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(54) IMPROVEMENTS IN OR RELATING TO TUNING-FORK TYPE ELECTRONIC CLOCKS

(71) We, BULOVA WATCH COMPANY INC., a corporation organised under the laws of the State of New York, one of the United States of America, of 630 Fifth Avenue, City and State of New York, United States of America, 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:—

This invention relates generally to an electronic timepiece.

In U.S. Patent No. 2,971,323 of Hetzel, there is disclosed an electronic timepiece including a tuning fork having a relatively high frequency, a battery powered transistorized drive circuit acting to sustain the vibratory motion of the fork. The reciprocating motion of the fork, which serves as a time-keeping standard, is transformed into rotary motion by means of a ratchet and pawl mechanism whose index finger is attached to one tine of the fork. The finger engages and advances a ratchet wheel provided with a pinion for operating the timepiece hands through a train of gears.

The invention aims to provide an improved electronic timepiece.

According to the invention there is provided an electronic timepiece comprising: a tuning fork having a pair of tines, means operatively coupled to said fork to sustain said fork in vibration at its natural frequency, and means including a motion transformer to convert the vibratory action of said fork into rotary motion to drive a gear train coupled to time-indicating hands, said means including at least one V-shaped indexing element whose ends are secured to the tines at corresponding points thereon, whereby the vertex of the element is caused to reciprocate in a rectilinear path substantially at right angles to the direction of tine motion, a ratchet wheel mounted on a worm gear, the teeth of said wheel being engaged by the vertex of said element whereby with each forward stroke thereof, said wheel is advanced one increment.

In one form of the invention, the electronic timepiece or clock comprises a tuning fork having a permanent magnet assembly secured to one tine thereof, and a hollow coil assembly to the other tine thereof, the magnet being inserted in the coil to provide an electromagnetic transducer for sustaining the fork in vibration. Bridged between the tines is a V-shaped indexing element whose ends are secured to corresponding points on the tines and whose vertex is flattened to define a rectangular tongue, the lower edge of which engages the ratchet teeth of an index wheel. The tongue is caused to undergo rectilinear motion at right angles to the direction of tine vibration, thereby to drive the index wheel. The index wheel is mounted on a worm gear supported between end pivots, one of which is spring-biased to create sufficient friction to prevent retrograde movement of the index wheel. The worm gear engages the first wheel in a gear train serving to drive the hands of the clock.

While such a clock is self-starting, accurate and reliable as well as being producable at low cost, in practice, the magnitude of voltage necessary to power the mechanism is such that more than one battery cell is required. In order to drive the fork with sufficient amplitude to advance the ratchet wheel one tooth per vibratory cycle, one needs a voltage at a level of 2.8 volts. This dictates the use of two 1.4 volt mercury cells in series.

Mercury cells are preferred in that such cells are characterized by a voltage which remains substantially constant during the full operating life of the cell and does not decline as is the case with conventional dry batteries. Since the amplitude of the tuning fork, as explained in the above-identified Hetzel patent, is governed with reference to the level of battery voltage, a constant battery voltage level makes possible effective amplitude stabilization. However, mercury cells are costly, and the need for two cells is objectionable.

Moreover, in such a clock, in the course of each vibratory cycle, when the two tines move away from each other, the V-shaped indexing element produces a forward stroke that advances the ratchet wheel one tooth, but when the two tines draw toward each other, the indexing element produces a return stroke which tends to cause retrograde motion of the wheel. The ratchet wheel is subjected to sufficient friction to prevent such retrograde motion.

In another form of the invention, the clock includes a motion converter constituted by an indexing mechanism adapted to exploit both the in and out movements of the tuning fork, whereby uni-directional rotary motion results from both movements.

A significant advantage of the motion converter in accordance with this form of the invention is that because both the in and out movements of the fork are converted into rotary motion, the amplitude of fork vibration necessary to provide a pre-determined advance of the indexing wheel is only half that required by the prior arrangement. This makes it possible to operate with half the fork amplitude to produce the same wheel advance, as a consequence of which the battery voltage for operating the system need be only half of that previously required.

The tuning fork is sustained in vibratory motion at its natural frequency by an electromagnetic drive circuit or equivalent means. Bridged between the tines of the fork are two V-shaped indexing elements, each having a flattened vertex to define a rectangular tongue. The two elements are attached in opposing relationship to the tine of the fork, whereby when the two tines move toward each other, one of the tongues advances at right angles to the direction of tine vibration, while the other tongue retracts at right angles to the direction of tine vibration, whereas when the two tines move away from each other, the one tongue retracts while the other advances.

For a better understanding of the invention, reference is made, by way of example, to the following detailed description to be read in conjunction with the accompanying drawings, wherein:

Fig. 1 is an elevational rear view (similar to Fig. 8) of a first embodiment of a tuning-fork type electronic clock in accordance with the invention;

Fig. 2 is a schematic diagram of the electrical circuit associated with the tuning fork in the clock;

Fig. 3 is a section taken through the clock structure;

Fig. 4 is a separate perspective view of the tuning fork and its associated electromagnetic transducer;

Fig. 5 is a perspective view of the indexing element associated with the fork;

Fig. 6 is a plan view of the indexing element and the ratchet wheel driven thereby;

Fig. 7 is a sectional view of the electromagnetic transducer associated with the tines of the tuning fork;

Fig. 8 is a plan view (similar to Fig. 1) of a second embodiment of an electronic clock of the tuning fork type including a push-pull indexing mechanism in accordance with the invention;

Fig. 9 is a separate perspective view of the tuning fork and the indexing elements attached thereto;

Fig. 10 is a perspective view of one of the indexing elements;

Fig. 11 is a sectional view taken through the clock;

Fig. 12 shows in side view, the relationship between the indexing elements and the index wheel; and

Fig. 13 is a plan view of the indexing mechanism.

Referring now to Fig. 1, there is shown a tuning-fork type electronic clock in accordance with a first embodiment of the invention, said clock comprising a U-shaped fork generally designated by numeral 10, having a pair of tines 10A and 10B. The fork is constructed of a single strip of metal having indentations at nodal points 10C and 10D adjacent the base 10E. The fork is attached to a mounting post 11 by a pair of tabs 12, each of which is bent to embrace base 10E. Mounting post 11 is anchored in pillar plate 13.

The free ends of tines 10A and 10B are provided with cut-outs to define mounting fingers holding a coil assembly 14 and a magnet assembly 15, which together constitute the electromagnetic transducer for sustaining the fork in vibration. The operating frequency of the fork is preferably 180 H_z, for while the clock is designed for battery operation, at this frequency it becomes possible to synchronize the operation of the fork with a 60 H_z power line (60 H_z is an integral sub-multiple of 180 H_z), thereby providing a timepiece of high accuracy. But should a-c power fail, the fork would still continue to function accurately on battery power. In practice, sync pulses may be derived inductively from the power line, thereby avoiding the need for a wired connection thereto.

The vibratory action of the fork is converted into rotary motion by a mechanical motion transformer constituted by a generally V-shaped indexing element 16, whose ends are attached at corresponding positions to tines 10A and 10B, the ends fitting into holes in the tines and being epoxied or otherwise bonded thereto. The indexing element in practice is preferably made from a single piece of stainless steel round wire having a diameter of .006 inches.

The round wire is flattened at the vertex of the indexing element to define a vertically oriented rectangular tongue 16A, better seen in Fig. 5, and the ends of the element are bent outwardly and flattened to define vertically oriented feet 16B and 16C. The sides of the indexing element are also flattened to define horizontally oriented legs 16D and 16E, whereby all that remains round in the wire are the links between the legs and the feet, and the links between the legs and the tongue.

As the vibrating tines move toward and away from each other, flexure occurs in the feet 16B and 16C of the indexing element, causing tongue 16A joined to legs 16D and 16E to undergo rectilinear motion at right angles to the motion of the tines. Since both tines oscillate to an equal extent, tongue 16A will move a distance equal to the distance travelled by an individual tine at the point at which the feet (16B and 16C) are connected thereto. Thus, as best seen in Fig. 6, as the tines vibrate, the tongue of the indexing element in the course of each cycle executes a forward stroke along the longitudinal axis of the fork and a return stroke along the same axis.

The lower edge of tongue 16A of the indexing element engages the ratchet teeth on an index wheel 17 such that with each forward stroke of the tongue the wheel is advanced one increment. The tuning fork has no pivots or bearings and its timekeeping action is therefore independent of the effects of friction. The amplitude of the fork tines is chosen so that the movement of tongue 16A is about one and one half times the distance between successive teeth on the index wheel. However, no pawl is used to prevent retrograde motion of the wheel. Such retrograde motion is prevented by a frictional bearing for the index wheel.

Index wheel 17 is integral with a worm gear 18, the two elements being preferably made of high-strength, low-friction plastics material. The worm gear is mounted for rotation between two tapered pivots 19 and 20, which project into holes bored in the opposite ends of the worm gear and index wheel shaft. Pivot 19 is rigidly supported whereas pivot 20 is borne on the free end of a flat spring 21, mounted on a bracket 22. Spring 21 is pre-stressed to apply axial pressure against the worm gear. In practice, the pivots are formed of hardened, highly polished stainless steel and are pointed to a 20° included angle.

The direction of pitch in the worm is chosen so that as it rotates, should there be any load imposed on the index wheel and the worm integral therewith, its direction is toward the fixed pivot 19, thereby preventing the worm from moving away from the fixed pivot under load conditions. The resultant combination of forces (that of friction at the pivots and the lesser friction of the indexing element and index wheel), prevents retrogression of the wheel during the return stroke of the indexing tongue.

Because the teeth in the ratchet wheel are engaged by the broad lower edge of the tongue, shock or vibration causing lateral displacement of the tongue relative to the wheel will not effect disengagement therebetween. The indexing element is downwardly biased against the index wheel which also serves to prevent disengagement therebetween. Thus the clock is capable of uninterrupted operation under the most arduous field conditions, for the clock includes no delicate balance wheel or motion transformer that may be rendered inoperative or upset by shock forces.

Intermeshing with worm gear 18 is a worm wheel 23 mounted on a center shaft 24 whose end, as shown in Fig. 3, terminates in the second hand 25 of the clock. The various time-indicating hands are associated with a dial plate 26. Worm wheel 23 has sixty teeth, the worm gear having a single lead pitch. Index wheel 17 has one hundred and eighty teeth to match the 180 H_z fork frequency and with this combination, worm wheel 23 makes one revolution per minute so that the second hand completes a full turn every minute.

Also keyed to shaft 24 at a position directly below worm wheel 23 is a pinion 27 having six teeth and which, in turn, drives a sixty-tooth gear 28. Gear 28 rotates on a shaft 29 and is fitted to a ten-tooth pinion 30 through a slip clutch arrangement that permits the setting of the hands without disturbing the driving portion of the train.

The ten-tooth pinion 30 drives a sixty-tooth gear 31 provided with a sixteen-tooth pinion 32. Fastened to the gear assembly 31, 32 is a tubular shaft 33 concentric with center shaft 24 and carrying the minute hand 34. The sixteen-tooth pinion 32 drives a forty-eight tooth gear 35 having a pinion 36 provided with fourteen teeth, pinion 36, in turn driving a fifty-six tooth gear 37 carrying the hour hand 38.

Gear 35, commonly called the minute wheel, which is combined with pinion 36, operates on the same shaft 29 as the clutch gear 28. This simplified arrangement is advantageous, for only one critical center distance for the gears is required, outside that of the worm and index wheel assembly. An idler gear 39 is required in the hand-setting arrangement, but this is not critical as far as center distance is concerned.

In the above described gear train assembly, all parts thereof may be fabricated of good-grade plastics material except for the two main arbors, which are preferably of stainless steel. By using stainless steel for all metal bearing parts, one is able to dispense with the need for a lubricant.

Coil assembly 14, as shown separately in Fig. 7 is constituted by a tubular coil former 40 divided by an annular partition 41 into two sections, one having a drive coil 42 wound therein, and the other a phase-sensing or pick-up coil 43. In practice, since the drive coil has more turns than the phase sensing coil, a portion of the phase-sensing former section may be occupied by drive coil turns, so that the drive coil is then made up of two series-connected parts.

Coil former 40 is provided with a cylindrical extension 44 projecting axially from one end thereof, which extension has one groove 44A adapted to receive the U-shaped cut-out on the end of tine 10A, and a second groove 44B for accommodating a timing regulator 45.

This regulator is in the form of an unbalanced loading mass constituted by a round piece of wire with a loop and a circular portion to fit into the coil form groove, such that by turning the regulator to different angular positions, the orientation of the unbalanced loading mass is shifted to bring about a fine adjustment in timing.

The three wires from coils 42 and 43 are connected to an electronic circuit housed in a module 46 secured to the pillar plate. The wires from coil assembly 14 run along the length of tine 10A and are fastened thereto, the wires then leaving the tine at the nodal point 10C to go to module 46. Since there is virtually no motion at nodal point 10C, negligible flexing of the wires is experienced despite the fact that the tine carrying the wires is in constant vibration.

Magnet assembly 15 is constituted by three parts, namely a permanent magnet rod 47, a mounting plug 48, preferably made of brass and cemented or otherwise bonded to one end of the magnet rod, and a regulator 49. Because the plug 48 is made of non-ferromagnetic material, the open magnetic flux path extends from the magnet rod, coaxially disposed within coils 42 and 43 through these coils, but is magnetically isolated from tine 10B on which the magnet assembly is mounted.

Plug 48 is provided with a groove 48A to receive the cutout in tine 10B and a groove 48B to receive the regulator 49, which is identical in form and function to regulator 45 on the coil assembly.

The electronic circuit housed in module 46 is powered by a replaceable battery cell 50, held in a suitable socket or by clips on pillar plate 13. The circuit, as shown in Fig. 2, is constituted by a transistor 51, whose emitter is connected to the positive pole of battery 50, the negative pole thereof being connected through drive coil 42 to the collector of the transistor. The negative pole is also coupled through phase-sensing coil 43 and through a resistance-capacitance bias circuit 52 to the base of the transistor. A bypass capacitor 53 is connected between the emitter and the junction of the phase-sensing coil 43 and the R—C bias circuit 52 to prevent parasitic oscillation.

In operation, when transistor 51 is rendered momentarily conductive, a current pulse derived from battery 50 flows through drive coil 42. The resultant magnetic field produces an axial thrust on magnet assembly 15, this action producing an equal and oposite repaction on the coil assembly 14. Since magnet assembly 15 is mounted on tine 10B and coil assembly 14 on tine 10A, the tines are deflected in opposing directions.

The movement of the magnet and coil assemblies relative to each other induces a back EMF both in drive coil 42 and in phase-sensing coil 43. Since this reciprocation is in accordance with fork motion, the back EMF assumes the form of an alternating voltage whose frequency corresponds to fork frequency (i.e., 180 H_z). The voltage induced in sensing coil 43 is applied to the base of the transistor and overcomes a bias imposed thereon by the R—C circuit, thereby to control the instant or phase position in the course of each cycle when the drive pulse is to be delivered to the drive coil.

The back EMF developed in the drive coil is in series opposition to the voltage applied by battery 50 between emitter and collector of the transistor. Battery voltage has a constant value, whereas the back EMF is a function of tine amplitude. The operation of the transistor during its conductive periods is controlled in accordance with the algebraic sum of the battery and back EMF voltages applied thereto, and the amplitude of the fork vibration is thereby regulated. The behavior of this and similar circuits is explained more fully in U.S. Patent 2,971,323.

The operating frequency of the fork is determined not by the fork per se, but by the combined mass of the tines and the assemblies mounted thereon. For highest operating efficiency, it is essential that symmetry exist as between the centers of gravity of the two oscillating masses with respect to the axis of symmetry of the fork. In practice, therefore, magnetic assembly 15 is made such that its mass and center of gravity substantially match that of the coil assembly 14.

Referring now to Fig. 8, there is shown a tuning-fork type electronic clock in accordance with a second embodiment of the invention, comprising a U-shaped fork generally designated by numeral 10′, having a pair of tines 10A′ and 10B′. The fork is constructed of a single strip of metal having indentations at nodal points 10C′ and 10D′ adjacent the base 10E′. The fork is attached to a mounting post 11′ by a pair of spaced tabs 12′, each of which is bent to embrace base 10E′. Mounting post 11′ is anchored in pillar plate 13′.

The free ends of tines 10A′ and 10B′ are provided with cut-outs to define mounting fingers for holding a coil assembly 14′ and a magnet assembly 15′, which together constitute the electromagnetic transducer for sustaining the fork in vibration. The operating frequency of the fork is preferably 180 Hz, for while the clock is designed for battery operation, at this frequency it becomes possible to synchronize the operation of the fork with a 60 Hz power line (60 Hz is an integral submultiple of 180 Hz), thereby providing a timepiece of high accuracy. But should a-c power fail, the fork would still continue to function accurately on battery power. In practice, sync pulses may be derived inductively from the power line, thereby avoiding the need for a wired connection thereto.

The vibrator action of the fork is converted into rotary motion by a mechanical motion transformer constituted by a pair of generally V-shaped indexing elements 16′ and 16″. The ends of element 16′ are attached at corresponding positions to tines 10A′ and 10B′ so that the vertex thereof is forwardly directed, the ends fitting into holes in the tines and being epoxied or otherwise bonded thereto. The ends of element 16″ are similarly attached to tines 10A′ and 10B′, but this element is positioned so that the vertex thereof is rearwardly directed. The indexing elements are preferably made from a single piece of stainless steel round wire having a diameter of .006 inches.

As best seen in Fig. 10, the round wire of each element is flattened at the vertex thereof to define a vertically oriented rectangular tongue 16A′, and the ends of the element are bent outwardly and flattened to define vertically oriented feet 16B′ and 16C′. The sides of the indexing element are also flattened to define horizontally oriented legs 16D′ and 16E′, whereby all that remains round in the wire are the links between the legs and the feet, and the links between the legs and the tongue.

As the vibrating tines move toward and away from each other, flexure occurs in the feet 16B′ and 16C′ of each indexing element, causing tongue 16A′ joined to legs 16D′ and 16E′ to undergo rectilinear motion at right angles to the motion of the tines. Since both tines ocillate to an equal extent, tongue 16A′ will move a distance equal to the distance travelled by an individual tine at the point at which the feet (16B′ and 16C′) are connected thereto. Thus, as best seen in Fig. 13, as the tines vibrate, the tongue of each indexing element, in the course of each cycle, executes a forward stroke along the same axis. But since elements 16′ and 16″ are in opposing relationship, when tines 10A′ and 10B′ move toward each other, element 16′ executes a forward stroke while element 16″ concurrently executes a return stroke, and when tine 10A′ and 10B′ move away from each other, the elements reverse direction.

The lower edge of tongue 16A′ of the indexing element 16′ engages the ratchet teeth on an index wheel 17′ such that with each forward stroke of the tongue 16A′ thereof, the wheel is pushed to advance one increment. The tongue of indexing element 16″ engages the ratchet teeth at another point such that with each forward stroke of the tongue, the wheel is pulled to advance another increment. The tuning fork has no pivots or bearing and its timekeeping action is therefore independent of the effects of friction. No pawl is used to prevent retrograde motion of the wheel, for as one element undergoes a return stroke, the other undergoes a forward stroke, and the wheel cannot therefore reverse direction.

Index wheel 17′ is integral with a worm gear 18′, the two members being preferably made of high-strength, low friction plastics material. The worm gear is mounted for rotation between two tapered pivots 19′ and 20′, which project into holes bored in the opposite ends of the worm gear and index wheel shaft. Pivot 19′ is rigidly supported whereas pivot 20′ is borne on the free end of a flat spring 21′, mounted on a bracket 22′. In practice, the pivots are formed of hardened, highly polished stainless steel and are pointed to a 20° included angle.

The direction of pitch in the worm is chosen so that as it rotates, should there be any load imposed on the index wheel and the worm integral therewith, its direction is toward the fixed pivot 19′, thereby preventing the worm from moving away from the fixed pivot under load conditions.

Because the teeth in the ratchet wheel are engaged by the broad lower edge of each tongue of the indexing elements, shock or vibration causing lateral displacement of the tongue relative to the wheel will not effect disengagement therebetween. The indexing elements are downwardly biased against the index wheel which also serves to prevent disengagement therebetween. Thus the clock is capable of uninterrupted operation under the most arduous field conditions, for the clock includes no delicate balance wheel or motion transformer that may be rendered inoperative or upset by shock forces.

Intermeshing with worm gear 18′ is a worm wheel 23′ mounted on a center shaft 124′ whose end, as shown in Fig. 11, terminates in the second hand 25′ of the clock.

The various time-indicating hands are associated with a dial plate 26′. Worm wheel 23′ has sixty teeth, the worm gear having a single lead pitch. Index wheel 17′ has one hundred and eighty teeth to match the 180 Hz fork frequency. With this combination, worm wheel 23′ makes one revolution per minute so that the second hand completes a full turn every minute.

Also keyed to shaft 24′ at a position directly below worm wheel 23′ is a pinion 27′ having six teeth which, in turn, drives a sixty-tooth gear 28′. The gear train arrangement for operating hour hand 38′ and minute hand 34′ is essentially the same as that disclosed in the first embodiment and the description thereof will therefore not be repeated.

Coil assembly 14′, as shown in Fig. 8 is constituted by a tubular coil former 31′ divided by an annular partition into two sections, one having a drive coil wound therein, and the other a phase-sensing or pick-up coil. In practice, since the drive coil has more turns than the phase sensing coil, a portion of the phase-sensing former section may be occupied by drive coil turns, so that the drive coil is then made up of two series-connected parts.

Coil former 31′ is provided with a cylindrical extension 32′ projecting axially from one end thereof, which extension has one groove adapted to receive the U-shaped cutout on the end of tine 10A′, and a second groove for accommodating a timing regulator 33′.

The regulator is in the form of an unbalanced loading mass constituted by a round piece of wire with a loop and a circular portion to fit into the coil former groove, such that by turning the regulator to different angular positions, the orientation of the unbalanced loading mass is shifted to bring about a fine adjustment in timing.

The three wires from the drive and phase sensing coils are connected to an electronic circuit housed in a module 34′ secured to the pillar plate. The wires from coil assembly 14′ run along the length of tine 10B′ and are fastened thereto, the wires at the nodal point 10C′ then leaving the tine to go to module 34′. Since there is virtually no motion at nodal point 10C′, negligible flexing of the wires is experienced despite the fact that the tine carrying the wires is in constant vibration.

Magnet assembly 15′ is constituted by three parts, namely a permanent magnet rod 35′, a mounting plug 36′, preferably made of brass and cemented or otherwise bonded to one end of the magnet rod, and a regulator 37′. Because the plug is made of non-ferromagnetic material, the open magnetic flux path extends from the magnet rod, coaxially disposed within coils of assembly 14′ through these coils, but is magnetically isolated from tine 10A′ on which the magnet assembly is mounted.

Plug 36′ is provided with a groove to receive the cutout in tine 10A′ and a groove to receive the regulator 37′ which is identical in form and function to regulator 33′ on the coil assembly.

The electronic circuit housed in module 34′ is powered by a replaceable battery cell 37′ held in a suitable socket or by clips on pillar plate 13′. The circuit is the same as that disclosed in the first embodiment.

The operating frequency of the fork is determined not by the fork per se, but by the combined mass of the tines and the assemblies mounted thereon. For highest operating efficiency, it is essential that symmetry exist as between the centers of gravity of the two oscillating masses with respect to the axis of symmetry of the fork. In practice, therefore, magnetic assembly 15′ is made such that its mass and center of gravity substantially match that of the coil assembly 14′.

While there have been shown and described preferred embodiments of a tuning fork clock in accordance with the invention, it will be appreciated that many changes and modifications may be made therein without, however, departing from the scope of the invention claimed. For example, the indexing elements, rather than being made of round wire as described herein, with flattened sections, may be made entirely of flat wire twisted at appropriate points to define the flat legs and tongue sections of the element. In a clock of the first embodiment type, it is possible, with a redesigned transducer, to operate with only a single (1.4 v) power cell, rather than two cells. But even with this redesigned transducer, the double index finger arrangement as shown in Figs. 8 and 9 is advantageous, for with the resultant reduction in fork amplitude, the current drain is reduced by about one-half, thereby almost doubling the life of the single power cell.

It will be appreciated that with the electronic time pieces described a tuning-fork type electronic clock may be provided which is accurate and reliable in operation, and which may be produced and sold at relatively low cost. In addition, an efficient and rugged motion transformer may be provided for an electronic clock of the above-described type, which converter is capable of operating successfully under arduous environmental conditions.

WHAT WE CLAIM IS:—

1. An electronic timepiece comprising: a tuning fork having a pair of tines, means operatively coupled to said fork to sustain said fork in vibration at its natural frequency, and means including a motion transformer to convert the vibratory action of said fork

into rotary motion to drive the gear train coupled to time-indicating hands, said means including at least one V-shaped indexing element whose ends are secured to the tines at corresponding points thereon, whereby the vertex of the element is caused to reciprocate in a rectilinear path substantially at right angles to the direction of tine motion, a ratchet wheel mounted on a worm gear, the teeth of said wheel being engaged by the vertex of said element whereby with each forward stroke thereof, said wheel is advanced one increment.

2. A timepiece as claimed in Claim 1, wherein said vertex is constituted by a rectangular tongue whose lower edge engages said teeth, said tongue lying in a plane transversely disposed relative to said rectilinear path.

3. A timepiece as claimed in Claim 2, wherein said V-shaped indexing element is formed by a piece of round wire whose ends are bent outwardly and are attached to said tines, the vertex being flattened to define said tongue.

4. A timepiece as claimed in Claim 3, wherein the sides of said element are flattened.

5. A timepiece as claimed in any one of the preceding claims, said worm gear engaging a first wheel in said gear train and being mounted for rotation on a friction bearing introducing sufficient drag to prevent retrograde motion of the ratchet wheel on the return stroke of the vertex.

6. A timepiece as claimed in Claim 5, and wherein said friction bearing is formed by two tapered pivots received in bores in the ends of the assembly comprising said worm gear and ratchet wheel, one pivot being fixedly mounted, the other being spring-biased to urge said worm gear in the direction of the fixed pivot.

7. A timepiece as claimed in Claim 6, wherein the direction of the pitch of said worm gear is such that any load imposed on the gear is directed towards the fixed pivot, thereby preventing the worm from moving away from the fixed pivot under load conditions.

8. A timepiece as claimed in any one of the preceding claims, wherein said means to sustain said fork in vibration includes an electromagnetic transducer coupled to an electronic drive circuit, said transducer being constituted by a magnet assembly mounted on one tine of said fork and cooperating with a coil assembly mounted on the other tine.

9. A timepiece as claimed in Claim 8, wherein said magnet assembly is constituted by a permanent magnet rod secured to the associated tine by a non-ferromagnetic spacer, whereby said magnet rod is magnetically isolated therefrom.

10. A timepiece as claimed in Claim 9, wherein said spacer includes a circular groove and a timing regulator in the form of an unbalanced mass supported by a circular wire portion in said groove.

11. A timepiece as claimed in any one of the preceding claims, including two oppositely directed ones of said V-shaped indexing elements whose ends are secured to the tines, whereby the vertex of one element is caused to reciprocate in a rectilinear path substantially at right angles to the direction of tine motion and the vertex of the other element is caused to reciprocate in phase opposition to the vertex of the one element, the teeth of said wheel being engaged at different points by the vertices of said elements whereby said wheel is pushed by one vertex and pulled by the other in the course of each vibratory cycle of the tuning fork.

12. A timepiece as claimed in Claim 11, wherein each vertex is constituted by a rectangular tongue whose lower edge engages said teeth, said tongue lying in a plane transversely disposed relative to said rectilinear path.

13. An electronic timepiece substantially as hereinbefore described with reference to Figures 1 to 7 of the accompanying drawings.

14. An electronic timepiece substantially as hereinbefore described with reference to Figures 8 to 13 of the accompanying drawings.

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1384618 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig.1.

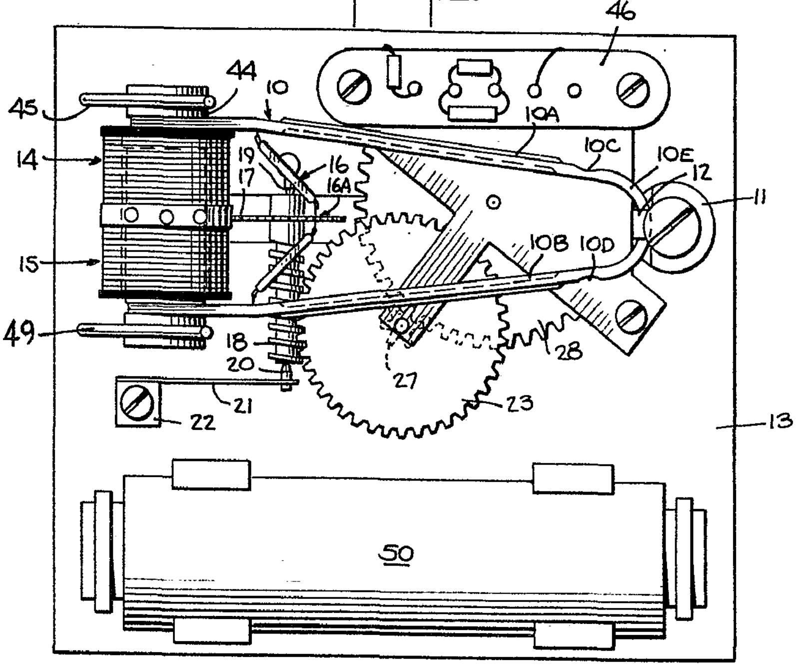
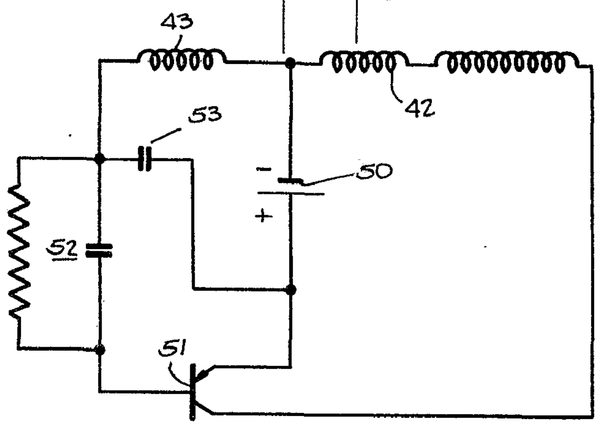


Fig.2.



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5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

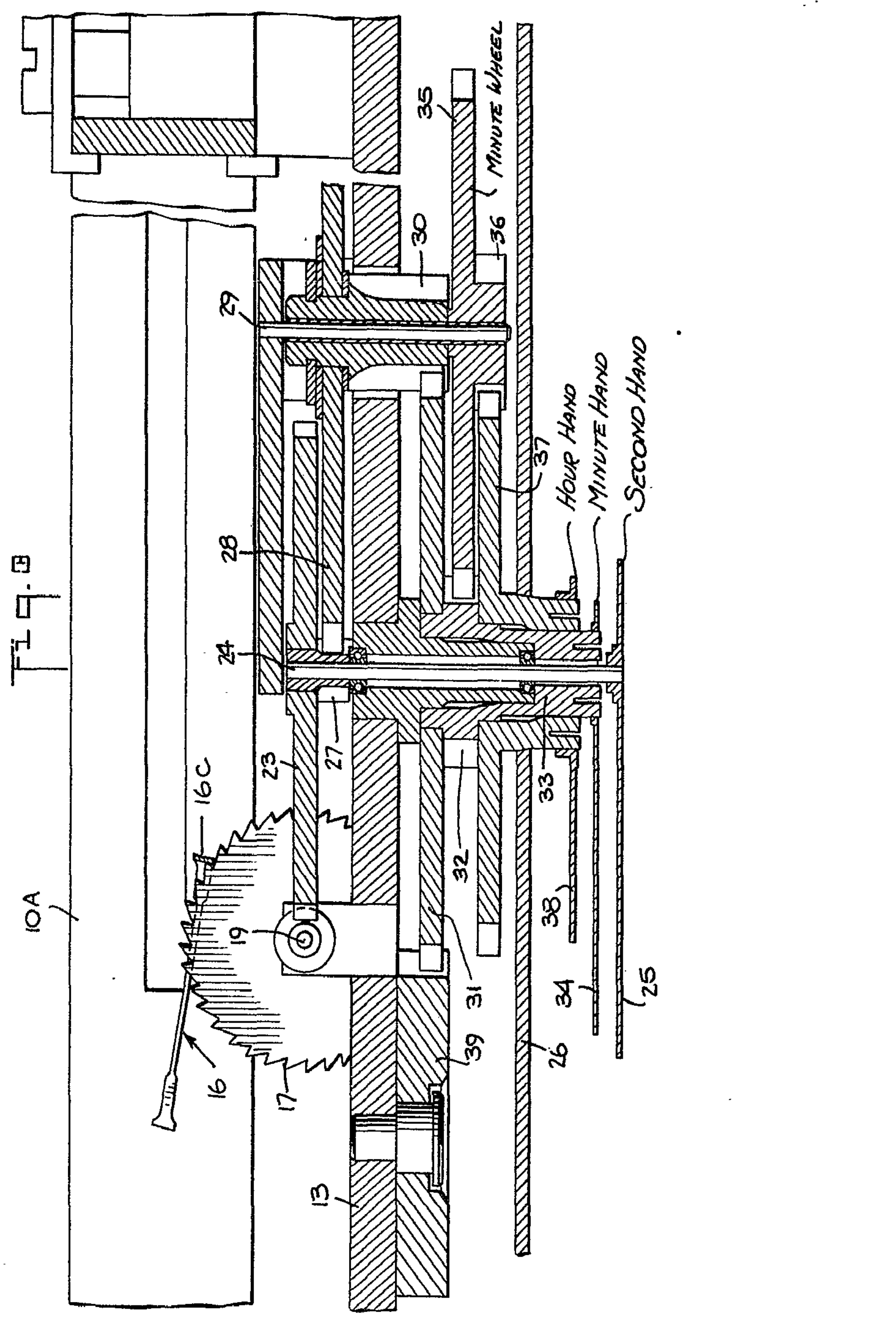
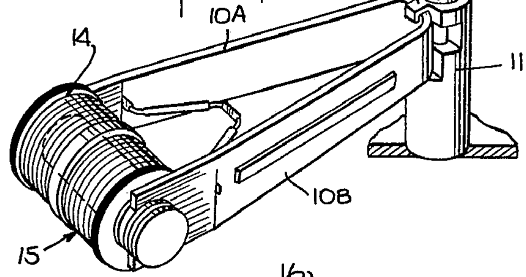


Fig. 8

Fig. 4.



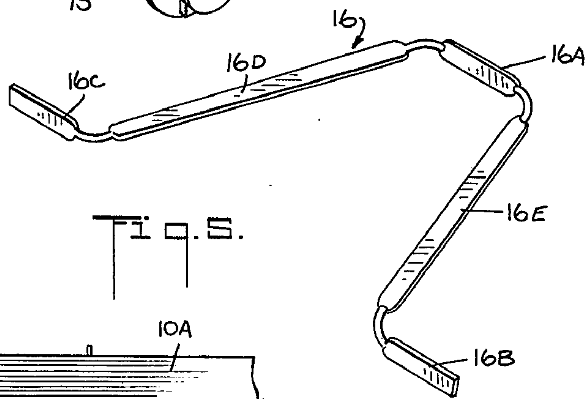


Fig. 5.

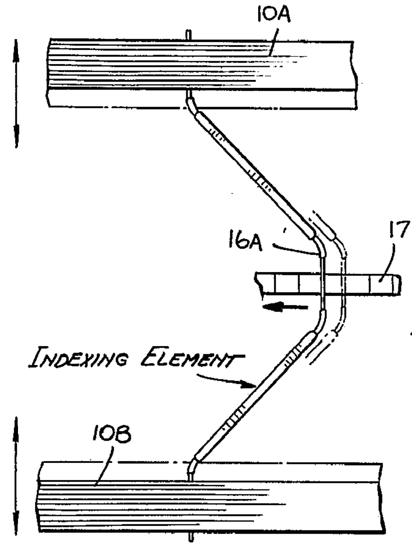
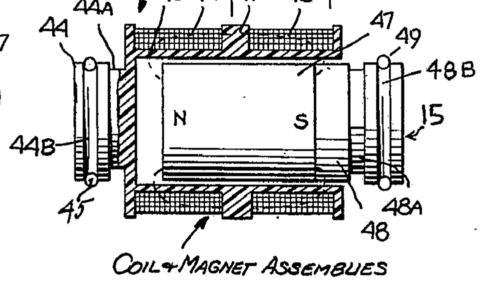


Fig. 6.

Fig. 7.

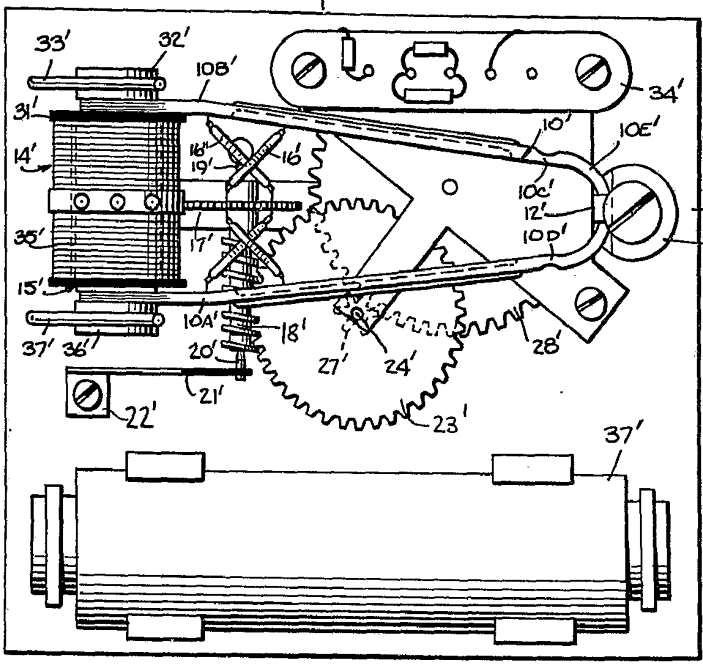


1384618 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 4

Fig. 8



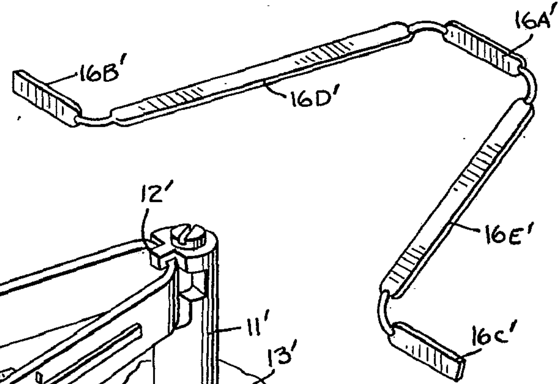


Fig. 9

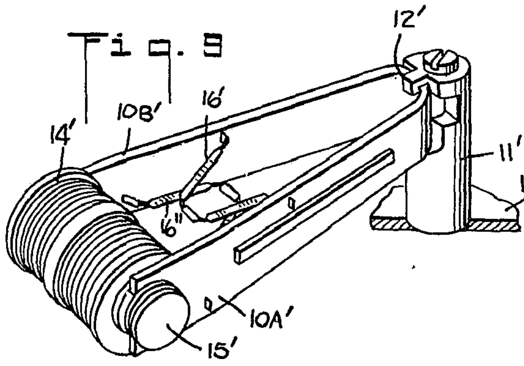


Fig. 10

1384618 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 5

Fig. 11

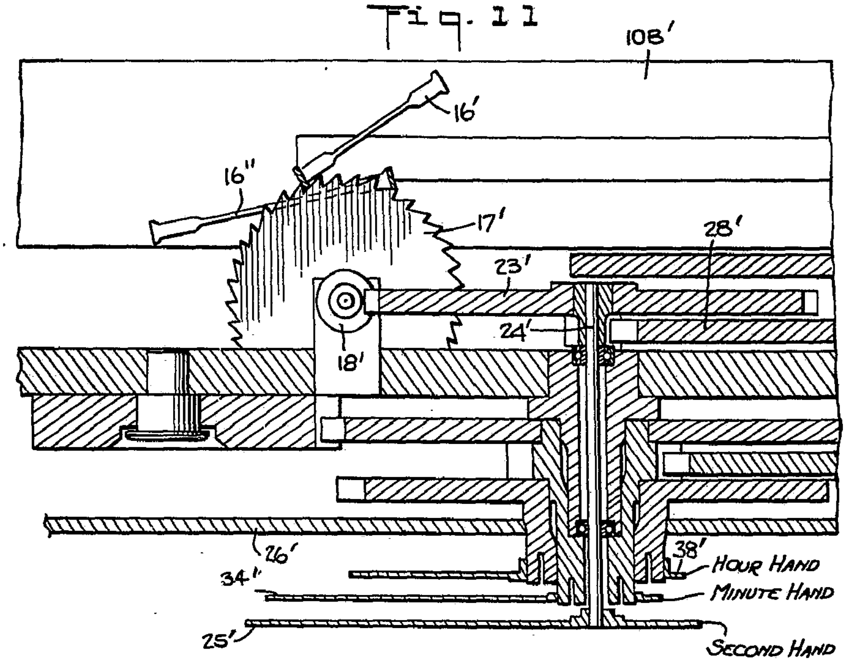


Fig. 12

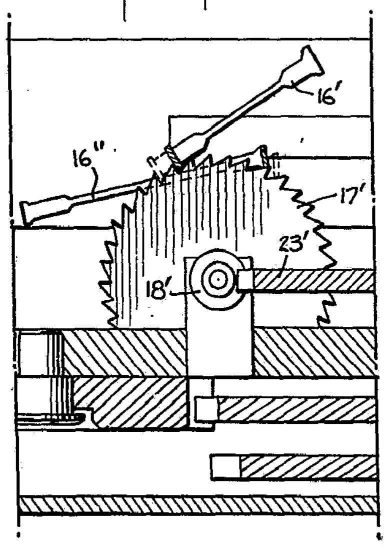


Fig. 13