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(54) VIBRATORY DRIVE SYSTEMS

(71) We, Omega Louis Brandt & Frere S.A., of 96 Staempflistrasse, 2500 Bienne, Switzerland; a Swiss body corporate, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to vibratory drive systems suitable, but not exclusively for electric timepieces, wherein a vibratory member is a part of a mechanical resonator constituting the time keeping element, the resonant vibrations of which are maintained by an electric drive.

In vibratory drive systems of this type, generally a vibratory member is fixed to an elastic arm permitting periodically occurring, substantially rectilinear movements of the vibratory member, the vibratory arm and vibratory member being considered as a resonator. For maximum stability of the resonance frequency the energy in the resonator when vibrating must be large compared with any energy drawn from the resonator.

In most of the vibratory drive systems of the type described there is a driving pawl fixed to the vibratory member and extending parallel to the direction of vibration. This driving pawl engages the teeth of a ratchet wheel, the pivot bearing of which is carried by a base supporting the resonator. There is also usually a non-return pawl which engages the teeth of the ratchet wheel.

The normal frequency of vibratory drive systems of the type described usually lies between 200 and 700 vibrations per second. The diameters of ratchet wheels of known construction lie between 1 and 3 mm. These dimensions show that the parts of vibratory drive systems for converting the periodic rectilinear movements into rotary movement offer serious technological problems to the designer. Thus the efficiency of the conversion of vibrational into rotary motion must be very high, for two reasons. The first that the energy consumption of a vibratory drive system, e.g. for small watches, is not allowed to exceed a predetermined value depending on the size of driving battery available. The second is that high energy transfer leads to the destruction of the vibratory drive system. In order to attain high efficiency the pawls must be very accurately adjusted relative to the ratchet wheel, and the pawls must be made of wear-resistant material. Unfortunately in known vibratory drive systems the adjustment of the pawls and the support of the ratchet wheel are subjected to undesired changes since the fixing points of vibratory member, ratchet wheel and non-return pawl are usually placed relatively far from each other on a base plate and all parts are subjected both thermic and mechanical disturbances.

In such vibratory drive systems the amplitude of the movements of the vibratory member must be kept constant within close limits and the positions of the pawls and the ratchet wheel must remain unchanged within small limits, to ensure accurate time keeping. Such requirements are difficult to fulfil.

A further problem in vibratory drive systems of the type described is that in wrist watches the rate of transmission of energy from vibratory to rotary motion should not exceed a few microwatts. The useful forces thereby appearing in a vibratory drive system are accordingly small. Therefore, very small disturbing forces may lead to operating troubles. Such disturbing forces appear e.g. between the pawls and the ratchet wheel if layers of liquids, such as water or oil form between these parts, the molecular attraction of which in the form of surface tension and adhesion exceeds the drive force available.

The aforesaid layers of liquids may arise by diffusion, i.e. volatilization of oil from oil-lubricated bearings of a watch, and condensation on the ratchet wheel, or by condensation of water vapor from moist air. If the bearings of a ratchet wheel are oil-lubricated the path of diffusion is relatively short. In many cases the condensation of water vapor cannot be avoided even in water-proof clock-cases.

According to the present invention there is therefore provided a vibratory drive system suitable, but not exclusively for timepieces, said drive system comprising a vibratory member, a motion converting system mounted on a vibrating portion of said vibratory member, said motion-converting system including a pair of pawls extending oppositely to one another and substantially parallel to the direction of vibration of said portion, a ratchet wheel located so as to be acted upon by both said pawls, support means for said ratchet wheel enabling it to rotate, said ratchet wheel or pawls being loosely mounted in order to allow free relative movement between said pawls and ratchet wheel to a limited extent to and fro in the direction of said vibration, a stepwise rotational movement being imparted to the ratchet wheel whenever the direction of motion of said vibratory motion is reversed, due to said relative movement caused by the inertia of the ratchet wheel or pawls respectively.

One embodiment of the vibratory drive system according to the invention is characterized in that the ratchet wheel's axis of rotation is movable relative to the vibratory member, whilst the pawls are fixed to the vibratory member. For the operation of the drive, however, only relative movements are necessary between the pawls and the ratchet wheel. Alternatively the ratchet wheel's axis of rotation could be fixed to the vibratory member, whilst then the pawls would be movable relative to the vibratory member.

Preferably the pawls and the ratchet wheel are located within a closed sleeve detachably mounted on the vibratory member. The sleeve may be filled with a liquid having a low vapor pressure or low vscosity, or with one of the known lubricating gases. As liquids silicone oils, or solutions the constituents of which change the physical properties of the liquid, such as the surface tension, may be used. It is advantageous to fill the sleeve with liquid, since surface tension can no longer appear as a disturbing force if the sleeve is totally filled. Since liquids in themselves have a greater density than gases their composition is not changed even after a long period of time.

To effect magnetic coupling between ratchet wheel and a coupling wheel a pair of magnetic poles is only necessary on one wheel, whilst the other wheel is a toothed ferromagnetic yoke consisting of magnetically soft material. Preferably the ratchet wheel assembly comprises a magnet with at least one pair of magnetic poles, having a relatively high magnetic intensity. This pair of magnetic poles may have their axis parallel to the rotational axis or a radius of the wheel, axially according to the arrangement of the coupling wheel and the ratchet wheel relative to each other. An especially powerful coupling exists if the rotation axes of the ratchet wheel and the coupling wheel are arranged nearly parallel with each other and if the periphery of one lies within the periphery of the other. Then both wheels have the same direction of rotation. The axis of the coupling wheel, however, may be displaced relative to that of the ratchet wheel in such a manner that both wheels rotate oppositely. If the coupling wheel is arranged coaxially with the ratchet wheel there are no radial components of the magnetic forces to disturb the dynamics of the ratchet wheel.

If the ratchet wheel is disposed on the vibratory member, and the vibratory member moves relative to the rotation axis of the coupling wheel, the ratchet wheel moves relative to the coupling wheel. Thus, during operation the reciprocal distance between the rotation axes of the two wheels is changed periodically. The magnetic coupling may be such that the transmission of the torque from the ratchet wheel to the coupling wheel is not affected by the periodical fluctuations of the distance between the rotation axes, even if the amplitude of the rectilinear movements of the vibratory member is substantially increased. In principle no special additional conditions need be considered for the construction of the vibratory drive system. If, however, the tolerances for production and adjustment need to be exceptionally great, the vibratory drive system is provided with stops fixed to the vibratory member, said stops limiting the possible movement between the ratchet wheel and pawls in the direction of vibration. Moreover the arrangement of the stops, the pawls and the ratchet wheel on the vibratory member is made in such a manner that from a position of rest the mobility in one direction is approximately one-fourth of the length of a tooth of the ratchet wheel, and in the opposite direction approximately three fourths of the length of a tooth.

Further particulars of the invention are now described in connection with the appended drawings, in which:

Fig. 1 shows the parts of a vibratory drive system serving as a time keeping element of an electric timepiece,

Fig. 2 is a detail of a vibratory drive system according to Fig. 1, illustrating a position of the ratchet wheel relative to the pawls,

Figs. 3*a* to 3*k* show ten stages of periodically appearing operating conditions between pawls and ratchet wheel in a vibratory drive system according to the invention. The distance between the pawls is shown as varying, but of course in practice this distance remains constant,

Fig. 4 is a top view of essential component parts of the vibratory drive system according to Fig. 1, said component parts being installed in a sleeve partially cut away,

Fig. 5 is a view in section taken along the line V-V in Fig. 4,

Fig. 6 is a partial view in section showing a modified embodiment of component parts of the vibratory drive system according to Figs. 1, 4 and 5,

Fig. 7 is a partial front view in section showing a modification of the vibratory drive system according to Figs. 1, 4 and 5,

Fig. 8 is a partial top view of another embodiment of a vibratory drive system according to the invention, and

Fig. 9 is a graph illustrating the reciprocal movements of mass points during the operation of the system.

As shown in Fig. 1 a pole shoe 1 is associated with a coil 2 and forms together with the latter the essential component parts of an electromechanic motion converter. The pole shoe 1 is magnetised, and the magnetic flux cuts the windings of the coil 2. The coil is mounted on a coil core 3, in the interior of which the parts of an electric oscillator circuit may be arranged, the output of which is connected to the ends of the coil. Screws 4 and 5 fasten the coil core and coil to a base plate (not shown). To the same base plate there is fixed the end of a vibratory arm 6, the free end of which is joined to a vibratory body 7 bearing the pole shoe 1. In practice the individual parts 1, 6 and 7 are connected to each other by soldering or bonding.

The pole shoe 1, the vibratory body 7 and the vibratory arm 6 together form one half of a mechanical resonator. In the vibratory arm 6 the accumulated intrinsic energy of the resonator appears in the form of potential or kinetic energy. The second half of the resonator is not shown and may be similar to the first half but located to the left of the core. In this second half a further pole shoe is associated with the windings of the same coil 2. In the described form the resonator and the oscillator-circuit controlled by the resonator serve both as a drive system and as the time keeping element of an electric wrist watch. On the vibratory body 7 there is a substantially circular cylindrical sleeve 8 enclosing a ratchet wheel 9 and two pawls 10 and 11. In Fig. 1 the relative sizes, especially of the pawls and the ratchet wheel, are distorted and the latter are only schematically indicated. In every case is should be noted that the pawls are set approximately parallel to each other and to the main direction of vibration of the vibratory body 7. The rotation axis of the ratchet wheel 9 is approximately perpendicular thereto.

The sleeve 8 is preferably sealed. The ratchet wheel 9 magnetically transfers a torque to a coupling wheel 12, which is arranged outside of the sleeve 8 and is also shown only schematically. The rotation axis of the coupling wheel 12 is designated by a cross 13 and extends approximately parallel with that of the ratchet wheel 9, but displaced from it. The coupling wheel could also be arranged approximately coaxial to the ratchet wheel 9. In this case, however, its magnetically effective diameter would be limited approximately to that of the ratchet wheel. The coupling wheel 12 may be connected to the gear train and the hands of a clock or watch.

In Fig. 2 only the ratio of sizes of the two rows of teeth 16 and 17, the diameter of a bore-hole 18 of a ratchet wheel 19, the diameter of a pivot 20, the size of the two pawl stones 21 and 22, and two pawls 23 and 24 correspond approximately. The ratchet wheel 19, which includes the teeth 16, 17, is shown considerably distorted. Two dash lines 25 and 26 connect the two teeth rows 16 and 17 and indicate that the periphery of the wheel consists of similar ratchet teeth. The pivot 20 is fixed to a base plate on sleeve 8 (not shown) which also carries the fixed ends of the pawls 23 and 24. The difference of the diameters of the bore-hole 18 and the pivot 20 is approximately equal to the length of a tooth in row 16 or 17.

In Fig. 2 there is shown the neutral position of the individual component parts relative to each other. The component parts are in the neutral position if there is no relative movement between them and if no other acceleration than the acceleration due to gravity acts on them. The axis 27 of the bore-hole 18 is at a distance from the axis 28 of the pivot 20 equal to a quarter of the pitch of the teeth in rows 16 and 17. If the last named requirements are complied with, both in the diameters of the bore-hole 18 and the pivot 20 and in the adjustment of the pawls 23 and 24, the production tolerance amounts to ± one quarter of the length of a tooth, and a quarter of a pitch, respectively.

In the case in point the pawls 23 and 24 are fixed to the sleeve base plate at points displaced from positions diametrically opposed about the pivot 20, in the direction of vibration, by a quarter of the length of a tooth of the ratchet wheel 19.

In Fig. 3 the component parts of Fig. 2 are shown schematically. In order to render the representation less complex, respective reference characters have been inserted only in Fig. 3*f*. Accordingly, the arrows in Fig. 3 represent the pawls 23 and 24. The steps are the teeth in rows 16, 17. The eccentric circles represent the peripheral lines of the bore-hole 18 and the pivot projecting into the bore-hole.

Fig. 3*a* shows the neutral position corresponding to Fig. 2. In the neutral position the free ends of the two pawls touch two diametrically disposed tooth profiles of the toothed wheel 19.

Fig. 3*b* shows a position which occurs when the vibratory member, the pawls and the pivot have moved to the right, the pivot 20 and the pawl 23 applying a force to the ratchet wheel 19, accelerating it. In this position the pivot 20 has covered a distance of a quarter of one pitch compared with the position in Fig. 3*a* and relative to the ratchet wheel 19, whilst the pawl 24 has covered twice the distance, i.e. approximately the distance of a half of one pitch with regard to the tooth profile which it had touched previously.

Fig. 3*c* shows the position of the component parts at a later point of time, wherein the ratchet wheel 19 continues moving to the right, whilst the acceleration of the pawls and the pivot controlled by the vibratory member is already reversed. As soon as the pivot is again concentric with the bore-hole 18 of the ratchet wheel 19 the pawl 24 strikes a tooth of the row 17, the pawl 23 having moved back from the tooth touched previously, by one half of one pitch.

Upon further movement of pivot and pawls to the left, relative to the ratchet wheel, the component parts reach a position according to Fig. 3*d*, where the pawl 24 still applies a left-directed force on the ratchet wheel, whilst the pawl 23 has nearly left the tooth upon which it lay hitherto. Very shortly after, the pawl 23 falls from this tooth to the next one. During the period of time between the positions of Figs. 3*c* and 3*d* the pivot has covered a distance of only a quarter of a pitch relative to the ratchet wheel, whilst the pawl 23 covers double the distance, i.e. a half of one pitch relative to the ratchet wheel. In this connection it should be pointed out that due to the construction the distance moved by both the pawls and by the pivot is the same and is determined by the movement of the vibratory member. The different illustrations in Fig. 3, however, show these distances relative to the ratchet wheel, which first contacts the free end of one pawl and second the free end of the other pawl, and rotates under the drive from these free ends.

The operating condition shown in Fig. 3*e* corresponds to that shown in Fig. 3*b*, but with the difference that the directions of forces and movements are opposite to those of the first condition. The only difference is that in the position according to Fig. 3*e* —compared with the position according to Fig. 3*b*—the ratchet wheel has been advanced by one tooth relative to the pawl 23.

In the position according to Fig. 3*f* the center of gravity of the ratchet wheel 19 still continues to move to the left, whilst pivot and pawls are already subjected to an opposite acceleration as compared with the position according to Fig. 3*e*.

The position according to Fig. 3*g* corresponds to that according to Fig. 3*c*, but with reversed forces and accelerations. To make clearer the function one must always consider that in the position according to Fig. 3*d* the movement of the ratchet wheel relative to the pawl 23 is irreversible and that the stated equivalents between different dynamic positions during the proceeding time cannot allow the reversibility of any intermediate occurrences. A certain periodicity occurs only at times after one revolution of the ratchet wheel.

The dynamic position according to Fig. 3*h* corresponds to that according to Fig.3*d*. but with opposite direction of the forces and accelerations. In the position according to Fig. 3*h* the pawls 23 and 24 have interchanged their functions compared with the position according to Fig. 3*d*. In the present case the pawl 24 is falling from one tooth of the row 17 on to the next tooth, which in effect causes the ratchet wheel to advance by one tooth relative to the pawl 24. The rotation of the ratchet wheel relative to the pawls 23 and 24, and the base plate and the vibratory member, amounts to one tooth pitch between the operating conditions according to Figs. 3*a* and 3*h*. Apart from the irreversible rotation of the ratchet wheel by this pitch, the dynamic operating condition according to Fig. 3*h* is completely comparable with that according to Fig. 3*a*.

The Figs. 3*i* and 3*k* show the same dynamic operating condition as the Fig. 3*b*. Both the last named Figures differ from each other only by a displacement of the teeth of rows 16 and 17 relative to the periphery of the bore-hole 18. This displacement is the progressive displacement of the ratchet wheel by one pitch relative to the pawls and the pivot.

Fig. 4 shows two pawls 31 and 32 engaging the teeth of a ratchet wheel 33. Each of two different adjustable support members 34 and 35 holds a pawl in position approximately parallel with the other, and parallel with the main direction of vibration of the vibratory member.

The adjusting member 34 is fixed to the bottom 36 of a sleeve 37 by means of three bolts 38, 39 and 40. Clearly the bolts may be replaced by soldering or by other fixing means. The free end of the adjusting member 34 rests against an eccentric screw 41 engaging a bore-hole 43 of the base 36 with a certain pre-load. If the eccentric screw 41 is turned by means of a screw driver the free end of the adjusting member is displaced and thereby also the free end of the pawl 31.

A pivot 44 is provided for the adjusting member 35, said pivot being inserted in a friction-tight bore-hole of the base 36. The free end of the adjusting member 35 and therewith the free end of the pawl 32 may be moved by turning the pivot 44.

For clarity the eccentric screw 41, the two adjusting members 34 and 35 and the two pawls 31 and 32 have been omitted from Fig. 5. This figure shows a hub 46, on which the ratchet wheel 33 is fitted. The hub consists of ferromagnetic material having a high coercivity and comprises at least one pair of magnetic poles. Thus, the hub may also be named a magnet wheel.

A pin 48 corresponding to pivot 20 projects into a bore-hole 47 of the hub 46, said pin being fastened in a corersponding bore-hole of the base plate or sleeve 37. The difference between the diameters of the bore-hole 47 and the pin 48 amounts approximately to one half of a pitch of the ratchet wheel 33.

The hub 46 rests on the surface of a flat watch jewel 49 at a peripheral edge, said watch jewel being also fixed to a base plate 36 of the sleeve 37. A further edge 50 of the hub 46 faces a cover plate 51, which is inserted in a flanged edge 52 of the sleeve 37 and closes the sleeve. The cover plate may consist of a mineral material, preferably of the same material as the watch jewels. Obviously the material of the cover plate 51 like that of the sleeve, must be non-magnetic so that coupling between the hub 46 and a coupling wheel positioned outside the sleeve 37 is not prevented. The sleeve 37 together with its contents corresponds with the sleeve 8 and its contents of Fig. 1. As before, a coupling wheel is driven by the ratchet wheel 33.

In the embodiment of Fig. 6 a ratchet wheel 55 and a magnet wheel 56 are fixed concentrically to a wheel axle 57. One end of this axle is supported in a jewel-bearing 58 without appreciable play. A jewel-bearing 59 surrounds the other end of the axle, with play of the magnitude of the length of a tooth of the ratchet wheel 55. The two bearings 58 and 59 are positioned in a bottom plate 60 and cover plate 61 of a sleeve respectively.

In operation the ratchet wheel 55 and the magnet wheel rotate together with the axle 57.

In the embodiment shown in Fig. 7 a ratchet wheel 63 and a magnet wheel 62 are fixed to an axle 64, one end of which projects into a jewel-bearing 65 and the other end of which is surrounded by a jewel-bearing 66. The two bearings are positioned in a base plate 67 and a cover plate 68 of a sleeve respectively. Between the axle 64 and the two bearings 65 and 66 there is a play of the magnitude of one pitch of the ratchet wheel 63. In operation the ratchet wheel 63, the magnet wheel 62 and the axle 64 move periodically to and fro, and also rotate.

In the embodiment of Fig. 8, there are stops fixed to the vibratory member in the form of sleeve walls 71 and 72. In operation of the ratchet wheel 70, movements thereof between the walls 71 and 72 are limited thereby, whilst rotation of the ratchet wheel 70 is initiated by pawls 73 and 74. This kind of construction is advantageous especially if the individual component parts of the vibratory drive system are very small and the tolerances are of microscopic dimensions.

In the graphs of Fig. 9 the amplitude of displacement of one end of the vibratory member, and of a center of gravity of a ratchet wheel and magnet wheel of a vibratory drive system according to the invention are plotted against time. The curve 76 represented by solid line shows the movement of the vibratory body, whilst the curve 77 represented by a dash line shows the movement of the center of gravity of the ratchet wheel and magnet wheel. The relation of the two curves to one another is clear when taken in connection with Fig. 2. The movement path which is represented by the curve 76 passes through the middle axis 28 (fig. 2), whilst the center of gravity of ratchet wheel and magnet wheel lies on the rotation axis 27. It should be remembered that the curves represent only a single component of movement, namely that in the main direction of vibratory movements of the vibratory member.

The curve 76 is a sine curve illustrating the oscillation of the mechanical resonator while curve 77 is the oscillating movement of the centre of gravity of a loosely mounted ratchet wheel. The abscissa of fig. 9 is the time axis, and the neutral positions of the mechanical oscillator and the wheel are at the points where the respective curves cut the abscissa.

When during operation the axis 28 passes through the neutral position, the individual component parts are located in a position to each other corresponding approximately to that according to Fig. 3*b*. The rotation axis 27 follows the axis 28 at a distance of about a half of a pitch of a tooth of the ratchet wheel. This condition is represented in the graph of Fig. 9 by the points 78 and 79. At the point 78 there an inversion of the acceleration of the axis 28 occurs, whilst the rotation axis 27 maintains a substantially constant speed at point 79. Therefore, the movement of the rotation axis from the point 79 may be represented by a straight line, to a point 80. At the point 80 the rotation axis 27 is in advance of the axis 28 by the length of one pitch. This condition corresponds to the representation of Fig. 3*e*.

From the point 80 the movement of the axis 28 determines the movement of the rotation axis 27. Therefore from the point 80 the curve 77 continues as a sine curve, to a point 82 lying vertically above the point of intersection 83 of the curve 76 with the time axis.

At the point 83 the acceleration of the axis 28 reverses whilst from point 82 the rotation axis 27 maintains a constant speed to a point 84 of the curve 77, so that here the curve 77 becomes a straight line. The position of the component parts with respect to each other shown in Fig. 3*i* corresponds to the working condition at point 84.

From point 84 the movement of the rotation axis 27 is again completely determined by the movement of the axis 28. Accordingly from point 84 the curve 77 changes back into a sine curve, until a point 86 lying vertically below the point of intersection 87 of the curve 76 with the time axis is reached.

Two points of intersection 88 and 89 of the two curves 76 and 77 represent the working conditions shown in Figures 3*c* and 3*g*.

The curve 77 disregards the influences of friction and of the pawls affecting the ratchet wheel. Therefore the identification of certain points of the two curves with certain positions of the component parts in Fig. 3 is not necessarily quite accurate. When for the curve 77 friction is considered, the points 80 an 84 are displaced to the right on the sinusoidal sections of the curve. Obviously therefore the sections of the curve lying between the points 79 and 80 on the one hand and between the points 82 and 84 on the other hand cannot be straight lines. When the influence of the pawls is also considered, the shape of curve 77 at points 80 and 84 may be appreciably different from that shown.

Generally it can be stated that the movement of the ratchet wheel and magnet wheel, and the movement of the rotation axis 27, respectively, includes two sine curve parts. One sine curve part is the section lying between the points 80 and 82 of the curve 77. The other sine curve part is the section lying between the points 84 and 86 of the curve 77.

Fig. 9 shows that the amplitude of the ratchet wheel exceeds the amplitude of the mechanical oscillator by approximately one tooth pitch, as explained previously.

WHAT WE CLAIM IS:—

1. A vibratory drive system suitable, but not exclusively for time-pieces, said drive system comprising a vibratory member, a motion-converting system mounted on a vibrating portion of said vibratory member, said motion-converting system including a pair of pawls extending oppositely to one another and substantially parallel to the direction of vibration of said portion, a ratchet wheel located so as to be acted upon by both said pawls, support means for said ratchet wheel enabling it to rotate, said ratchet wheel or pawls being loosely mounted in order to allow free relative movement between said pawls and ratchet wheel to a limited extent to and fro in the direction of said vibration, a stepwise rotational movement being imparted to the ratchet wheel whenever the direction of motion of said vibratory motion is reversed, due to said relative movement caused by the inertia of the ratchet wheel or pawls respectively.

2. A vibratory drive system as claimed in claim 1, wherein the axis of the ratchet wheel is movable relative to the vibratory member, whilst the pawls are fixed to the vibratory member.

3. A vibratory drive system as claimed in claim 1, wherein the ratchet wheel has a hole into which a pivot fixed to the vibratory member projects, the cross-section of said pivot being smaller than that of the hole.

4. A vibratory drive system as claimed in claim 3, wherein the hole is formed as a concentric hole in the ratchet wheel and the pivot is formed as a circular cylinder.

5. A vibratory drive system as claimed in claim 1, wherein the ratchet wheel is fixed to a wheel axle at least one end of which projects into an axle bearing, the diameter of said axle bearing being greater than that of the wheel axle.

6. A vibratory drive system as claimed in claim 1, wherein the ratchet wheel is arranged between stops, the distance between which in the direction of the vibration is greater than the diameter of the ratchet wheel.

7. A vibratory drive system as claimed in claims 6 wherein the stops limiting the reciprocal mobility between ratchet wheel and pawls in the direction of vibration are fixed to the vibratory member.

8. A vibratory drive system as claimed in claim 4, wherein the play between the hole and the pivot, i.e. the difference of the diameters of hole and pivot, amounts to substantially the length of a tooth of the ratchet wheel, and wherein the pawls are fixed to the vibratory member at points displaced in the direction of vibration by a quarter of the length of a tooth of the ratchet wheel from positions diametrically opposed about the pivot.

9. A vibratory drive system as claimed in claim 1, wherein the pawls and ratchet wheel are arranged in a closed sleeve detachably mounted on the vibratory member.

10. A vibratory drive system as claimed in claim 1, comprising a magnetic pole shoe located on the vibratory member and a drive coil therefor, the coil being located on a fixed core.

11. A vibratory drive system as claimed in claim 1, comprising a sleeve enclosing the ratchet wheel, the sleeve being filled with a liquid having a low vapor pressure or a low viscosity, or a lubricating gas.

12. A vibratory drive system as claimed in claim 11, wherein the sleeve is filled with silicone oil.

13. A vibratory drive system as claimed in claim 1, wherein the vibratory member is a part of a mechanical resonator forming the time keeping element of an electric timepiece the resonant vibrations of said mechanical resonator being maintained by an electric drive.

14. A vibratory drive system as claimed in any one of the preceding claims, wherein a torque is magnetically transferred from the ratchet wheel to a rotatable coupling wheel driving the gear train of a timepiece.

15. A motion converter comprising a support adapted to be rigidly fastened to an element which performs a periodic oscillatory movement, at ratchet disc arranged loosely on said support with the plane of the disc lying approximately parallel to the plane of said movement, a pair of abutment blocks or stops fixed to said support, arranged on opposite diametral points of the disc and spaced apart a distance slightly greater than the diameter of the disc, and a pair of parallel oppositely directed pawls fixed to the support and arranged so as to be capable of engaging the disc at diametrically opposed peripheral locations, the inertia of the disc under the effect of the periodic movement causing its periphery to engage the stops and pawls, the engagement of the ratchet teeth with said pawls causing the periodic movement of said element to be transformed into unidirectional rotary movement of said disc.

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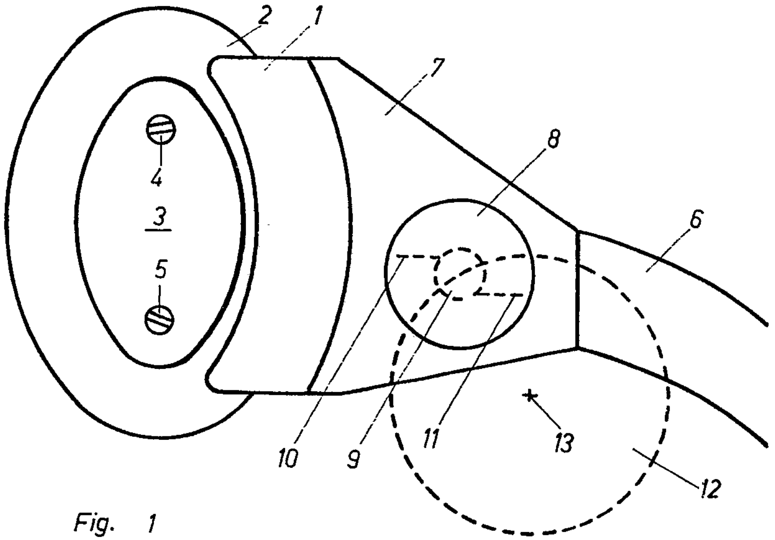


Fig. 1

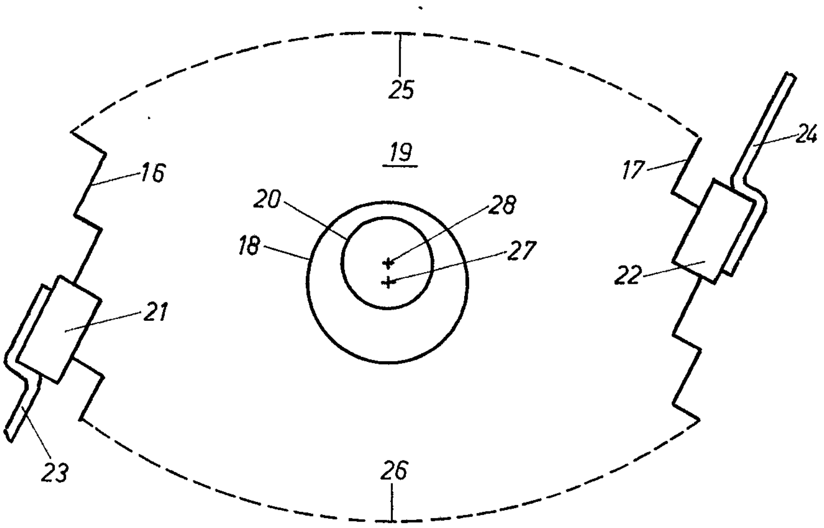
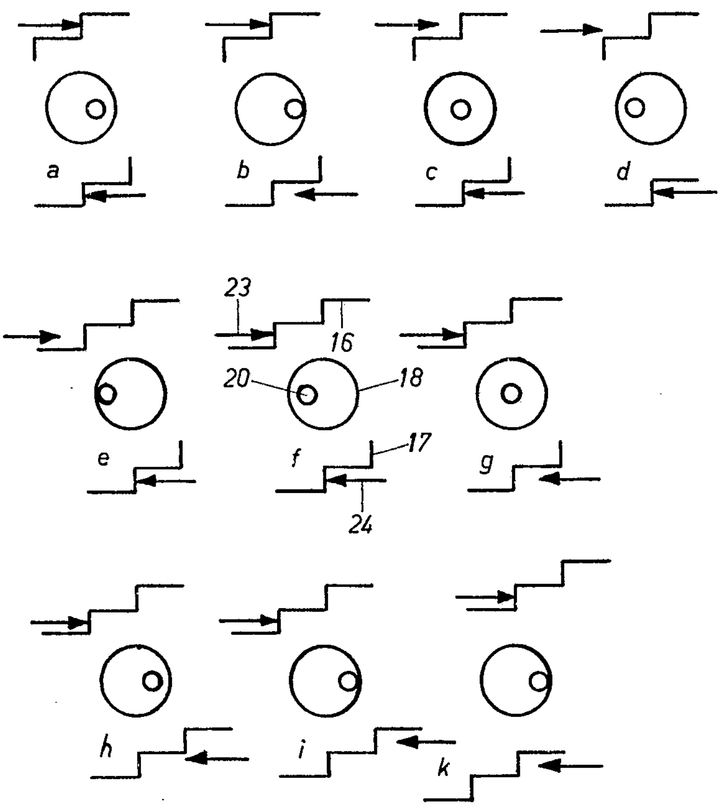


Fig. 2

Fig. 3



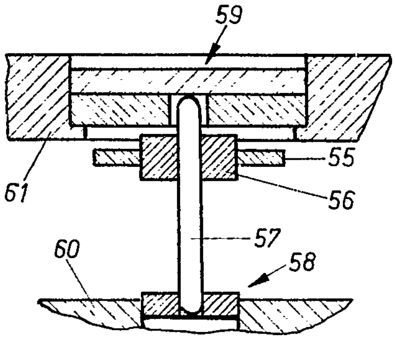


Fig. 6

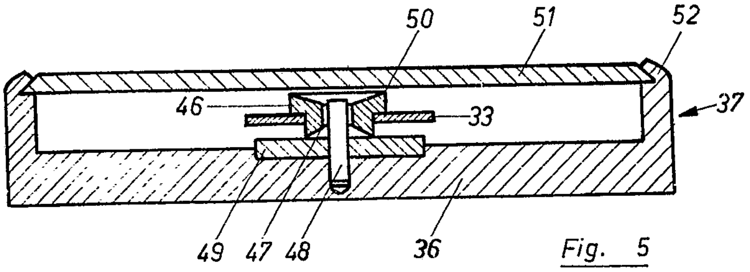

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Fig. 5

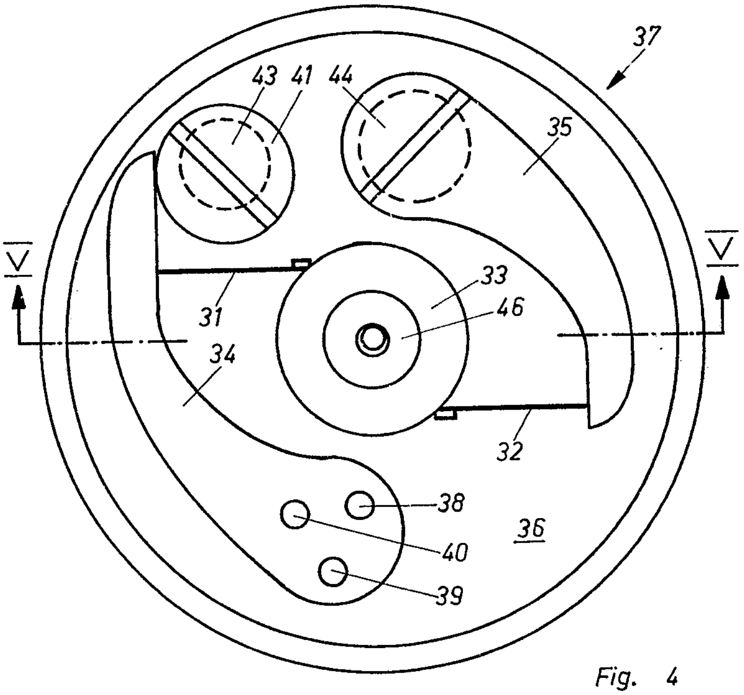
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Fig. 4

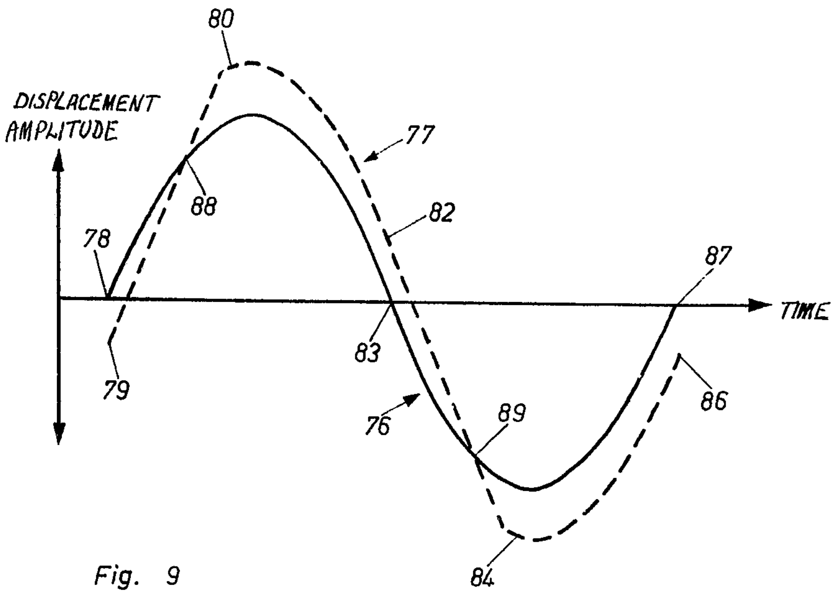
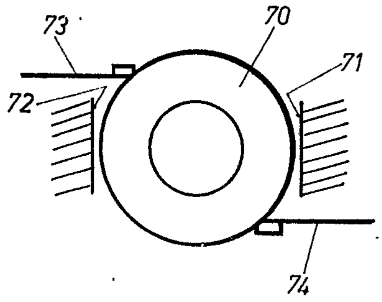


Fig. 9



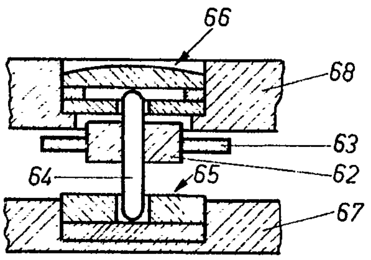


Fig. 8

Fig. 7