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Elkuch

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[45] **Sept. 24, 1974**

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[54] **SYSTEM FOR GENERATING PERIODICAL MECHANICAL VIBRATIONS**

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[73] Assignee: **Etablissement Procor,** Vaduz, Liechtenstein

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Related U.S. Application Data

[60] Continuation-in-part of Ser. No. 209,142, Dec. 17, 1971, , which is a division of Ser. No. 863,056, Oct. 2, 1969, Pat. No. 3,641,373.

[30] **Foreign Application Priority Data**

Feb. 1, 1973 Great Britain 5129/73

[52] **U.S. Cl.** **310/6,** 58/23

[51] **Int. Cl.** **H02n 1/00**

[58] **Field of Search** .... 310/5, 6, 21, 22, 25; 58/23, 28, 23 MV, 23 TP

[56] **References Cited**

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Attorney, Agent, or Firm—Werner W. Kleeman

[57] **ABSTRACT**

A simplified swing system producing mechanical vibratory movements by means of electric energy and dispensing with any active elements execpt for any energy source. Three electrodes are arranged to constitute a mechanical oscillating arrangement, one electrode of which is a resilient vibrating reed capable of oscillating by flexing and swinging toward and away from the other electrodes, a charge compensation occurring when the vibrating reed electrode approaches either one of the other two electrodes closely enough within an electric field established therebetween. In the position of rest, said electrodes are sufficiently spaced from each other but aligned face to face. When said vibrating reed is vibrated, it acts, via a movement-converting body fixed at its free vibrating end, upon a cog-wheel advanced by one tooth for each period of oscillating movement of said vibrating reed. Control means adjust the frequency of said vibrating reed and are arranged in such a way that the requirements for isochronism are met in any frequency-adjusting position of said control means.

7 Claims, 6 Drawing Figures

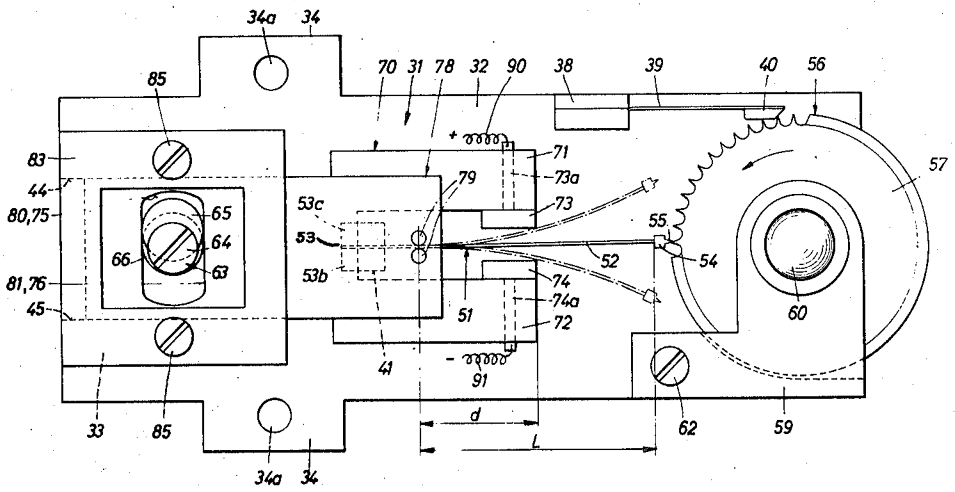

FIG. 1

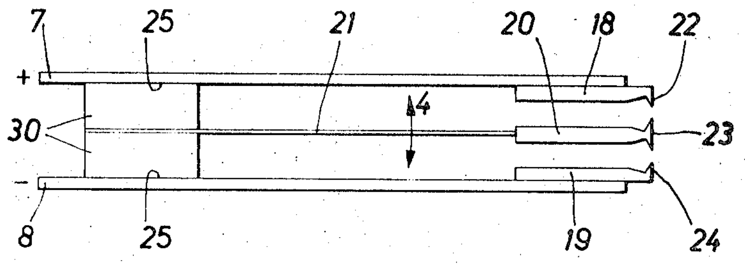

FIG. 2

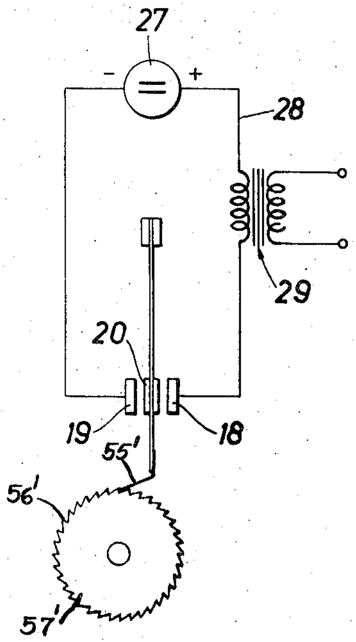

FIG. 3

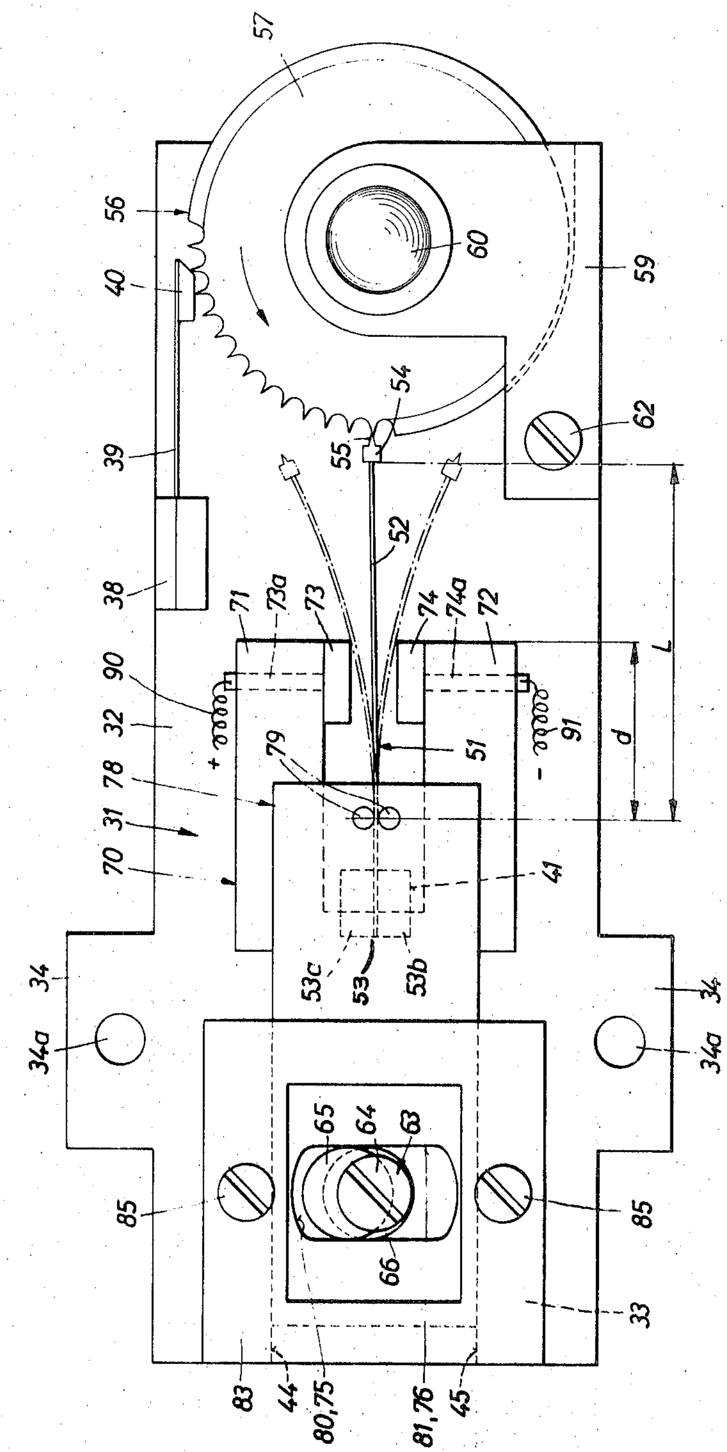
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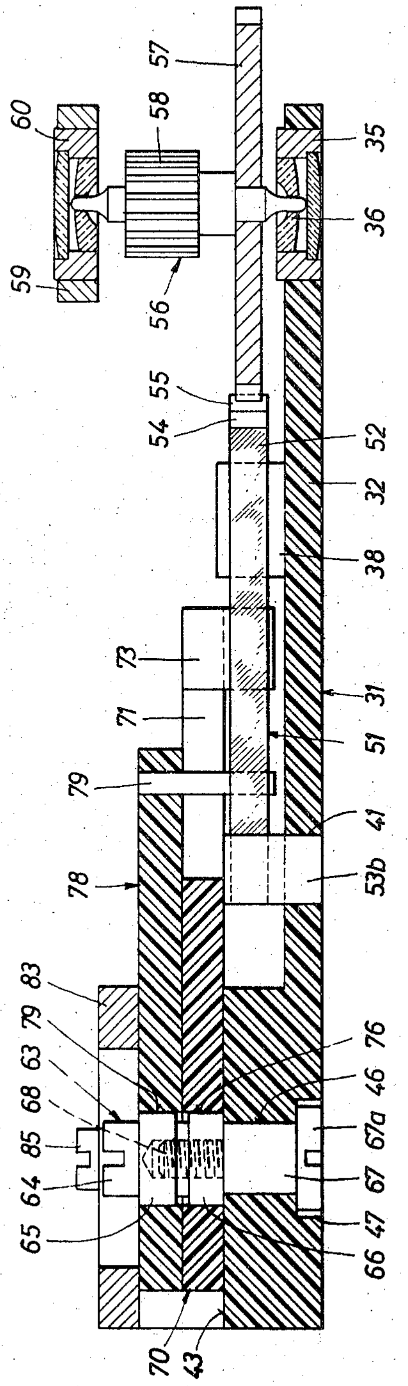
FIG. 4



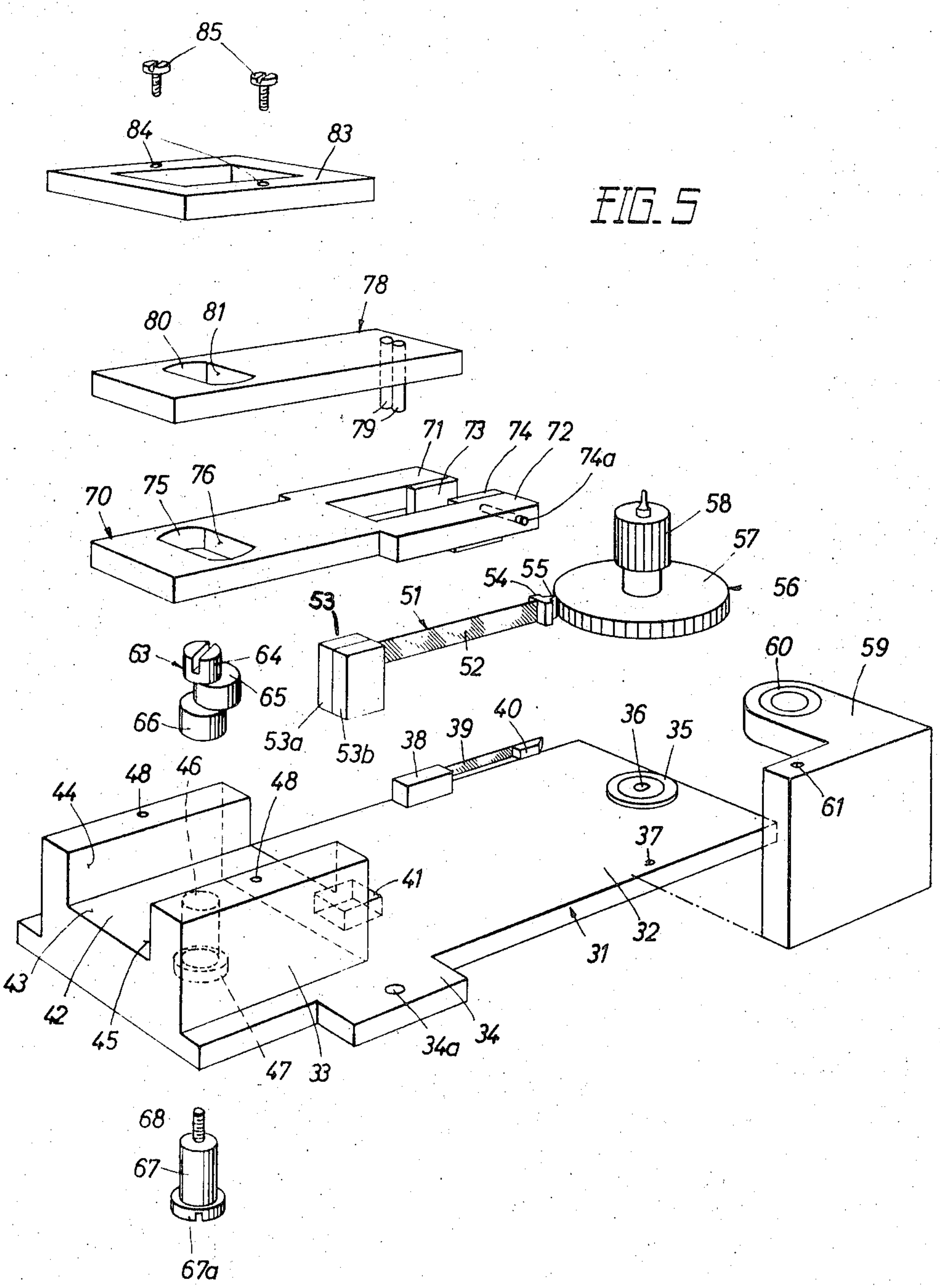

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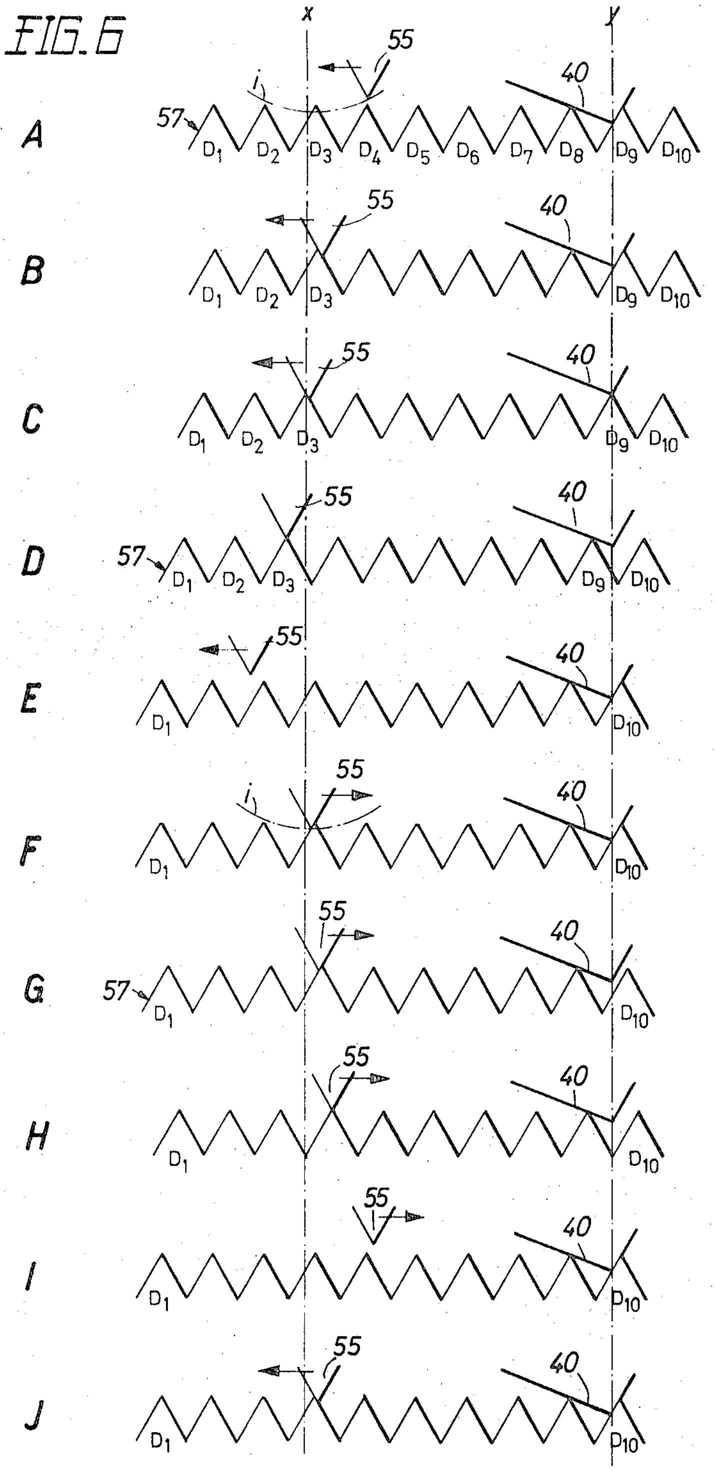
FIG. 5

FIG. 6



SYSTEM FOR GENERATING PERIODICAL MECHANICAL VIBRATIONS

CROSS-REFERENCE TO RELATED CASE

This is a continuation-in-part application of my commonly assigned U.S. application Ser. No. 209,142, filed Dec. 17, 1971, now U.S. Pat. No. 3,769,531, granted Oct. 30, 1973, which in turn is a division of U.S. application Ser. No. 863,056, now U.S. Pat. No. 3,641,373, granted Feb. 8, 1972.

BACKGROUND AND OBJECTS OF THE INVENTION

The invention is applicable more generally to the operation and performance of clocks, watches, and similar instruments requiring substantially no supervision and nevertheless acting dependably and accurately for an extensive length of time.

It is therefore one of the important objects of the invention to provide means resulting in a highly economical and inexpensive vibratory drive system which can be easily adapted to the clockwork of timepieces and similar instruments, preferably employable in the scientific field, which require precision and exactitute for their operation.

It is another object of the present invention to provide means conducive to a compact and relatively sturdy device for transferring electric energy to a mechanical drive arrangement which includes vibratory motion release and distribution, the vibratory movable elements being very few in number and having a greatly simplified design or configuration.

It is still another object of the invention to provide an arrangement of the said device in which the vibratory movable elements comprise a vibrating reed and in which means are provided for sustaining the vibratory movement of this vibrating reed without disturbing its isochronism within a wide range of amplitude values.

It is a further object of the invention to provide means for adjusting the frequency of the said vibrating reed which are capable of modifying the frequency of the latter while maintaining it in good isochronism conditions for any frequency-adjusting position to which said means are set.

Yet another object of the invention is to provide a device for suitably converting the vibratory movement of the said vibrating reed into a rotatory movement of a precise speed capable of driving the gear-train of a precision timepiece, especially a precision wrist-watch, this device being so arranged that its operation remains correct within a wide range of amplitude values of said vibrating reed.

Now in order to implement these and still further objects of the invention which will become more readily apparent as the description proceeds, the invention contemplates the provision of a system for generating isochronous periodical mechanical oscillations or vibrations for the drive of a timepiece or like instrument, comprising three electrode means arranged in face alignment with each other and located at a predetermined spacing or interval from each other in inoperative position of said electrode means. The electrode means consist of two outer electrodes and one intermediate electrode means. Vibrating reed means include a vibrating tongue at least a portion of which forms said intermediate electrode means, said tongue being movable relative to the two outer electrodes from an intermediate position towards and away from each of the two outer electrodes and limited thereby in its course of movement. The tongue when at the region of its intermediate position being neither electrically coupled to ground nor with either of the outer electrodes. Conductor means respectively connect the outer electrodes with different poles of a dc-power source. The three electrode means are arranged such that a definite ratio exists between the operative length of the vibrating tongue which deflects during vibration thereof and the distance from the immobilized end of said length to the point of the vibrating tongue at which impacts between the latter and the outer electrodes occur, in order to preclude impacts between them of the type which would have any disturbing effect upon the basic frequency of the vibratory movement of the vibrating reed means.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features of the invention ensue from the following detailed specification, reference thereto being made in the attached drawings illustrating preferred embodiments of the invention.

FIG. **1** schematically illustrates an embodiment of a vibrating device having three electrode means, only one of which is movable;

FIG. **2** schematically illustrates the application of the embodiment of FIG. **1** to a ratchet wheel drive;

FIG. **3** is a plan view of a device constituting an improvement on the embodiment of FIG. **2** and arranged to convert the vibratory movement of a vibrating reed constituting the movable electrode means into a rotatory movement capable of driving the gear-train of a watch, and to adjust the frequency of this vibrating reed, and hence the speed of the rotatory movement, without modifying its isochronism;

FIG. **4** is a longitudinal vertical sectional view of the device of FIG. **3**;

FIG. **5** is an exploded perspective view of the device of FIGS. **3**; and

FIG. **6** is a diagram explaining the operation of the conversion of vibratory movement into unidirectional rotatory movement in the device of FIG. **3**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

For achieving a structure capable of performing desired vibrations, a vibrating member comprising a vibrating tongue with a mass must be mounted in a resilient or elastic manner and in a fashion which fulfills the specific physical conditions for proper oscillation of a vibrating reed. When such a member vibrates, i.e., when kinetic (velocity) and static elastic deflection energies are in reciprocal propagation within the member, there is a certain damping of the vibration due to the losses of energy which are caused in particular by internal and external friction. To maintain the resultant vibration, it becomes necessary to replace any inevitably resulting energy losses.

In FIG. **1** a device is disclosed with an arrangement capable of executing vibratory motions for the drive of a clock or timepiece mechanism, the latter requiring good frequency stability. An end portion of an elastic or resilient member or tongue **21** forms an electrode portion **20**. The other end of tongue **21** is rigidly connected between two insulating blocks **30**. Tongue **21** constitutes a vibrating member which can swing back and forth in the direction of the double-headed arrow 4 when it is excited to do so. For this purpose, the tongue 21 including electrode portion 20 is electrically insulated from the remaining parts of the arrangement (as shown), and two outer electrodes 18 and 19 are fixedly mounted or held in position by means of two relatively heavier supports or carriers 25 which are fastened on the outer faces of said blocks 30. These two outer electrodes 18 and 19 are further electrically insulated from each other and are located spaced apart from each other and opposite movable electrode portion 20 on each side of the latter.

The two supports 25 constitute electric conductors, so that through connections 7 and 8 electric current (opposed electrical potentials) can be supplied to outer electrodes 18 and 19 from a suitable voltage source or energy cell, merely schematically indicated by reference characters (+) and (−), for the charging of these electrodes. Blocks 30 contain or consist of insulation material.

It should be apparent from the electrotechnical theory that when movable electrode portion 20 touches neither electrode 18 nor electrode 19, it is only electrostatically under the influence of outer electrodes 18 and 19, being totally insulated from the other parts. The mechanical action of this electrostatic influence on movable electrode portion 20 depends upon both the electrical charge and the location of the latter at that particular instant, assuming that both the outer electrodes are charged at predetermined potentials.

If movable electrode portion 20 has, for instance, a negative electrical charge, and, if it comes near outer electrode 18 (which bears a positive potential, as shown), the electric field between these two electrodes will act on them and will cause an attraction of the one toward the other, movable electrode portion 20 being displaced against the force of elastic tongue 21 toward and up to electrode 18.

As soon as the electrodes closely approach or touch each other, the potential difference (or electrical charge disparity) between these two electrodes is compensated and the electric field rapidly disappears. Electrode portion 20 with the entire tongue 21 now assumes the same polarity as electrode 18 and will be repelled from the latter as long as it touches it or is in close proximity thereto. Portion 20 is exposed to the action or force of elastically tensioned tongue member 21 and hence can swing back, passing, owing to its inertia, beyond the neutral or initial position and then approaching outer electrode 19, which, as shown, carries a negative polarity. Since electrode portion 20, with the entire tongue 21 now has a positive electrical charge (from preceding contact with electrode 18) the same aforementioned action will occur, with respect to electrode 19 and with reverse polarities and directions. Subsequently the electrode portion 20 comes successively and alternately in contact with outer electrode 18 and then with outer electrode 19, thereby causing a charge exchange each time, the aforementioned operation and phenomenon being repeated in each direction.

As is evident from FIG. 1, the vibrating member formed of tongue 21 including electrode portion 20 is completely insulated from the rest of the arrangement; it is clearly apparent, therefore, considering the laws of electrostatic theory, that the potential which this member 20, 21 would theoretically exhibit as compared with the outside (if it were possible to measure it) will undergo certain fluctuations in the course of the movement which takes electrode portion 20 from one of the outer electrodes to the other, these fluctuations in theoretical potential being due to the fact that the electric charge itself cannot vary as long as member 21 remains completely insulated. This theoretical potential will undergo the greatest fluctuation at the outermost parts of the movement, i.e., just at the moment when electrode portion 20 is leaving an outer electrode or is about to touch one. It is also at those points that the mechanical force, which is electrostatic in origin, acting upon electrode portion 20, will be by far the greatest. During the entire remainder of the movement, the mechanical force of electrostatic origin will be much weaker and practically negligible.

This distinguishes the system according to FIG. 1 (and FIG. 2) from a system in which, e.g., by means of a capacitor of appreciable capacitance connected between an electrode similar to electrode portion 20 and a point of fixed potential, the potential of this electrode would remain practically the same during the entire movement of that electrode, the result of which would be that the electric charge carried by the movable electrode would undergo changes. In such case, as a matter of fact, at the moment when this electrode moves close to one of the other of the outer electrodes (which would cause it to undergo fluctuations of potential if the latter were not sustained from the outside, e.g., by means of said capacitor), it would, if its potential is sustained, acquire or lose electric charges precisely intended to prevent said potential fluctuations. The consequence of this gain or loss of electric charge (in the case of such operation with sustained potential) would be to extend the terminal portions —beginning and end— of the movement, upon which appreciable mechanical forces of electrostatic origin act.

That feature of the system shown in FIGS. 1 and 2 according to which the intermediate vibrating member 21, 20 is completely insulated from the rest of the arrangement appears to be a very important one, for it tends to make as short as possible those periods of time during which the mechanical forces of electrostatic origin act upon the vibrating member to maintain its oscillation.

It will be noted that forces act upon the vibrating member in either direction of movement thereof, and during the brief contact of electrodes 18, 20 and 19, 20, there flows only a relatively small compensating current which is independent of the resistance of the circuit including electrode 18, support 25 for electrode 18, terminal 7, voltage source, terminal 8, support 25 for electrode 19, and electrode 19. The voltage source must merely replenish the electrons intermittently absorbed by electrode portion 20 from electrode 19, which it transfers to electrode 18. Therefore, the efficiency of this device is extremely high and dependable.

Contact points 22, 23 and 24, of a known conductive material resistant to burning down or melting, are arranged on the end faces of the respective electrodes. These contact points might be conducted to be very sharp in order to render it possible when using a voltage source of 1,000 volts, for example, that the electrodes need not approach each other completely for the charge exchange or load compensation, in that at a sufficiently minute or small distance between the contact and the electrode portion **20**, a spark already arcs over which suffices for charge compensation. In this way, one could expect a better harmonic vibratory movement of tongue **21** by cancelling disturbances due to any possible impact of the electrode means with one another.

These measures would, however, not be of a great significance because it is known in the domain of vibrating reeds that with such a vibrating device, contrary to what happens with an oscillator device of the spiral-balance type, for example, a mechanical action for maintenance of the oscillation, applied at the end of the path of movement, is in any case not more unfavorable than a mechanical action for maintaining the oscillation applied in mid-course. As long as the mechanical maintenance action applied to a vibrating reed at the end of the movement remains relatively sudden and retains a magnitude corresponding merely to the compensation of the energy losses which would otherwise damp the vibration movement, it is known that the vibration will remain a harmonic vibratory movement (having a frequency determined by the physical parameters of the vibrating reed).

FIG. **2** illustrates that for high impedance detection of the vibration, a transducer may be inserted in the circuit, which transforms the current surges occurring during a charge reversal into an alternating voltage pulse, which can be tapped at the terminals of the secondary winding of a transformer or transducer. At the resilient tongue a pawl **55'** may be arranged which engages the ratchet teeth **56'** of a gear **57'**, the latter being advanced by one tooth during each vibratory movement.

Since for generating a force necessary for vibrating the electrodes, a voltage source of relatively high voltage, say, of at least 100 volts, is necessary, an isotopic generator is advantageously employed. Such voltage cells or sources can be accommodated within a minimum of space and yet furnish a terminal voltage of more than 1,000 volts.

The electric circuit of the above-described aggregates or arrangements is very simple, and any necessary changes of direction of the electric polarity are automatically effected by the movements of the intermediate electrode means. The great advantage of this arrangement is that a vibration generator can be conveniently accommodated at greatly reduced dimensions.

It has been found that particularly interesting characteristics can be imparted to a device designed as an improvement upon those disclosed above in conjunction with FIGS. **1** and **2**. These improved particularities impart a very accurate isochronism to the vibrating member which includes the intermediate electrode means. It has been disclosed that said vibrating member is oscillating in the manner of a vibrating reed and it is known that such a vibrating element tends to oscillate at its natural frequency. Particular factors could, of course, contribute toward disturbing the isochronism of such a vibrating reed. It is known that the vibration of a vibrating reed proceeds from the phenomena of the propagation of mechanical waves within the vibrating reed, the latter normally oscillating at its basic frequency, which corresponds to a "quarter-wave vibration." According to the theory of vibrating strings and reeds, there is a node of deflection and an antinode of internal mechanical strain (stress) at the fixation (or immobilization) point, and an antinode of deflection and a node of internal strain at the free end. To the basic vibration wave could be added some upper harmonic waves (harmonics) which fulfill the same requirements; this will be the case for odd (uneven) upper harmonic waves. The occurrence of a greater or smaller proportion of upper harmonic waves of various orders will depend, as is generally known, i.e., for stringed instruments where the sound is produced by striking the strings, upon the point along its length where the vibrating element undergoes excitation.

It has been found —in the case of a device similar to that of FIG. 2 for instance— that by causing the mechanical forces of electrostatic origin which sustain the oscillations of the vibratory tongue to act within a predeterminated portion at a predetermined optimum point, along the length of said tongue, one can obtain a vibration which remains isochronous even when the impacts reach relatively great intensity. This means that in order to secure a very accurate isochronism, the point of the vibrating member which comes in contact with the outer electrodes (i.e., the point where the sudden mechanical actions which sustain the vibrations will occur) must be situated at a specific place along the vibrating tongue. This specific place will be referred to hereafter as "the point of impulse."

In the embodiment of FIG. **2** another structural characteristic may tend to affect the basic quarter-wave vibration of the vibrating tongue. This characteristic consists in the presence of the flexible pawl-shaped member at the free end of the vibrating tongue, such characteristic not being prejudicial because of the mass of the pawl-shaped member but eventually because of the flexibility or second-order mobility thereof.

According to an improved constructional embodiment, the specific construction of which has been shown in FIGS. **3, 4** and **5**, the above-stated considerations are taken into account.

The structural assembly shown in FIGS. **3, 4** and **5** will be further explained regarding the details of its construction. It should be noted, however, that (as best seen from FIG. **3**) the configuration of vibrating member **52, 54** is somewhat different from that of the vibrating member shown in FIG. **2**. As a matter of fact the movement-transforming mechanism (i.e., the mechanism which transforms the vibratory movement of the vibrating member into a rotative movement) has been modified. This mechanism is now of an "elliptic" type (which will be further explained in detail) which includes a simple, rigid movement-converting body **54** provided with a non-flexible movement-converting tip **55**, said movement-converting body being rigidly fixed at the free end of the tongue constituting the vibrating member (or vibrating reed).

In the device according to FIGS. **3–5** there are also provided adjusting pins **79**. They are intended to permit modification of the operative length of the vibratory reed, said modification causing a change of its basic frequency. Pins **79** thus render it possible to adjust the vibrating frequency by longitudinally displacing them. The manner in which such displacement occurs will be described hereinafter. It is important to note at this point, however, that the operative fixed point (nodal point for deflection) of vibrating reed **52** is lengthwise situated in the immediate vicinity of pins **79**. In FIG. **3**, a representative value *d* is marked for the distance between the position of pins **79** and the position of those corner ends of outer electrodes **73, 74** which the vibrating tongue **52** touches when it vibrates. The distance between pins **79** and the free end of vibrating tongue **52** (excluding the movement-converting body) is indicated by the representative value L in FIG. **3.** In order to render the vibration of vibrating reed **52, 54** accurately isochronous, i.e., in order that the frequency of said vibrating reed remains constant, independent of the intensity of the mechanical sustaining actions which are applied at the point of impact, and independent of the exact amplitude of the course travelled by end body **54** of the vibrating member, a well defined ratio must exist between value *d* and value L, which ratio is related to the fact that the impacts occur at the "point of impulse." This definite or defined ratio depends to a certain extent upon the mass of body **54.** Such mass will be advantageously small. In the embodiment according to FIGS. **3–5** as realized in practice, this mass is actually small since body **54** has very small dimensions and is made of a strong electrically insulating material. When such mass is so small, the ratio *d*:L will have to lie at a well defined value which is essentially not greater than 50:100, said value in any case causing the impacts to occur at a place no more advanced than the static center of gravity of the tongue with or without said body. Thus a wholly correct isochronism will be obtained with the vibrating reed working at its natural frequency. The requirements for such an accurate oscillation of the vibrating reed at its natural frequency are as follows: first, that the relationship of the distance *d* (from nodal point determined by pins **79** to sustaining-action point determined by said corners of the outer electrodes) to the distance L (operative vibrating length of the tongue) corresponds to the above-mentioned defined ratio: and second, that the sustaining mechanical action (which occurs when the electrode-forming portion of the vibrating tongue in the immediate vicinity of either of the outer electrodes) is a sudden action. This latter requirement has already been fulfilled by the embodiments pursuant to FIGS. **1** and **2** and is, of course, also fulfilled by the embodiment of FIGS. **3–5.**

In order to maintain the ratio d:L constant, it is clear that when pins **79** are longitudinally displaced for modifying the operative vibration length of the vibrating reed, the outer electrodes must also be displaced in the same direction by an amount dependent upon but less than the displacement of pins **79.**

The device shown in FIGS. **3, 4** and **5** is more particularly intended to permit a variation of the operative vibration length of the vibrating reed while maintaining the relationship of *d* to L at the predetermined ratio which ensures for correct isochronism. This device is also designed for carrying out the transformation of the vibratory movement of the vibrating member into a rotational movement, which transformation must be correctly effected, i.e., in such a way that, on the one hand, the isochronism will not be disturbed and, on the other hand, the transformation of the movement will occur with great reliability in that the angle through which the rotatable member moves for each period of the vibration of the vibrating member always remains the same, without fail, and independently of the amplitude of the vibration of the vibrating member.

In FIGS. **3, 4** and **5** —wherein FIG. **5** shows an exploded perspective view of the device and provides the best illustration thereof— it can be seen that the device structurally includes a base **31** comprising a flat, low part **32** and a raised U-shaped part **33** which forms a raised longitudinal slide **42.** The flat part **32** of the base **31** is provided with two lateral projections **34,** each being pierced at **34***a* for fixing the device, e.g., on a watch-plate. Part **32** of base **31** supports at the end thereof opposite the raised part **33** a pierced piece **35,** the bore **36** of which forms a bearing for a rotating member **56** which is intended to be rotatably driven by the vibratory motion of vibrating member **52, 54.** Part **32** of base **31** is further provided with a threaded bore **37** for fixing a bridge member **59** to the base, this bridge member having a bearing **60** providing a second support for pivoting rotating member **56.** A screw **62,** passing through vertical bore **61** of bridge member **59,** is threaded into bore **37,** whereby bridge member **59** is fixed to the flat part **32** of the base **31.** The latter also supports a pawl **39, 40** by means of a block **38;** said pawl is intended to cooperate with rotating member **56** in order to allow the latter to rotate correctly and unidirectionally. The detailed operation of pawl **39, 40** will be explained hereinafter.

Raised part **33** of base **31** forms a longitudinal slide **42** having a bottom **43** which is situated at a higher lever than the upper face of flat part **32** of base **31.** This slide **42** is laterally limited by walls **44** and **45,** between which two pieces can be slid in order to adjust the basic frequency of the device.

It will be noted that base **31,** shown in the drawing as constructed of one single piece incorporating flat part **32** and raised part **33,** also could be made of two assembled pieces, the one forming flat part **32** and the other being fixed to it and forming the raised portion exhibiting the slide **42.** Base **31** may be made of electrically insulating material, preferably such as can be molded. In the latter case, parts **32** and **33** together will constitute a single moled piece. Base **31** also may be made of metal, i.e., of steel or brass, or partly of metal and partly of insulating material. If it is made at least partially of metal, it will preferably have the above-mentioned two-piece construction.

Base **31** has a square or rectangular opening **41** into which engages a vibrating reed piece **51.** This vibrating reed piece includes a block **53** formed of two parts **53***a* and **53***b* and between which there is secured the vibrating tongue **52** of the vibrating reed (or vibrating member). This tongue **52** may be held in any suitable manner. If base **31,** or at least flat part **32** thereof, is made of metal, block **53** must be made of electrically insulating material, tongue **52** will be advantageously fastened to block **53** by molding the latter of suitable insulating material and inserting tongue **52** in said material during the molding process. If the base is made entirely of insulating material then the block **53** can be made of metal. The two parts **53***a* and **53***b* of the block **53** will be pressed against one another by fastening means, e.g., by countersunk screws, tongue **52** being kept in the correct position by suitable means between the two parts of block **53.** The lower portion of block **53** projects downwards beyond the lower edge of tongue **52,** said lower portion engaging, preferably by force, into the opening **41** in the base. Alternatively, block **53** also could be held in opening **41** by suitable fastening means (tightening-screw, gluing, adhesive, etc.).

The portion of the base which includes the raised part **33** is further provided with a bore **46,** the lower end of which is enlarged or widened as shown at **47.**

This bore **46** is preferably cylindrical and its upper end opens into the bottom **43** of the slide **42.** A pivot **67** with a head **67***a* is engaged from below into the bore **46,** head **67***a* being received in the enlarged part **47** thereof. The upper part of pivot **67** terminates in a threaded pin **68** onto which there is screwed a piece **63** provided with two eccentrics. This piece **63** comprises an upper part **64** provided with means for rotating it (e.g., a screw-head slot, a square shape, etc). Piece **63** further comprises a first eccentric **65** of high eccentricity and a second eccentric **66** of lower eccentricity but with its axis displaced in the same direction with respect to the axis of upper part **64** (which is the same as the axis of pivot **67**). Piece **63** has a threaded bore at its lower end (not shown) into which there is screwed the threaded pin **68.** As can be seen from FIG. **4,** the member consisting of pivot **67** and piece **63** with the two eccentrics is then rotatably mounted on base **31.**

The assembly comprising base **31,** vibrating reed piece **51** mounted on the base, rotating member **56** held by means of bridge member **59,** pawl member **38, 39, 40,** and member **63, 67** rotatably mounted on the base, is further supplemented by two sliding pieces **70** and **78** which engage in slide **42** on part **33** of the base. Piece **78** is superimposed on piece **70,** both pieces **70** and **78** being retained by walls **44** and **45** of the slide **42.** Place **70** has substantially the form of a U-shaped element with its base extending rearwardly in the form of a rectangle. This base of the U-shaped element or piece **70** is intended to engage in the slide **42;** it is pierced by an oblong opening or slot **74** having two walls perpendicular to the axis of the U-shaped element, said walls being smooth and located opposite each other, with a distance between them equal to the diameter of eccentric **66.** When sliding piece **70** is placed in slide **42** the eccentric **66** will be located in opening **75** and determines the exact longitudinal position of such sliding piece **70** by pressing against the sidewalls **76** of opening **75.** Thus when the eccentric is rotated, a longitudinal displacement of piece **70** is brought about.

Piece **70** is made, at least partially, of an insulating material, and at the end of each arm of the U-shaped piece it supports a respective inwardly directed electrode **73** and **74** extending downward in such a way that when piece **70** is in place in slide **42,** the two electrodes are situated one on each side of tongue **52** of vibrating member **52, 54,** spaced from the latter when in inoperative condition. Electrodes **73, 74** will thus constitute the outer electrodes of a device with a general structure like the system schematically shown in FIG. 2.

Electrodes **73** and **74** are fastened to the arms **71** and **72** respectively, of sliding piece **70** by means of pins **73***a* and **74***a*, respectively, which pass horizontally through the arms of the U-shaped piece **70.** Pins **73***a* and **74***a* protrude beyond the outer sides of the said arms, where they form electrical connection terminals for leads **90** and **91,** which are intended to be connected to a high-potential electrical source for delivering a positive potential to electrode **73** and a negative potential to electrode **74.** If piece **70** is only partially made of insulating material it must be designed in such a way that each of two electrodes **73, 74** is electrically insulated from the other and from the remaining conductive parts of the device.

Sliding piece **78,** which is placed in slide **42** on top of sliding piece **70,** takes the form of parallelepiped; and in the part thereof which engages in slide **42** there is an oblong opening **80** identical with opening **75** of piece **70.** Two walls **81** of said opening **80,** and which are perpendicular to the sliding axis and opposite each other, are separated by a distance equal to the diameter of eccentric **65.** When piece **78** is in place on and above piece **70** then the eccentric **67** enters opening **80** and determines the longitudinal position of sliding piece **78** in the same way as eccentric **66** does for piece **70.**

Sliding piece **78** is provided with a pair of frequency-adjusting pins **79** which project downward through the free space between the arms of U-shaped sliding piece **70.** Adjusting pins **79** pass one on each side of vibrating tongue **52,** not far from the point where tongue **52** is attached to block **53.** These two adjusting pins **79** are preferably made of steel. Sliding piece **78** is made of an insulating material in which the two pins are embedded or into which they are driven.

Finally, a frame **83** is fixed on part **33** of the base and on sliding pieces **70** and **78.** Two screws, passing through bores **84** of frame **83,** are screwed into threaded bores **48** provided at the upper edges of raised part **33** of base **31.**

All tolerances relating to the heights of pieces are established in such a manner that when frame **83** is fastened by tightening screws **85,** the two sliding pieces **78** and **70** are firmly pressed vertically and are therefore immobilized and locked in the slide of part **33** of the base.

When the two adjusting pins **79** must be longitudinally displaced then the screws **85** must be loosened, whereupon pieces **70** and **78** become unlocked. Eccentric member **63** then can be rotated by action upon its part **64,** and the pieces **70** and **78** undergo a longitudinal displacement brought about by eccentrics **66** and **65.**

It is to be noted that because of the lesser eccentricity of eccentric **66,** the sliding piece **70,** which bears the elctrodes **73** and **74,** is longitudinally displaced by a smaller amount than sliding piece **78** which supports the frequency-adjusting pins **79.** When base **31** and pieces **70** and **78** are in their respective portions according to FIGS. **3** and **4,** the eccentricities of eccentrics **64** and **65** are directed transversely, so that they cause no displacement of pieces **70** and **78.** If the aforementioned requirement concering the ratio d:L is met by the said respective positions of pieces **70** and **78** relative to the base, as shown, it will be sufficient for the eccentricities of eccentrics **66** and **65** to be in the ratio of $L - d/L$, i.e., $1 - d/L$ in order to keep the desired ratio of d:L constant since the sliding pieces are longitudinally displaced by means of eccentric member **63.**

For the main function of causing and sustaining the oscillation of the vibrating member, the device thus realized operates like the systems shown in FIGS. **1** and **2,** with the further particularity that the vibration of the vibrating member (which constitutes a true vibrating reed) always remains isochronous at a frequency which can be adjusted by rotating eccentric member **63.** Frame **83** will of course be tightened again to lock pieces **70** and **78** once the frequency adjustment has been effected by means of the eccentrics.

The potential difference which is applied to electrodes **73, 74** is delivered by a high voltage cell with an average voltage of approximately 500–600 volts. The delivered voltage can reach about 1,000 volts when the source is new and can drop to about 350 volts when the source approaches the end of its life, for instance when an isotropic cell is used. According to the value of applied potential difference, the amplitude of the vibratory course effected by movement-converting body **54** is greater or less, which means that a greater or lesser proportion of upper harmonic waves are superimposed on the basic vibration wave, but without any modification of the basic frequency. Obviously, the alternating movement of tongue **52** at the place where the impacts occur is always the same by definition, the effect of greater or smaller movement of the free end (body **54**) being only to modify the curve formed by the vibrating reed when it is deflected.

The device has been used to drive a watch movement, and the energy losses in the vibrating members and in the mechanical gear-trains were less than 0.5 microwatt. It is well known that an isotopic voltage source (isotopic cell) of a size such as can be housed in a wristwatch can furnish power in the order of from 0.5–1 microwatt under 500 volts. Thus the device possesses an adequate power reserve. Power consumption at an average potential difference of 500 volts is on the order of one or two tenths of a nanoampere (0.0001–0.0002 μ A), and an isotopic cell is capable of supplying that power for some fifteen years, at the end of which time the potential difference is still about enough to maintain operation of the device.

As there should be no electric contact between the mass and the electrode formed by the vibrating tongue, the movementconverting body **54** is made of insulating material. In such case, the body may weigh approximately 0.5–1 mg, and the length of the vibrating tongue will preferably be from 9–10 mm, about 15 mm wide with a thickness corresponding to the material coefficient. This vibrating tongue preferably will be made of platinum, beryllium, or even beryllium-bronze. Under these conditions, the vibrating reed may be given a nominal natural frequency of 100 Hz, adjustable to 95 and 105 Hz by means of the adjustment device described above, the aforementioned ratio *d*:L being maintained at said definite value no greater than 50:100.

If the device is used to drive a wristwatch, as is contemplated and has been successfully tried, it is advantageous —for various reasons of a practical nature— that the first rotating member driven by the vibrating member rotate at the rate of one revolution per second. The device converting vibratory movement into rotary movement causes rotating member **56** to advance by one tooth per period of vibration of the vibrating member; and thus toothed wheel **57** of said rotating member, which is driven by body **54** of vibrating member **52, 54,** will advantageously have 100 teeth. Pinion **58,** fastened to the same axis of the wheel **57** and intended to drive the gear-train of the watch, will naturally have a much smaller number of teeth.

The movement-converting system used in the device described has the great advantage of not being in any way dependent upon the vibrating amplitude of the vibrating member. This device makes use of pawl **39, 40,** which must have a specific shape and a specific position.

FIG. **6** illustrates the operation of the unidirectional drive of wheel **57** by tip **55** of movement-converting body **54.** This Figure schematically shows ten teeth D_1 to D_{10} of wheel **57,** spread out in a straight line, in successive phases A to J of one cycle which causes an advance of one tooth (an arc being equal to the circular pitch) of wheel **57.** In the phases designated A and F, a dot-dash line *i* shows the trajectory of tip **55** with respect to the teeth of wheel **57.** It should be understood that this trajectory is the result of the intersection of an approximately elliptical curve traced by tip **55** with a circular path along which move the points of the teeth of wheel **57**; this circular path has been spread into a straight line of FIG. **6,** which means that by way of compensation, curve *i* has a more pronounced curvature than the elliptical trajectory of tip **55.**

FIG. **6** shows a vertical axis X corresponding to the line joining the center of wheel **57** with the fixation point of the vibrating tongue, i.e., to the center line of the device. Trajectory *i* of tip **55** is symmetrical with respect to this axis X. There is also another axis Y drawn vertically, which corresponds to the position of the extremity of pawl **40.** It can be seen that pawl **40** will push toward the left the point of every tooth against which is presses with the sloping surface to the left of its extremity, and will push toward the right the point of every tooth against which it presses with the sloping portion to the right of its extremity.

In phase A of FIG. **6,** teeth D_1 to D_{10} are being stopped by pawl **40** pressing on the points of teeth D_8 and D_9. Tip **55** is passing above tooth D_4, and as can be seen in phase B, it comes to rest against the right flank of tooth D_3, the wheel not having moved as yet. In phase C, it is seen that tip **55** has pushed tooth D_3, the point of which has now passed over to the other side of axis X, while the point of tooth D_9 is just passing under the extremity of the pawl.

Phase D shows the moment when tip **55** is just leaving tooth D_3, i.e., is ceasing to act upon it. The point of tooth D_9 has then passed to the left of the extremity of the pawl, so that as is shown further on in phase E, while tip **55** continues its movement toward the left, the left-hand slope of the pawl, acting upon the point of tooth D_9, advances this point until the pawl stops the teeth in the position shown in phase E where the pawl is acting simultaneously upon teeth D_9 and D_{10}.

As can then be seen in phase F, tip **55** of the movement-converting body returns from the left to the right and this time comes to rest against the left-hand side of tooth D_4. The effect of this, as seen in phase G, is to push that tooth very slightly toward the right, the pawl once again acting only with its left-hand slope on the point of tooth D_9. This return movement toward the right will continue until the position shown in phase H has been reached, where tip **55** is leaving tooth D_4 to travel toward the right, while the point of tooth D_9 is still subjected only to the effect of the left-hand part of the pawl. As soon as tip **55** ceases to act upon the teeth, this effect of the left-hand part of pawl **40,** as will be seen in phase I, brings the teeth back into the same position they already occupied in phase F.

Finally, in phase J, it will be seen that tip **55** returns from the right, the position of the teeth remaining the same as in phase I, and tip **55** is about to act upon tooth D_4 exactly as it acted upon tooth D_3 in phase B.

Thus, by means of the interaction between pawl **40** and tip **55** of movement-converting body **54,** an advance of the wheel **57** by one tooth per period of vibration of the vibrating member has been obtained. Hence wheel **57,** having 100 teeth, will accomplish one revolution per second if the vibrating member oscillates at

100 Hz. It should be noted that this device, even though it requires a very precise adjustment of the pawl and of the tip of the movement-converting body, is not as delicate as it may seem at first glance. With a vibrating member which is approximately 9 mm long and a toothed wheel which is approximately 9 mm in diameter with 100 teeth, a tolerance of at least two hundredths of a millimeter can be accepted for the penetration of tip **55** into the diameter defined by the points of the teeth of wheel **57**. In the stopping position, the extremity of the pawl will advantageously be situated at least four to five times closer to the point of the toothed which is about to pass then to the point of the tooth which has just passed. Also in the stopping position, the point of the tooth which is about to be acted upon by the movement-converting body will advantageously be very slightly set back (in the case envisaged above, about ½° behind the center line), because in this manner, the travel or path through which it is driven by said tip is greater in the advancing direction than in the direction of the momentary backward movement.

It should also be noted that this momentary backward movement (phases G and H of FIG. **6**) does not interfere in any way with the driving of the rest of the gear-train of the watch, because it can be compensated by a very slight clearance between the driving pinion of the first rotating part and the driven gearwheel of the second rotating part.

The device just described can be applied particularly advantageously to a timepiece, and especially to a watch —above all a wristwatch—, but very many other applications can be found for it in numerous other instruments where it is necessary to sustain a rotary movement at a constant speed with minimum energy consumption, and where this energy can advantageously be drawn from a high-voltage, low current source of electric energy, e.g. from an isotopic cell.

While there is shown and described present preferred embodiments of the invention, it is to be distinctly understood that the invention is not limited thereto but may be otherwise variously embodied and practiced within the scope of the following claims. ACCORDINGLY,

What is claimed is:

1. A system for generating isochronous periodical mechanical oscillations for the drive of a timepiece or like instrument, comprising three electrode means arranged in face alignment with each other and located at a predetermined spacing from each other in an operative position of said electrode means, said electrode means consisting of two outer electrodes and one intermediate electrode means, vibrating reed means including a vibrating tongue at least a portion of which forms said intermediate electrode means, said tongue being movable relative to the two outer electrodes from an intermediate position towards and away from each of the two outer electrodes and limited thereby in its course of movement, said tongue when at the region of its intermediate position being neither electrically coupled to ground nor with either of the outer electrodes, conductor means respectively connecting said outer electrodes with different poles of a direct current power source, said three electrode means being arranged such that a definite ratio exists between the operative length of the vibrating tongue which deflects during vibration thereof and the distance from the immobilized end of said length to the point of the vibrating tongue at which impacts between the latter and the outer electrodes occur, in order to preclude impacts between them of the type which would have any disturbing effect upon the basic frequency of the vibratory movement of the vibrating means, said vibrating reed means further including a rigid movement-converting body having a tip and fixed at a free end of said vibrating tongue, a toothed ratchet wheel, said tip acting on the teeth of said ratched wheel for advancing the latter by one tooth per period of the vibratory movement of the vibrating reed means, said tip sweeping over a path interfering with the circumference of said ratchet wheel, said rigid movement-converting body cooperating via said tip with said ratchet wheel in such a manner that during each alternation of the vibratory movement of said vibrating reed means said rigid movement-converting body via its tip pushes each tooth of said ratchet wheel only along a fraction of an arc equal to the circular pitch of said ratchet wheel independently of the magnitude of the vibratory movement, and siad ratchet wheel cooperates with an asymmetrical ratchet-pawl in such a way that in one direction, representing an advance of said ratchet wheel, said ratchet-pawl acts to complete each movement of a fraction of an arc in order to make said movement equal to the full circular pitch while, in the opposite direction; representing a backward movement of said ratchet wheel, the movements of a fraction of an arc are cancelled out by said ratchet-pawl.

2. The system according to claim **1**, intended for incorporation in a wristwatch, wherein said vibrating reed means has a length which is less than 11 mm.

3. Device for generating isochronous periodical mechanical oscillations for the drive of a time-piece or like instrument, comprising three electrode means arranged in face alignment with each other and located at a predetermined interval from each other in inoperative position of said electrode means, said electrode means consisting of two outer electrodes and one intermediate electrode means, vibrating reed means including a vibrating tongue at least a portion of which forms said intermediate electrode means, said tongue being movable relative to the two outer electrodes from an intermediate position towards and away from each of the two outer electrodes and limited thereby in its course of movement, said tongue when at the region of its intermediate position being neither electrically coupled to ground nor with either of the outer electrodes, conductor means respectively connecting said outer electrodes with different poles of a d.c. power source, said three electrode means being so arranged that a specific ratio exists between the operative length (L) of the vibrating tongue which deflects during vibration thereof and the distance (*d*) from the immobilized end of said length to the point of the vibrating tongue at which impacts between the latter and the outer electrodes occur, further comprising a mechanism for adjusting the basic frequency of the vibrating reed means, said mechanism comprising two adjusting pins for laterally immobilizing the vibrating tongue at a point near the fixation point thereof, a first slidably adjustable piece which bears said two adjusting pins in an electrically insulating manner, a second slidably adjustable piece at least partially made of insulating material which bears said two outer electrodes, and means for displacing said first and said second pieces simultaneously and in the same direction but by different amounts so that said ratio d:L remains constant for any position which can be given to said frequency-adjusting pins.

4. The system according to claim **3,** wherein said vibrating tongue is made from a member selected from the group consisting of a platinum, beryllium or bronze-beryllium.

5. Device according to claim **3,** wherein said vibrating reed means, said first and second pieces, and said means for displacement thereof are so arranged that the frequency of the vibrating reed can be adjusted between 95 and 105 c/s.

6. Device according to claim **3,** wherein said means for displacement of said first and second pieces are eccentric means.

7. Device according to claim **3,** wherein said first and second slidably adjustable pieces are both made of electrically insulating material, and said two adjusting pins are made of steel.

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