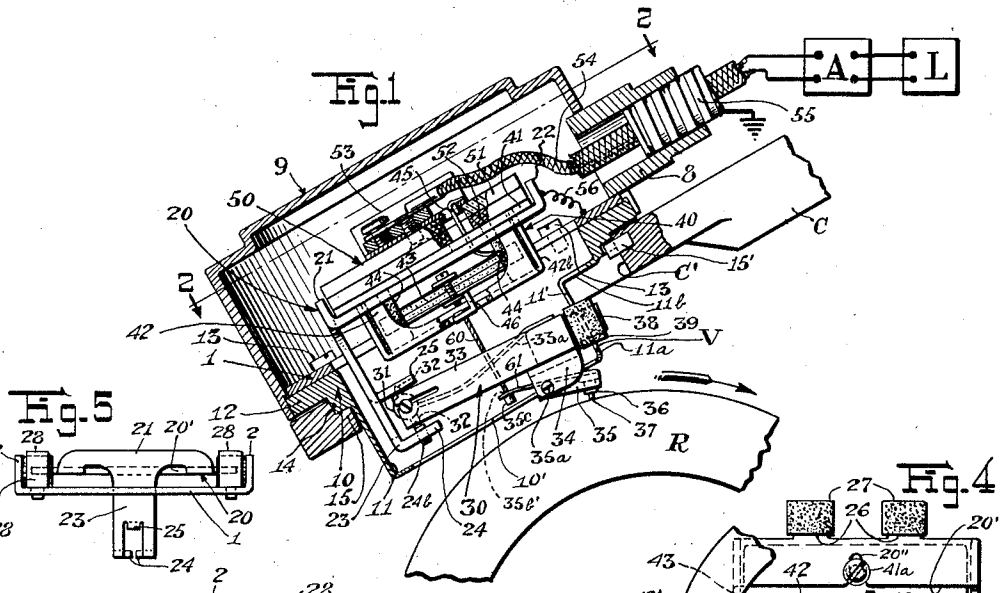
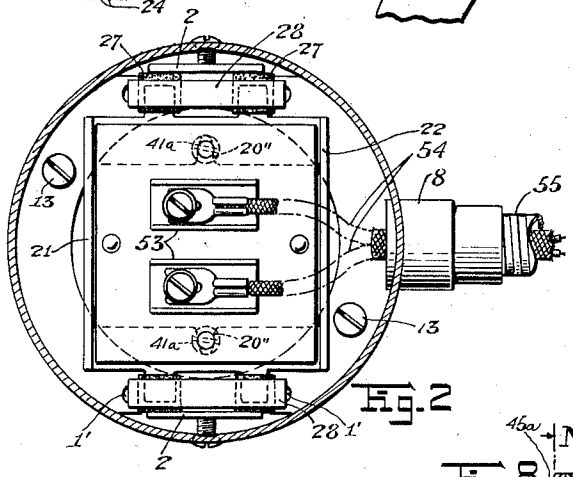
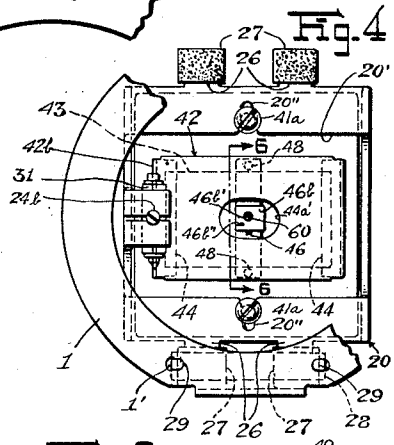
Dec. 31, 1940. M. J. DI TORO 2,227,072

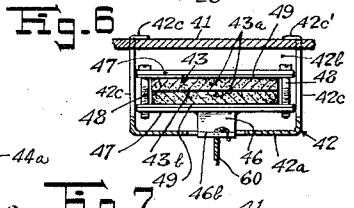
ELECTROMECHANICAL TRANSLATING DEVICE

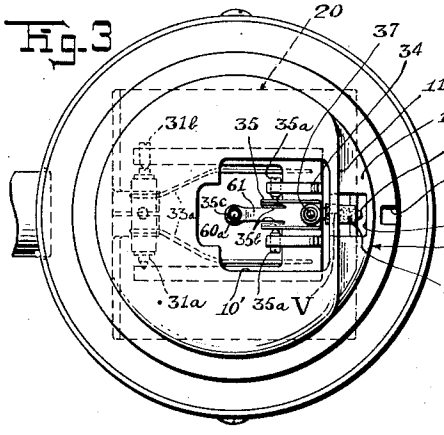
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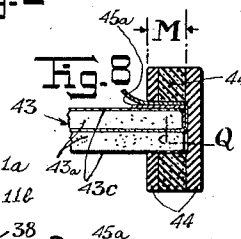


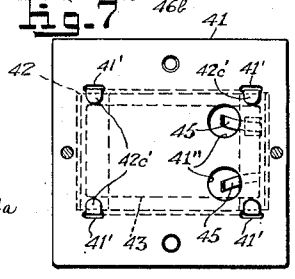


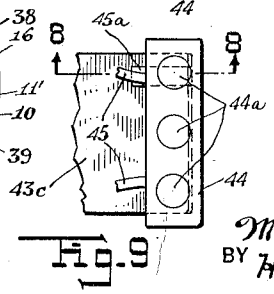












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UNITED STATES PATENT OFFICE

2,227,072

ELECTROMECHANICAL TRANSLATING DEVICE

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Application October 20, 1937, Serial No. 169,944

11 Claims. (Cl. 179—100.41)

This invention relates to electromechanical translating devices, and in its more important aspects to such devices wherein there is employed a translating unit adapted upon bending to generate an electrical voltage, and vice versa.

While not in all aspects limited thereto, the invention has particular utility, and has been illustrated and described, in connection with a phonographic reproducer or pick-up for the creation of electric oscillations corresponding with mechanical oscillations recorded upon a record.

It is an object of the invention to increase the efficiency of a translating device of the character described.

It is an object to increase the frequency range of response of such a translating device without impairment of its efficiency.

It is an object to provide improved and simplified means for controlling the response-frequency characteristic of such a device.

It is another object to provide mounting means for the translating unit of generally improved and simplified nature.

It is another object to provide mounting means for the translating unit of suitable characteristics to fulfil the objects above stated.

It is another object to introduce damping into the device in a novel, effective and simple manner.

It is another object to employ effectively for damping purposes highly viscous materials which have a tendency to "cold-flow."

It is another object to provide an improved translating system whose mechanical and electrical parameters are appropriately related to each other for good efficiency and response-frequency characteristic.

It is another object to provide, for co-operation with a record, an improved translating device characterized by good efficiency and response-frequency characteristic and yet by small tendency to wear the record.

It is another object to provide an improved and simplified construction for a phonographic pick-up.

It is another object to provide a particularly effective and simple means for adjusting the pick-up for proper "tracking" of the record by the stylus.

It is another object to provide an improved stylus arm construction for a phonographic pick-up.

Other and allied objects will more fully appear from the following description and the appended claims.

In the description of my invention, hereinafter set forth, reference is had to the accompanying drawing, of which:

Figure 1 is a vertical view, elevational as to interior and sectional as to exterior portions, of a translating device according to my invention, this having been shown as a phonographic reproducer or pick-up;

Figure 2 is a cross-sectional view taken along the line 2—2 of Figure 1;

Figure 3 is a bottom view of the translating device of Figure 1;

Figure 4 is a fractional bottom view of the same device, but with the bottom cover and the stylus assembly, hereinafter described, removed for the better illustration of other components;

Figure 5 is a front elevational view of the device, but with the same omissions made as from Figure 4 and additionally with the translating unit assembly, hereinafter described, removed;

Figure 6 is a vertical cross-sectional view, taken generally along the line 6—6 of Figure 4, of the translating unit assembly;

Figure 7 is a top view of the same assembly;

Figure 8 is a vertical cross-sectional view of the end of the translating unit and of the therewith associated end cap; and

Figure 9 is a top of plan view of the same subject matter, Figure 8 having been taken along the line 8—8 of Figure 9.

A complete phonographic reproducer or pick-up embodying my invention has been illustrated in the accompanying drawing, and may be generally described as comprising an approximately washer- or ring-shaped member 1 to which the other parts are assembled; top cover 9 and flanged bottom cover 10 finally secured to the ring member 1; a cradle 20 resiliently clamped to the ring member 1; a stylus system 30 pivotally supported to the cradle 20; a translating unit assembly 40 carried by the cradle 20 and vibrationally coupled with the stylus; and a terminal board assembly 50 secured to the translating unit assembly 40.

The bottom cover 10 comprises a generally cup-shaped central portion 11, and a washer- or ring-shaped flange 12 extending outwardly from 11 and forming the portion immediately secured to the ring member 1 (as by screws 13); in the angle formed between 11 and 12 there may be provided an annular shoulder 14. When in use the reproducer may be carried on a carriage C, the central bottom cover portion 11 extending downwardly through a circular aperture C' in the

carriage toward a record R therebeneath, the shoulder 14 fitting against a shoulder 15 formed in the aperture C', and a pin 15' in the carriage engaging a slot 16 in the shoulder 14 to maintain the reproducer in fixed orientation in the aperture C'. The record R has been fractionally illustrated in Figure 1 as a cylindrical record arranged for rotation, for example in the direction of the arrow; and it will be understood that the carriage C may be arranged for slow movement, in a direction transverse of the record rotation direction and by means not herein necessary to show, simultaneous with the rotation of the record—thereby keeping constant the relationship of the carriage C to a progressive spiral groove of oscillatorily varying depth already formed in the record as a recording of oscillations to be reproduced.

Attention is now conveniently directed to the cradle 20, to which the operative portions (e. g., stylus system 30 and translating unit assembly 40) are secured. This cradle consists in general of a flat rectangle having up-turned front and back edge portions 21 and 22 respectively, and provided with a large rectangular central aperture 20' extending from one such edge portion to the other. A standard 23 extends downwardly from the center of the front edge portion 21, being folded rearwardly at its bottom extremity to form the bottom lug 24, and having a central portion folded rearwardly at an intermediate point to form the higher lug 25; between these lugs is pivoted the stylus system 30 as hereinafter more fully appears. At each of its side-to-side extremities the cradle 20 is provided with two tabs or extensions 26; these are encircled by relatively thick bands 27 of rubber, which slightly overhang the extremities of the extensions 26. The pairs of rubber bands 27 at each cradle extremity are lightly clamped against the top of ring member 1 by inverted U-shaped strips 28, which have small terminal ears 29 passed through holes 1' in ring member 1 and folded over against the bottom of the latter; a lug 2 is up-turned from the ring member 1 against the extremities of each pair of the rubber bands 27. It will be understood that by this arrangement the cradle 20 is supported to the ring member 1 while being vibrationally insulated therefrom.

The stylus system 30 comprises a generally horizontal shaft 31 provided with central vertical pivot points 32, one of which engages the higher lug 25 abovementioned and the other of which engages an adjustable bearing 24b provided in the bottom lug 24; a U-shaped generally horizontal weight 33 pivoted near its extremities to the ends of shaft 31 (as by horizontal pivot 31a and adjustable horizontal pivot 31b) and extending therefrom rearwardly; an inverted short channel member 34 secured to the bottom of the weight 33 in the central portion of the latter removed from its pivoting points; a small and light stylus arm 35 of inverted channel form, pivoted as at 35a near its forward extremity between the sides of the channel member 34; and a stylus holder 36, secured to and down-hanging from the bottom of the stylus arm 35 near the rearward extremity of the latter, and carrying the stylus 37 at its own bottom extremity. It will be understood that by virtue of the double pivoting (at 32 and at 31a—31b) the weight 33 is freely movable both up and down and from side to side—while by virtue of the pivoting of the stylus arm 35 to the weight 33 (at 35a) the stylus 37 is in turn freely movable up and down with respect to the weight 33. A suitable aperture 10' in the bottom cover 10 permits the downward extension therethrough of the channel member 34 and the stylus arm and holder 35 and 36 and stylus 37. To limit the downward and side-to-side movements of the weight 33, the otherwise cylindrical wall of the bottom cover portion 11 is provided at the rear with a vertical plane portion 11a, joined to the flange 12 by a horizontal plane portion 11b; a central aperture 11' is provided in 11a—11b; and through this aperture is extended a fin 38 secured to the center of the rearward extremity of weight 33. The fin 38 is encircled by a rubber band 39 to cushion any impingement on the side or bottom edges of aperture 11', which aperture is of course made wide enough to allow a considerable range of side-to-side and of downward weight movement. The bottom of aperture 11' may be V-shaped, as indicated by the apex V in Figure 3, so as to centralize fin 38 and hence the stylus system when the fin rests on that bottom (i. e., when the carriage C is raised as hereinafter mentioned).

The translating unit assembly 40 comprises a rectangular plate or base 41 resting on the cradle 20 and fitting between the front and back edges 21—22 of the latter for linear side-to-side movement with respect to the cradle; an inverted box-like housing 42 secured to the bottom of the base 41 and down-hanging therefrom through the oversize aperture 20' in the cradle; and a translating unit 43 (hereinafter more fully described) within the housing 42, the unit 43 having rubber caps 44 fitted about its ends and clamped between the bottom 42a of the housing 42 and the base 41. The ends 42b and the sides 42c of the housing may be folded over from the housing bottom 42a; while those ends 42b are shown as solid and as terminating in impingement against the bottom of base 41, those sides 42c are shown as partially cut away to terminate in four small ears 42c' passing through respective small holes 41' in base 41 and folded over against the top of the latter to secure the housing thereto. The coupling of the translating unit to the stylus system is hereinafter described.

The terminal board assembly 50 may comprise a block of Bakelite or the like 51; suitable terminals 53 for the device carried on top of block 51; and a block of Bakelite or the like 52, recessed to fit over the ears 42c' abovementioned and so to lie in close contact against the top of the translating unit assembly base 41, through which block 52 the block 51 is secured to the base 41. Output leads 45 from the translating unit may pass upwardly, through large holes 41'' in base 41 and through smaller holes aligned therewith in the Bakelite blocks, to connect respectively with the terminals 53. Through a bushing 8 in the top cover 9 flexible conductors 54 may pass outwardly from terminals 53 to a circuit wherein the electric oscillations translated by the device from the record R are utilized—for example, to a tandemed amplifier and loud-speaker schematically shown as A and L, respectively. Grounded shielding 55 may surround these leads, if desired; the electrical contacting by this shielding of bushing 8, and therethrough the top cover 9, bottom cover 10, and ring member 1, may serve to establish all those parts at ground potential. To establish at a similar potential the cradle 20 and the metallic components thereto

secured, I have shown between the cradle and ring member 1 a flexible conductor 56 (Figure 1).

The translating unit 43 is preferably in the form of a piezo electric bending unit of the type comprising a plurality of thin piezo-electric crystal slabs equipped with appropriate electrodes, the several such slabs being held together (as by cementing) and the electrodes being so interconnected that upon bending of the unit (i. e., effective lengthening of some and shortening of other of the slabs) mutually aiding potentials will be developed by the several interconnected electrodes. Such translating devices, sometimes referred to as of "bi-morph" type, are of course in themselves known, having been disclosed for example in United States Patent No. 1,802,782 (and its Reissue No. 20,213) to C. B. Sawyer. As illustrated in the accompanying drawing, the unit 43 comprises the two crystal slabs 43*a*, the central foil electrode 43*b* cemented to both, and the outer (top and bottom) foil electrodes 43*c* connected together; the entire unit is desirably coated with a slightly flexible Bakelite (phenol-resin) varnish. As I prefer to employ the unit, it is arranged as a "clamped-clamped" beam—i. e., is clamped at both ends (through the rubber caps 44 abovementioned)—and is provided at its center with a connector 46 for a means (hereinafter described) coupling it with the stylus system. The connector 46 may be a small and light L-shaped bracket secured to and down-hanging from the center of the bottom one of a pair of light metal strips 47, which strips are clamped against the bottom and top, respectively, of the unit 43 by screws 48 disposed on each side of the unit (fibre or other thin padding strips 49 being preferably provided between each strip 43 and the unit for the avoidance of metallic contact to the unit).

The means coupling the translating unit 43 with the stylus system 30 is a fibre or other cord 60 terminally secured to the horizontal portion 46*b* of the connector 46 abovementioned, passing through an oversize aperture 44*a*′ in the bottom of the housing 44, and terminally secured at its other extremity to a small spring 61 extending forwardly from the stylus arm 35 and hereinafter more particularly described. To insure an absence of side-strain from its pull on each of the components to which it is terminally secured, the cord 60 is passed through a respective hole (46*b*′ and 35*b*′) in each and appropriately secured beyond that hole. Thus after passage downwardly through the hole 35*b*′ the cord 60 may be provided with a knot 60*a* larger than that hole, and retained (preferably with wax) within a light and small protecting cylinder 35*c* secured to and down-hanging from the extremity of spring 61; while after passage upwardly through the hole 46*b*′ the cord 60 may be folded over and crimped in a small slot 46*b*″ in the connector portion 46*b*. It will be understood that the inertness of the coupling cord 60 is of great value in avoiding unwanted resonance effects and tendencies to rattle, both of which characterize so many forms of coupling media which might be employed between the translating unit and the stylus system.

A particularly convenient manner of providing the coupling spring 61, secured to and extending forwardly from the stylus arm 35, is the simple extension in that direction of the base portion only of the channel cross-section of that arm; the spring 61 has been illustrated in the drawing as so formed. The compliance requirements for the spring 61, hereinafter discussed, may be higher than are readily met by this mere extension unless it be carried to an undue length; in such case it is convenient to obtain the necessary compliance by slotting the base portion of the arm 35 for a distance forwardly from its rear extremity, as has been illustrated by the slots 35*b* on either side of the rearward portion of spring 61.

When the device is out of use the carriage C may be raised from the position in which it is shown in Figure 1; the weight 33 will then be in the lowest position permitted by fin 33 and aperture 11′ (and consequently centralized from side to side), and the cord 60 will form a very obtuse angle with the spring 61 and stylus arm 35. When the device is to be placed in operation the carriage will be lowered to such a position as the illustrated one; in the lowering operation there will first occur a contacting of stylus 37 with the record R, and thereafter a reduction of the abovementioned angle, for example to the only slightly obtuse value illustrated in Figure 1. The weight 33 will then operate as a means for biasing the stylus against the record R and for keeping the coupling cord 60 and spring 61 under tension. This action of the weight 33 may be supplemented by spring means such as a pair of springs 33*a* terminally secured in the horizontal shaft 31 and extending to bear lightly downwardly on the central portion of the weight 33; this has been found desirable in that it avoids excessive weight values and consequent undue inertia effects. The supplemental spring action also has a special advantage when the normal direction of the weight extension from its pivots is, as illustrated, somewhat upward: Thus when a thick record R, with consequent high surface, is presented to the stylus 37, the weight 33 becomes more nearly vertically directed, and consequently less effective in producing bias of the stylus against the record; on the other hand, the springs 33*a* are then displaced to a maximum from their normal position, and are consequently most effective in contributing to such bias—and vice versa, so that there is effected an automatic compensating action tending toward the maintenance of a constant bias.

It will be understood that as the record R is rotated, the stylus 37 will be held with constant average bias against the moving recorded groove therein; the oscillatory variations in the groove will cause corresponding oscillations of the stylus arm 35 about its pivoting point 35*a*—the inertia of the weight 33 precluding any appreciable loss of magnitude of these oscillations through up-and-down weight movement. Corresponding oscillatory variations or modulations will be caused in the tension applied through coupling spring 61 and cord 60 on the center of the translating unit 43. These modulations will cause the translating unit 43 to bend oscillatorily, thereby developing therein corresponding electric voltage oscillations, which are impressed by the conductors 54 onto the amplifier A—to be thereby amplified, as for translation into sound by the loudspeaker L.

It is convenient to assume, as a typical but of course non-limitative condition, that over the bulk of the range of frequencies recorded upon and to be reproduced from the record R the recordation has been effected substantially on a "constant velocity" basis—i. e., for different frequency oscillations which should be reproduced at mutually similar sound intensities and at similar electric voltage amplitudes across the con-

ductors 54, the product of frequency by the amplitude of undulation in the groove is constant. Generally speaking, the various mechanical components of the device herein described tend to cause such different frequency recorded oscillations to produce deflections of the translating unit 43 (i. e., of its center) approximately inversely proportional to frequency, and thus also of constant velocity (this action nicely lending itself, as hereinafter appears, to the production of approximately constant amplitude output voltages by such different frequency recorded oscillations). There are of course limitations on the range of frequencies throughout which this approximate action can be preserved, which limitations may become more and more severe as attempts are made to increase the efficiency of the device; furthermore even within that range there may be certain appreciable deviations from constancy of velocity of translating unit deflection. A manner in which there may be secured a favorably wide such range and at the same time good efficiency, as well as a reduction of deviations within the range to desirably low values, is hereinafter considered.

In the chain of components proceeding from the record R toward the output conductors 54 there is first seen the effective mass of the stylus 37 with its holder 36 and arm 35 together with coupling spring 61; this mass is made of as small a value as is consistent with ruggedness, and in most instances is subordinate to other parameters in its effect on performance. There is next seen the compliance of the coupling spring 61; the other compliances of the mechanical portion of the chain are in general of such a low magnitude as to present too high a mechanical impedance to the record for satisfactory record life, but by choice of a sufficient compliance for this spring 61 the impedance presented to the record (or mechanical input impedance to the device) is readily made as low as may be found desirable. Of course the choice of unnecessarily low values for the coupling spring compliance will be avoided, since the overall efficiency of the device tends to vary in inverse proportion therewith; in practical cases, however, the value of this compliance will many times overshadow the magnitudes of the other compliances. (It will of course be understood that the effective mass of the weight 33 will be great enough to resonate with the compliance of coupling spring 61 at a frequency below the lowest of the frequency range over which it is desired that the device operate.) It may here be pointed out that for satisfactorily low record wear the compliance of coupling spring 61 must be greater than the effective compliance of the record material (i. e., that compliance as seen at the spring 61), and this tends to fix the minimum usable value of this compliance, and the maximum efficiency of the device insofar as that is affected by this coupling spring compliance. With respect to record wear it may also be mentioned that a low value for the effective mass of the stylus and associated parts, abovementioned, is particularly desirable so that a minimum of biasing force against the record will be sufficient to give this mass an acceleration equal to the largest acceleration met by the stylus in the undulations in the record groove.

There is next seen the effective mass (I_c) of the translating unit 43, augmented by the masses of the coupling cord 60, of connector 46, of strips 47 and screws 48, etc. as localized masses at its center—these localized masses again being made as small as practicable. Then there is seen the compliance (C_c) of the translating unit. If the ends of the translating unit were immediately supported to a relatively massive member such as base 41 and/or housing 42 in any non-yielding manner which yet permitted proper bending of the unit, the mechanical portion of the chain of components would end with the unit compliance. The constancy of velocity of unit deflection would be preserved from very low frequency up to near the frequency (f_3) of resonance between the effective mass (augmented as abovementioned) and the compliance of the translating unit; at approximately this frequency the deflection would be exaggerated, or characterized by a resonant peak; and with increasing frequency therebeyond the deflection would fall off rapidly to negligible values, so that the peak just mentioned may be termed the "cut-off" peak. The frequency f_3 of this resonance, which would of course in this simple case approximately define the upper limit of the frequency range of useful mechanical action of the device (e. g., of substantially constant-velocity deflection), of course varies inversely with the square root of the compliance (C_c) of the translating unit. But the efficiency of the device varies directly with the square root of this compliance (for which reason the translating unit will of course be designed, in any particular case, to have the minimum practicable mass and the maximum compliance). These considerations clearly show that increased efficiency tends to be secured at the sacrifice of frequency range, and vice versa. By the structure according to the preferred form of my invention, however, there is provided a material extension of the frequency range without reduction of unit compliance and hence of efficiency, or an increase of unit compliance and efficiency without reduction of frequency range, or some of each of these benefits, as may be desired. It is to provide these benefits, as well as to serve other highly useful functions considered hereinbelow, that I resiliently clamp the translating unit, as in the rubber caps 44.

In view of the presence of the caps 44 the mechanical chain does not stop with the compliance of the translating unit 43, but continues so that beyond that compliance there is seen the effective mass (L_p) of the rubber caps 44, and finally the compressional compliance (C_p) of the caps (i. e., the compliance to up-and-down movement of the translating unit therein). While it is true that they lie beyond the translating unit whose deflection is the objective of the mechanical action, they nevertheless have a definite influence on that action through their coupling to that unit. This influence includes the production of an anti-resonant peak, or "valley," at approximately the frequency (f_2) of resonance of the effective mass (L_p) and the compressional compliance (C_p) of the caps 44; the production of a resonant peak at a somewhat lower frequency (f_1); and the shifting of the frequency of the cut-off peak abovementioned from its initial approximate frequency f_3 to a new frequency f_3', higher than either f_3 or f_2. The last of these effects will be understood to amount to an upward extension of the frequency range of useful mechanical action; and, since it has been obtained without reduction of the compliance C_c of the translating unit, it is achieved without a noticeable decrease in efficiency. If preferred, of course, the compliance C_c may be increased to increase the efficiency, the useful frequency range

extension provided by the resilient clamping of the translating unit (e. g., by the caps **44**) being utilized to offset the restriction of frequency range which would otherwise attend such compliance increase. It will be appreciated that there are practical limitations on the increases of frequency range or efficiency which may be effected in this manner, as a result of corresponding limitations on the physical realizability of various effective mass and compressional compliance values (L_p and C_p) for the rubber caps **44** or their equivalents; but an increase of either range or efficiency in the very significant ratio of 1.7:1 or 2:1 is readily possible in typical cases.

The relationships between the several frequencies abovementioned will be more exactly apparent from the following expressions for the several frequencies:

$$f_3=\frac{1}{2\pi\sqrt{L_cC_c}}$$

$$f_2=\frac{1}{2\pi\sqrt{L_pC_p}}$$

$$f_1=\frac{1}{2\pi\sqrt{L_pC_p}}\cdot\frac{1}{\sqrt{1+(L_c/L_p)+(L_cC_c/L_pC_p)}}$$

$$f_3'=\frac{1}{2\pi\sqrt{L_pC_p}}\cdot\sqrt{1+(C_p/C_c)+(L_pC_p/L_cC_c)}$$

or

$$f_3'=\frac{1}{2\pi\sqrt{L_cC_c}}\cdot\sqrt{1+(L_c/L_p)+(L_cC_c/L_pC_p)}$$

frequency of course being expressed in cycles per second, effective masses in grams, and compliances in centimeters per dyne. L_p will of course be understood for the illustrated structure to represent twice the effective mass of a single one of the caps **44**, and C_p to represent half the compressional compliance of a single one of the caps.

There may be pointed out the analogy of the mechanical chain to a tandemed series of three electrical circuits each comprising series inductance and shunt capacity, the three inductances and three capacities respectively corresponding to the three masses and the three compliances in the order in which they are seen as abovementioned.

For the limitation of the amplitude of the cut-off peak, and of the amplitudes of the other resonant and the anti-resonant peak abovementioned (i. e., for the "flattening" of the response-frequency characteristic over the frequency range up to and including the cut-off peak), there is desirable the introduction of mechanical resistance or damping into the mechanical chain. At least some slight mechanical resistance will normally characterize the rubber caps **44**, but frequently the use of a much greater resistance is desirable. For producing any desired resistance, within wide limits, I have found particularly effective the fitting, into the caps **44** or their equivalent, of inserts of highly viscous and permissibly little resilient material—such for example as the pliable cellulose nitrate currently sold under the trade name "Viscoloid." Thus in the device illustrated in the drawing I have shown, in a plurality of vertical holes passing through each of the caps **44** above and below the unit **43**, a respective plurality of inserts **44***a* of such material as just mentioned, each insert **44***a* being clamped between the unit **43** and either the bottom (**42***a*) or the top (base **41**) of the housing **42**, as the case may be. Such material is normally of little utility in compression because of its tendencies to "cold-flow," which action is likely to reduce and finally to eliminate its effectiveness; but by relying on resilient means for confining it laterally, such as the caps **44** inherently provide, this difficulty is obviated with no impairment whatever of effectiveness. It will readily be understood that the value of the mechanical resistance so provided may be regulated by the number and size of the inserts **44***a* employed, thereby securing for example almost any desired degree of flattening of the response-frequency characteristic.

It will be understood, of course, that I intend no limitation of my invention to the use of the device over the entire frequency range up to the cut-off peak at approximate frequency f_3'; it may in cases, for example, be desirable to use it only up to near the frequency f_1, or to some frequency between f_1 and f_2, in which cases there may be found sufficient considerably less resistance than would otherwise be desirable. The resilient or rubber cap clamping of the translating unit remains of particular utility for the introduction, as abovementioned, of such resistance as may be desired—and, independently of the use of the inserts **44***a* and of the range-extending effect, it forms an especially simple and effective means of mounting the translating unit, particularly when that is in the illustrated form of a "clamped-clamped" beam.

In view of its influences, above described, it is desirable that the compressional compliance C_p of the caps **44** be as uniformly maintained in the production of intendedly similar devices as are other compliances in the mechanical chain. It is a function among other things of the degree of compression in which the caps are placed, and hence of the height of the caps before their compression by housing **42** and of the height of the ends **42***b* of that housing; while the latter height may obviously be held fairly accurately, and while the caps may be molded for greatest approach to uniformity, some variations are practically unavoidable. It has been found that, when relatively low, the degree of compression markedly affects the compressional compliance, which decreases as that degree is raised; but that when that degree becomes sufficiently great, that compliance becomes substantially independent of quite wide variations therein—i. e., becomes substantially asymptotic with respect to degree of compression. I prefer to employ a sufficient degree of compression to cause this substantial independence of the compressional compliance from variations in the degree of compression, and I appropriately fix the relative heights in question.

It is desirable, in arranging the caps **44** for properly low compressional compliance C_c, at the same time to avoid rendering too low their torsional compliance (D_p)—i. e., that compliance which permits a simple "bowing" of the unit **43** (as seen in Figure 1) to extend without serious restraint to the extremities of the unit, or, in other words, which permits an angular deviation of the end portions of the unit from parallelism with base **41**. This is because any serious restraint upon that simple bowing causes the unit to bend or tend to bend in a more complicated configuration, with sign of curvature reversing between different longitudinal sections instead of remaining the same in all; this tends to cause the generation of mutually opposing voltages in the different such sections, with consequent reduction of net output voltage and efficiency. This torsional compliance D_p of the caps may be meas-

ured for a first (either) end of the unit with the other end free, as by applying a known force at a measured distance from the mid-point Q (see Figure 8) of the longitudinal extension M of the cap along that first end of the unit, and may be expressed from that measurement in the conventional units of radians of deflection per dyne of force per centimeter of distance of force application as abovementioned.

As an expression of the effect just described, it may be shown that the efficiency of the device is substantially directly proportional to

$$\frac{D_p}{D_p+(24C_c/N^2)}$$

wherein N is the length of the unit in centimeters, D_p representing the torsional compliance for the cap at either end of the unit. To maintain good efficiency I therefore make D_p at least equal to $24C_c/N^2$, and preferably equal to $48C_c/N^2$ or even greater. Latitude to do this without forcing the choice of an unwanted compressional compliance value C_p is afforded in the design of the caps by the fact that, while both compliances are substantially uniformly affected by other factors such as cap width and height and material and compression, C_p varies inversely with only the first power of the longitudinal extension M of the cap, but D_p varies inversely with the cube of that extension.

It will be understood that the use of the resilient clamping means for the translating unit in the form of caps **44**, while preferred, is not intended to be unnecessary limitative—as the extension of these means about the ends and sides of the unit serves the subordinate, though still useful, functions of determining the lateral position of the unit within the housing **42** (against the ends and sides of which the caps **44** may fit), and of insulating from the housing **42** the output leads **45** from the end of the translating unit, these leads being desirably folded over within the cap (with insulation strip **45***a* interposed between at least one of them and the unit) to emerge from the cap at the end of the exposed top surface of the unit.

A generally constant velocity deflection of the translating unit **43** by constant velocity recordings will tend to cause the generation within the unit of voltages approximately inversely proportional to frequency; these voltages may be made to cause substantially constant amplitudes of power in the input of amplifier A by proper choice of the relative electrical impedances of the latter and of the translating unit. Thus when the translating unit **43** is in the form of a piezoelectric bending unit, its electrical or output impedance consists principally of a small capacity, considerable choice of the value of which (though the mechanical unit dimensions be fixed) is afforded by choice of the number of slabs in the unit; choice may of course be made of the input impedance R (which may be assumed principally resistive) of the amplifier A in accordance with well understood practice. At all lower frequencies whereat the capacitive reactance of the translating unit is a few or more times the input resistance R of the amplifier, such constancy of power in the amplifier input will inherently be obtained, since the current in the input circuit is controlled essentially by the relatively high reactance of the translating unit; at the frequency whereat that reactance equals that resistance there will be a loss from that constancy of approximately 3 decibels; and at still higher frequencies the loss will steadily increase. Of course the lower the frequency at which this equality or matching is made to occur, the higher will be the efficiency of the device throughout the frequency range therebelow—the square root of the power in the amplifier input over this range varying approximately inversely with the matching frequency. Accordingly the matching frequency is desirably made the lowest at which there can be tolerated the approximate 3 db. loss from the level of the lower-frequency response—the loss, over a limited range in the region of the matching frequency, being used if desired to offset or partially to offset the increasing effect of one or the other of the resonant mechanical peaks abovementioned on the response-frequency characteristic. In either of these cases the matching may be effected at a frequency of the general order of f_1 or f_3', as the case may be.

The fin **33** and rubber band **39** have a considerable side-to-side range of movement within the aperture **11'** in the bottom cover wall **11**, with the result that the stylus system **30** and stylus **37** have a range of side-to-side movement equal in typical cases to the width of many record grooves—this being deliberately intended for reasons well understood in the art of acoustic phonograph sound reproducers. To insure a proper "tracking" of the record by the stylus, or selection by the stylus of one groove and its remaining therein, the coupling cord **60** is made short enough (by a sufficient downward extension of the connector **46**) so that sideward movement of the stylus system from a centralized position would cause the weight **33** to be lifted. The weight of course opposes such lifting, and therefore insures proper "tracking" by the stylus. This statement, however, assumes the entry of the coupling cord **60** into the coupling spring **61** to be laterally aligned with the entry of the coupling cord into the connector **46**, when the stylus is precisely rearwardly disposed from the pivots **32**. To attempt to maintain this condition by accuracy of formation and assembly of the several pertinent parts of the device is an extremely onerous requirement — there being involved, among other things, the centralizings of the stylus **37** in the stylus arm **35**, of the stylus arm between the sides of channel member **34**, of the channel member on the weight **33**, of the weight through its pivots **31***a*—**31***b* about the vertical pivots **32**, of the base **41** with respect to pivots **32**, of the housing **42** relative to the base, of the unit **43** within the housing, and of the connector **45** with respect to the unit, as well as the entries of the coupling cord **60** into the precise centers of the connector **46** and spring **61**. To circumvent the need for close attention to all these individual accuracies, I provide a single adjustment; this is of the base **41** laterally with respect to the cradle **20**. It is conveniently provided by slots **20''** extending laterally in the cradle outwardly from the aperture **20'**, and by screws **41***a* passing upwardly through those slots into the base **41** for securing the base to the cradle. With these screws in slightly loosened condition the base may be slid laterally within the cradle to a position found by test to provide proper "tracking," and then simply tightened—with the assurance of having at once overcome the harmful effects of many possible inaccuracies.

It will be understood that while I have disclosed my invention in terms of a particular embodiment thereof, I intend no unnecessary limitations by virtue of the details of that embodi-

ment, which are intended as illustrative rather than comprehensive. Thus, for example, while that embodiment is in the form of a phonographic pick-up, many features of the invention will have utility in connection with other forms of electromechanical translating devices. Accordingly in many of the appended claims I undertake to express the scope of my invention broadly, subject only to such proper limitations as the state of the art may impose.

I claim:

1. In a phonograph having a carriage movable relatively to a record: a cradle resiliently supported to said carriage; a piezo-electric bending unit resiliently mounted to said cradle; a stylus system, including a record-engaging stylus, movably supported to said cradle; and resilient means coupling said stylus with said unit.

2. A phonographic pick-up comprising a cradle; a translating unit assembly carried by said cradle and including a piezo-electric bending unit resiliently clamped at each end; a stylus system movably supported to said cradle and including a pivoted stylus arm carrying a record-engaging stylus; and resilient means coupling said arm with a central portion of said unit.

3. A phonographic pick-up comprising a cradle; a translating unit assembly, including a translating unit, carried by said cradle; a stylus system, including a record-engaging stylus, supported to said cradle underneath said assembly for both lateral and vertical movement relative to said cradle; and means, operatively held under tension by said system, for coupling said stylus with said translating unit, said translating unit assembly being laterally adjustable relative to said cradle.

4. In a phonographic pick-up, a translating unit adapted to generate voltage upon the bending thereof; a small and light arm of channel cross-section pivotally supported at an intermediate point on its sides; a stylus secured to the base portion of said arm near one extremity thereof, said base portion being extended beyond the second extremity of said sides to form a spring; and vibration-transmitting means connected to said spring near its free extremity and coupling the same to said unit.

5. The combination according to claim 4, wherein said arm is provided with slots extending toward its first extremity from said other extremity of said sides, whereby to increase the compliance of said spring.

6. In a translating system including vibration-transmitting means: the combination of an electromechanical translating device comprising a translating unit adapted to generate voltage upon the bending thereof and with which said vibration-transmitting means is connected, and resilient means terminally clamping said unit, the torsional compliance of said resilient means in radians per dyne-centimeter being at least equal to 24 times the product of the compressional compliance of said resilient means in centimeters per dyne by the reciprocal of the square of the length of said unit in centimeters.

7. In a translating system including vibration-transmitting means: the combination of an electromechanical translating device comprising a translating unit adapted to generate voltage upon the bending thereof and with which said vibration-transmitting means is connected, and resilient means terminally clamping said unit, the torsional compliance of said resilient means in radians per dyne-centimeter being at least equal to 48 times the product of the compressional compliance of said resilient means in centimeters per dyne by the reciprocal of the square of the length of said unit in centimeters.

8. In a translating system including vibration-transmitting means: the combination of an electromechanical translating device comprising a translating unit adapted to generate voltage upon the bending thereof and with which said vibration-transmitting means is connected, resilient means terminally clamping said unit, and inserts of highly viscous material in said resilient clamping means.

9. In a translating system including vibration-transmitting means: the combination of an electromechanical translating device comprising a translating unit adapted to generate voltage upon the bending thereof and with which said vibration-transmitting means is connected, resilient means terminally clamping said unit, inserts of highly viscous material in said resilient clamping means, and common means placing both said resilient clamping means and said inserts under compression.

10. In a translating system including vibration-transmitting means: the combination of an electromechanical translating device comprising a translating unit adapted to generate voltage upon the bending thereof and with which said vibration-transmitting means is connected, damping means compressed against said unit and comprising a highly viscous element, and resilient means also compressed against said unit and disposed about said element and retaining the same against deformation.

11. In a phonographic pick-up, a translating unit adapted to generate voltage upon the bending thereof; an intermediately pivoted lever having relatively rigid and compliant portions on respectively opposite sides of its pivoting point; a stylus carried by said rigid lever portion; and vibration-transmitting means connected to said compliant lever portion and coupling the same to said unit.

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