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(54) **MECHANICAL TIMEPIECE WITH TIMED ANNULAR BALANCE POWER GENERATING CONTROL MECHANISM**

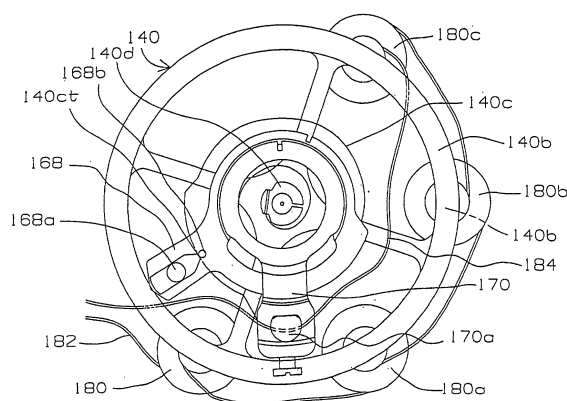
(57) A mechanical timepiece according to the invention includes a mainspring, a front train wheel and an escapement & speed control apparatus. The escapement & speed control apparatus includes a balance with hairspring, an escape wheel & pinion and a pallet fork.

The mechanical timepiece according to the invention further includes a crystal oscillator constituting an oscillation source, IC including a dividing unit for outputting a signal with respect to time by inputting an output signal outputted by oscillating the crystal oscillator and dividing the output signal and an electricity storing member for operating IC. The mechanical timepiece accord-

ing to the invention further includes a rate detecting unit for detecting a rate of the mechanical timepiece and a balance power generation control unit constituted to control a period of rotational oscillation of the balance with hairspring based on a divided signal divided by the dividing unit and an operational state signal indicating the rate detected by the rate detecting unit and generate power by the rotational oscillation of the balance with hairspring.

By the constitution, rotation of the balance with hairspring can be controlled accurately and the rate of the mechanical timepiece can be adjusted accurately.

FIG. 2



Description

[Technical Field]

5 **[0001]** The present invention relates to a mechanical timepiece capable of displaying time with high accuracy.

[0002] The invention particularly relates to a mechanical timepiece having a balance power generation control mechanism capable of controlling a period of rotational oscillation of a balance with hairspring by energy generated by using the rotational oscillation of the balance with hairspring in order to adjust the rate of the timepiece.

10 [Background of the Invention]

(1) Constitution of mechanical timepiece

15 **[0003]** According to a conventional mechanical timepiece, as shown in Fig. 10 and Fig. 11, a movement (machine body) 1100 of a mechanical timepiece is provided with a main plate 1102 constituting a base plate of the movement. A winding stem 1110 is rotatably integrated to a winding stem guide hole 1102a of the main plate 1102. A dial 1104 (shown in Fig. 11 by an imaginary line) is attached to the movement 1100.

[0004] Generally, in both sides of the main plate, a side thereof having the dial is referred to as "back side" of the movement and a side thereof opposed to the side having the dial is referred to as "front side" of the movement. A train wheel integrated to the "front side" of the movement is referred to as "front train wheel" and a train wheel integrated to the "back side" of the movement is referred to as "back train wheel".

25 **[0005]** A position in the axis line direction of the winding stem 1110 is determined by a switch apparatus including a setting lever 1190, a yoke 1192, a yoke spring 1194 and a setting lever jumper 1196. A winding pinion 1112 is provided rotatably at a guide shaft portion of the winding stem 1110. When the winding stem 1110 is rotated in the state in which the winding stem 1110 is disposed at a first winding stem position (0-stage) on a side most proximate to the inner side of the movement along the rotational axis line, the winding pinion 1112 is rotated via rotation of a clutch wheel. A crown wheel 1114 is rotated by rotation of the winding pinion 1112. A ratchet wheel 1116 is rotated by rotation of the crown wheel 1114. By rotating the ratchet wheel 1116, a mainspring 1122 contained in a barrel complete 1120 is wound up. A center wheel & pinion 1124 is rotated by rotation of the barrel complete 1120. An escape wheel & pinion 1130 is rotated via rotation of a fourth wheel & pinion 1128, a third wheel & pinion 1126 and the center wheel & pinion 1124. The barrel complete 1120, the center wheel & pinion 1124, the third wheel & pinion 1126 and the fourth wheel & pinion 1128 constitute a front train wheel.

35 **[0006]** An escapement & speed control apparatus for controlling rotation of the front train wheel includes a balance with hairspring 1140, the escape wheel & pinion 1130 and a pallet fork 1142. The balance with hairspring 1140 includes a balance stem 1140a, a balance wheel 1140b and a hairspring 1140c. Based on rotation of the center wheel & pinion 1124, a cannon pinion 1150 is simultaneously rotated. A minute hand 1152 attached to the cannon pinion 1150 displays "minute". The cannon pinion 1150 is provided with a slip mechanism relative to the center pinion & wheel 1124. Based on rotation of the cannon pinion 1150, via rotation of a minute wheel, an hour wheel 1154 is rotated. An hour hand 1156 attached to the hour wheel 1154 displays "hour".

40 **[0007]** The barrel complete 1120 is supported rotatably by the main plate 1102 and a barrel bridge 1160. The center wheel & pinion 1124, the third wheel & pinion 1126, the fourth wheel & pinion 1128 and the escape wheel & pinion 1130 are supported rotatably by the main plate 1102 and a train wheel bridge 1162. The pallet fork 1142 is supported rotatably by the main plate 1102 and a pallet bridge 1164. The balance with hairspring 1140 is supported rotatably by the main plate 1102 and a balance bridge 1166.

45 **[0008]** The hairspring 1140c is a leaf spring in a helical (spiral) shape having a plural turn number. An inner end portion of the hairspring 1140c is fixed to a hairspring holder 1140d fixed to the balance stem 1140a and an outer end portion of the hairspring 1140c is fixed via a hairspring stud 1170a attached to a stud support 1170 fixed to the balance bridge 1166 by fastening screws.

50 **[0009]** A regulator 1168 is attached rotatably to the balance bridge 1166. A hairspring bridge 1168a and a hairspring rod 1168b are attached to the regulator 1168. A portion of the hairspring 1140c proximate to the outer end portion is disposed between the hairspring bridge 1168a and the hairspring rod 1168b.

(2) Rate of mechanical timepiece

55 **[0010]** Generally, according to a conventional representative mechanical timepiece, as shown by Fig. 12, with elapse of a duration time period of rewinding the mainspring from a state in which the mainspring has completely been wound up (fully wound state), mainspring torque is reduced. For example, in the case of Fig. 12, the mainspring torque is about 27 g·cm in the fully wound state, becomes about 23 g·cm after elapse of 20 hours from the fully wound state

and becomes about 18 g·cm after elapse of 40 hours from the fully wound state.

[0011] Generally, according to a conventional representative mechanical timepiece, as shown by Fig. 13, when the mainspring torque is reduced, the swing angle of the balance with hairspring is also reduced. For example, in the case of Fig. 13, when the mainspring torque is 25-28 g·cm, the swing angle of the balance with hairspring is about 240-270 degrees and when the mainspring torque is 20-25 g·cm, the swing angle of the balance with hairspring is about 180-240 degrees.

[0012] In reference to Fig. 14, there is shown a transitional change of instantaneous rate with regard to swing angle of a balance with hairspring according to a conventional representative mechanical timepiece (numerical value indicating accuracy of timepiece). In this case, the "instantaneous rate" or the "rate" is defined as "a value indicating gain or loss of a mechanical timepiece after elapse of one day after the mechanical timepiece is assumed to be left for one day while maintaining state or environment of swing angle of a balance with hairspring or the like when the rate is measured". In the case of Fig. 14, when a swing angle of a balance with hairspring is equal to or larger than 240 degrees or is equal to or smaller than 200 degrees, the instantaneous rate is retarded.

[0013] For example, according to a conventional representative timepiece, as shown by Fig. 14, when the swing angle of the balance with hairspring falls in a range of about 200 through 240 degrees, the instantaneous rate is about 0 through 5 seconds / day (gain of 0 through 5 seconds per day), however, when the swing angle of the balance with hairspring is about 170 degrees, the instantaneous rate becomes about -20 seconds / day (loss of about 20 seconds per day).

[0014] In reference to Fig. 15, there is shown a transitional change of elapse time and instantaneous rate when a mainspring is rewound from a fully wound state in a conventional representative mechanical timepiece. In this case, in the conventional mechanical timepiece, "rate" indicating gain of the timepiece or loss of the timepiece per day, is provided by integrating instantaneous rate with regard to elapse time of rewinding the balance with hairspring from a fully wound state, which is indicated in Fig. 15, over 24 hours.

[0015] Generally, according to the conventional mechanical timepiece, with elapse of duration time period of rewinding the mainspring from the fully wound state, the mainspring torque is reduced, the swing angle of the balance with hairspring is also reduced and accordingly, the instantaneous rate is retarded. Therefore, according to the conventional mechanical timepiece, by estimating loss of the timepiece after elapse of the duration time period of 24 hours, instantaneous rate when the mainspring is brought into the fully wound state, is previously gained and previously adjusted such that the "rate" indicating gain of the timepiece or loss of the timepiece per day becomes positive.

[0016] For example, according to the conventional representative timepiece, as shown in Fig. 15, although in the fully wound state, the instantaneous rate is about 3 seconds / day (gain of about 3 seconds per day), after elapse of 20 hours from the fully wound state, the instantaneous rate becomes about -3 seconds / day (loss of about 3 seconds per day), after elapse of 24 hours from the fully wound state, the instantaneous rate becomes about -8 seconds per day (loss of about 8 seconds per day) and after elapse of 30 hours from the fully wound state, the instantaneous rate becomes about -16 seconds / day (loss of about 16 seconds per day).

[0017] According to the conventional mechanical timepiece, the accuracy of the timepiece is determined by accuracy of operating the escapement & speed control apparatus including the balance with hairspring alternately repeating right rotation and left rotation, the escape wheel & pinion rotating based on rotation of the front train wheel and the pallet fork for controlling rotation of the escape wheel & pinion based on operation of the balance with hairspring.

(3) Problem which the invention intends to resolve

[0018] Therefore, in order to promote the accuracy of the timepiece, the period of the rotational oscillation of operating the balance with hairspring is obliged to increase and it is difficult to fabricate the escapement & speed control apparatus including such a balance with hairspring.

[0019] Moreover, according to the conventional mechanical timepiece, a range of capable of increasing the period of the rotational oscillation of operating the balance with hairspring is limited and accordingly, there poses a problem that a range of capable of improving the accuracy of the timepiece is limited.

[0020] Therefore, accuracy of the conventional mechanical timepiece is inferior to accuracy of a quartz type timepiece. Therefore, the user of the conventional mechanical timepiece is obliged to correct time indicated by the mechanical timepiece at every constant period of time.

(4) Object of the invention

[0021] Hence, it is an object of the invention to provide a mechanical timepiece having extremely excellent accuracy.

[0022] Further, it is other object of the invention to provide a highly accurate mechanical timepiece capable of being used over a long period of time.

[Disclosure of the Invention]

(1) Constitution of mechanical timepiece of the invention

[0023] The mechanical timepiece of the invention includes a movement constituted to include a mainspring constituting a power source of the mechanical timepiece, a front train wheel rotated by a rotational force in rewinding the mainspring and an escapement & speed control apparatus for controlling rotation of the front train wheel, the escapement & speed control apparatus including a balance with hairspring alternately repeating right rotation and left rotation, an escape wheel & pinion rotated based on rotation of the front train wheel and a pallet fork for controlling rotation of the escape wheel & pinion based on an operation of the balance with hairspring and the balance with hairspring including a hairspring, a balance stem and a balance wheel.

[0024] The mechanical timepiece of the invention further includes a crystal oscillator constituting an oscillation source, IC including a dividing unit for outputting a signal with respect to time by inputting an output signal outputted by oscillating the crystal oscillator and dividing the output signal and an electricity storing member for operating IC.

[0025] The mechanical timepiece of the invention further includes a rate detecting unit for detecting a rate of the mechanical timepiece and a balance power generation control unit constituted to control a period of rotational oscillation of the balance with hairspring based on a divided signal divided by the dividing unit and an operational state signal indicating the rate detected by the rate detecting unit and generate power by the rotational oscillation of the balance with hairspring.

[0026] It is preferable that the balance power generation control unit of the mechanical timepiece according to the invention, includes a balance magnet provided at the balance with hairspring and coils arranged to be capable of exerting magnetic force to the balance magnet, wherein the coils are capable of restraining rotation of the balance with hairspring by exerting the magnetic force to the balance magnet based on the divided signal divided by the dividing unit and the operational state signal indicating the rate detected by the rate detecting unit.

[0027] Further, it is preferable that in the balance power generation control unit of the mechanical timepiece according to the invention, current generated by the rotational oscillation of the balance with hairspring is rectified by a rectifying circuit and is stored to an electricity storing member.

[0028] Further, the balance power generation control unit of the mechanical timepiece according to the invention, can change a period of the rotational oscillation of the balance with hairspring by controlling rotation of the balance with hairspring by applying the "Airy's theorem".

[0029] Here, the "Airy's theorem" indicates that "oscillation of a pendulum is not disturbed even when energy is applied at a center point of oscillation".

[0030] Therefore, it is known in the balance with hairspring of the mechanical timepiece that even when external force is exerted at the center point of the rotational oscillation of the balance with hairspring, the period of the rotational oscillation of the balance with hairspring remains unchanged and when the balance with hairspring is accelerated at and before the center of the rotational oscillation of the balance with hairspring or is decelerated at and after the center of the rotational oscillation of the balance with hairspring, the period of the rotational oscillation of the balance with hairspring gains. Further, it is known in the case of the balance with hairspring that when the balance with hairspring is accelerated at and after the center of the rotational oscillation of the balance with hairspring or is decelerated at or before the center of the rotational oscillation of the balance with hairspring, the period of the rotational oscillation of the balance with hairspring loses.

[0031] That is, it is preferable that the balance power generation control unit of the mechanical timepiece according to the invention, is constituted such that the rotation of the balance with hairspring is braked at a timing prior to constituting a center of the rotational oscillation of the balance with hairspring when the rate of the mechanical timepiece gains and is constituted to brake the rotation of the balance with hairspring after passing through the center of the rotational oscillation of the balance with hairspring when the rate of the mechanical timepiece loses.

[0032] By the constitution, the rotation of the balance with hairspring can be controlled accurately and the rate of the mechanical timepiece can be adjusted accurately.

[0033] Further, it is preferable that the rate detecting unit of the mechanical timepiece according to the invention, includes a pallet fork detecting piezoelectric element provided at a bank pin for detecting operation of the pallet fork and a pallet fork detecting signal counting unit for counting a pallet fork detecting signal outputted from the pallet fork detecting piezoelectric element.

[0034] According to the mechanical timepiece of the invention, an electricity storing member may be, for example, a chargeable secondary battery or a chargeable condenser. As the chargeable secondary battery, for example, a lithium secondary battery can be utilized.

[0035] Further, the mechanical timepiece according to the invention may be provided with an automatic winding power generation unit. In this case, it is constituted that electric energy generated by the automatic winding power generation unit is stored to the electricity storing member.

[0036] Further, it is preferable according to the mechanical timepiece of the invention that the rectifying circuit is constituted by using a Schottky barrier diode. The reason is that according to the Schottky barrier diode, the operational speed is faster than that of a PN couple diode and forward direction voltage is low, which is optimum for rectifying low voltage.

[0037] Further, it is preferable in the mechanical timepiece of the invention that the IC is constituted by using an SOI technology. The reason is that when the "SOI technology" is used, electrostatic capacitance of a transistor can be reduced, the operational speed can be accelerated and current consumption can be reduced.

[0038] Further, it is preferable according to the balance power generation control unit of the mechanical timepiece of the invention that the balance power generation control unit is constituted to generate inductive current in the coils by the rotational oscillation of the balance with hairspring by conducting the coils in a constant time interval including the center of the rotational oscillation of the balance with hairspring.

[0039] By the constitution, inductive current can be generated in the coils firmly and efficiently.

(2) Effect of mechanical timepiece of the invention

[0040] In a normal analog type quartz timepiece, there are used battery, quartz, IC, motor, train wheel, hands and the like. According to such an analog type quartz timepiece, energy provided by battery is used for measuring time by operating quartz and IC and displaying time by rotating a motor. A ratio of energy used for measuring time by operating quartz and IC to energy used for displaying time by rotating a motor is about 3:7.

[0041] Therefore, when only a function of measuring time is used in the analog type quartz timepiece, even in the case of using the same battery, the battery life is prolonged by a multiplication of 3 or more. In the normal analog type quartz timepiece, a battery life is about 2 years.

[0042] In contrast thereto, according to the mechanical timepiece of the invention, when there is used an electricity storing member having dimensions and shape substantially the same as those of the normal analog type quartz timepiece, that is, a secondary battery or a condenser, the secondary battery or the condenser can be used over a time period longer than the battery life of the normal analog type quartz timepiece.

[0043] Further, the normal mechanical timepiece can be used for about 5 years without repairing the mechanical timepiece at all and when the mechanical timepiece is overhauled after 5 years from start of use, the mechanical timepiece can be used further for about 5 years. Therefore, when the normal mechanical timepiece is overhauled once, the mechanical timepiece can be used for about 10 years.

[0044] Therefore, according to the mechanical timepiece of the invention, even when there are used quartz and IC similar to those of the normal analog type quartz timepiece and the electricity storing member having dimensions and shape substantially the same as those of the normal analog type quartz timepiece, that is, the secondary battery or the condenser, it is not necessary to interchange the battery until the timepiece needs to overhaul. Further, according to the mechanical timepiece of the invention, when the capacity of the electricity storing member, that is, the secondary battery or the condenser is increased and power consumption of IC is reduced, there can be provided a timepiece which can be used until life of a portion of a mechanical structure expires.

[0045] Further, according to the mechanical timepiece of the invention, the timepiece is operated by the mechanical structure and accordingly, even when electric energy stored to the electricity storing member, that is, the secondary battery or the condenser is dissipated, there is no concern of stopping the timepiece and only accuracy of time display becomes inferior to that before the electric energy stored to the secondary battery or the condenser is dissipated.

[0046] Further, according to the mechanical timepiece of the invention, when an automatic winding power generation mechanism or a handwinding power generation mechanism is mounted, there is less concern that the electric energy stored to the storing member, that is, the secondary battery or the condenser is dissipated.

[Brief Description of the Drawings]

[0047]

Fig. 1 is a plane view showing an outline shape of a front side of a movement according to an embodiment of a mechanical timepiece of the invention (in Fig. 1, portions of parts are omitted and bridge members are indicated by imaginary lines).

Fig. 2 is an enlarged partial plane view showing an outline shape of a portion of a balance with hairspring according to the embodiment of the mechanical timepiece of the invention.

Fig. 3 is an enlarged partial sectional view showing the outline shape of the portion of the balance with hairspring according to the embodiment of the mechanical timepiece of the invention.

Fig. 4 is a perspective view showing an outline shape of a balance magnet according to the embodiment of the mechanical timepiece of the invention.

Fig. 5 is a block diagram showing an outline of operation of controlling operation of the balance with hairspring according to the embodiment of the mechanical timepiece of the invention.

Fig. 6 is a time chart showing principle of controlling operation of the balance with hairspring according to the embodiment of the mechanical timepiece of the invention.

Fig. 7 is an outline partial plane view showing a constitution of a portion of detecting operation of a train wheel according to the embodiment of the mechanical timepiece of the invention.

Fig. 8 illustrates time charts showing the principle of controlling the operation of the balance with hairspring according to the embodiment of the mechanical timepiece of the invention.

Fig. 9 is a flowchart showing operation of a portion of controlling the operation of the balance with hairspring according to the embodiment of the mechanical timepiece of the invention.

Fig. 10 is a plane view showing an outline shape of a front side of a movement of a conventional mechanical timepiece (in Fig. 10, portions of parts are omitted and bridge members are indicated by imaginary lines).

Fig. 11 is an outline partial sectional view of the movement of the conventional mechanical timepiece (in Fig. 11, portions of parts are omitted).

Fig. 12 is a graph showing an outline of a relationship between an elapse time of rewinding from a fully wound state and mainspring torque in the mechanical timepiece.

Fig. 13 is a graph showing an outline of a relationship between a swing angle of a balance with hairspring and mainspring torque in the mechanical timepiece.

Fig. 14 is a graph showing an outline of a relationship between the swing angle of the balance with hairspring and an instantaneous rate in the mechanical timepiece.

Fig. 15 is a graph showing an outline of a relationship between the elapse time of rewinding from a fully wound state and the instantaneous rate in the mechanical timepiece.

[Best Mode for Carrying Out the Invention]

[0048] An explanation will be given of embodiments of a mechanical timepiece according to the invention in reference to the drawings as follows.

(1) Total constitution of mechanical timepiece of the invention

[0049] In reference to Fig. 1 and Fig. 2, according to an embodiment of a mechanical timepiece of the invention, a movement 640 includes a main plate 102 constituting a base plate of the movement. A winding stem 110 is integrated rotatably to a winding stem guide hole 102a of the main plate 102.

[0050] A dial (not illustrated) is attached to the movement 640 of the mechanical timepiece of the invention. The dial is provided with, for example, 12 o'clock graduation, 3 o'clock graduation, 6 o'clock graduation and 9 o'clock graduation.

[0051] The winding stem 110 is provided with a square portion and a guide shaft portion. A clutch wheel (not illustrated) is integrated to the square portion of the winding stem 110. That is, the clutch wheel is provided with a rotational axis line the same as a rotational axis line of the winding stem 110. That is, the clutch wheel is provided with a square hole and is provided to rotate based on rotation of the winding stem 110 by fitting the square hole to the square portion of the winding stem 110. The clutch wheel is provided with tooth A and tooth B. The tooth A is provided at an end portion of the clutch wheel proximate to the center of the movement. The tooth B is provided at an end portion of the clutch wheel proximate to an outer side of the movement.

[0052] The movement 640 is provided with a switch apparatus for determining a position of the winding stem 110 in the axial line direction. The switch apparatus includes a setting lever 132, a yoke 134, a yoke spring 136 and a setting lever jumper 136. Based on rotation of the setting lever 132, the position in the rotational axis line direction of the winding stem 110 is determined. Based on rotation of the yoke 134, a position in the rotational axis line direction of the clutch wheel is determined. Based on rotation of the setting lever 132, the yoke 134 is positioned to two positions in the rotational direction.

[0053] A winding pinion 112 is provided rotatably at the guide shaft portion of the winding stem 110. When the winding stem 110 is rotated in a state in which the winding stem 110 is disposed at a first winding stem position (0-stage) most proximate to the inner side of the movement 640 along the rotational axis line, the winding pinion 112 is constituted to rotate via rotation of the clutch wheel. A crown wheel 114 is constituted to rotate by rotation of the winding pinion 112. A ratchet wheel 116 is integrated to rotate by rotation of the crown wheel 114.

[0054] The movement 640 is provided with a mainspring (not illustrated) contained in a barrel complete 120 as its power source. The mainspring is made of an elastic material having spring performance such as iron. By rotating the ratchet wheel 116, the mainspring is constituted to be capable of being wound up.

[0055] A center wheel & pinion 124 is constituted to rotate by rotation of the barrel complete 120. A third wheel & pinion 126 is constituted to rotate based on rotation of the center wheel & pinion 124. A fourth wheel & pinion 128 is

constituted to rotate based on rotation of the third wheel & pinion 126. An escape wheel & pinion 130 is constituted to rotate based on rotation of the fourth wheel & pinion 128. The barrel complete 120, the center wheel & pinion 124, the third wheel & pinion 126 and the fourth wheel & pinion 128 constitute a front train wheel.

(2) Constitution of escapement & speed control apparatus

[0056] The movement 640 is integrated with an escapement & speed control apparatus for controlling rotation of the front train wheel. The escapement & speed control apparatus includes a balance with hairspring 140 repeating right rotation and left rotation at a constant period, the escape wheel & pinion 130 rotating based on rotation of the front train wheel and a pallet fork 142 for controlling rotation of the escape wheel & pinion 130 based on operation of the balance with hairspring 140.

[0057] The basic operational principle of the escape wheel & pinion 130, the pallet fork 142 and the balance with hairspring 140 is similar to that of the movement of the conventional mechanical timepiece.

[0058] In reference to Fig. 7, the pallet fork 142 includes an inlet finger jewel 142a provided to be capable of being brought into contact with the escape wheel & pinion 130, an outlet finger jewel 142b provided to be capable of being brought into contact with the escape wheel & pinion 130, a pallet fork sword tip portion 142c provided such that a swing jewel (not illustrated) of the balance with hairspring enters and leaves and a pallet fork rod portion 142d.

[0059] When the balance with hairspring and the swing jewel are rotated in the left direction (counterclockwise direction), the swing jewel enters the pallet fork sword tip portion 142c. Then, the swing jewel rotates the pallet fork 142 in the right direction (clockwise direction) and makes the pallet fork 142 stop and release on the side of the inlet finger jewel 142a. Then, a rocking corner of the escape wheel & pinion 130 moves to an impact face of the inlet finger jewel 142a. By force of the escape wheel & pinion 130, the impact face of the inlet finger jewel 142a is pushed up and the pallet fork 142 is rotated in the right direction (clockwise direction). Then, the pallet fork sword tip portion 142c presses the swing jewel and rotates the swing jewel in the left direction (counterclockwise direction).

[0060] When the impact is over, a tooth of the escapement wheel & pinion 130 leaves the inlet finger jewel 142a, the escape wheel & pinion 130 rotates idly and the escape wheel & pinion 130 drops. When the escape wheel & pinion 130 finishes dropping, other tooth of the escape wheel & pinion 130 is brought into contact with a stop face of the outlet finger jewel 142b to thereby constitute a first stationary state.

[0061] When the first stationary state is over and the swing jewel leaves the pallet fork sword tip portion 142c, by the force of the pallet wheel & pinion 130, the pallet fork 142 rotates the swing jewel in the left direction (counterclockwise direction). Further, the pallet fork rod portion 142d is brought into contact with a first bank pin 102d of the main plate and rotation of the pallet fork 142 is stopped to thereby constitute a secondary stationary state.

[0062] Further, the balance with hairspring 140 is rotated in the left direction (counterclockwise direction) and carries out free rotation.

[0063] Next, when the balance with hairspring 140 reaches a position of a maximum swing angle, the balance with hairspring 140 is rotated in the right direction (clockwise direction) and the swing jewel is rotated also in the right direction (clockwise direction).

[0064] Then, the swing jewel is brought into contact with the pallet fork sword tip portion 142c and the pallet fork 142 is rotated in the left direction (counterclockwise direction). Then, the pallet fork 142 is made to stop and release on the side of the outlet finger jewel 142b and operation similar to that of the outlet finger jewel 142b is repeated on the side of the inlet finger jewel 142a.

(3) Constitution of train wheel

[0065] Referring back to Fig. 1, based on rotation of the center wheel & pinion 124, a cannon pinion (not illustrated) is simultaneously rotated. A minute hand (not illustrated) attached to the cannon pinion is constituted to display "minute". The cannon pinion is provided with a slip mechanism having a predetermined slip torque relative to the center wheel & pinion 124.

[0066] Based on rotation of the cannon pinion, a minute wheel (not illustrated) is rotated. Based on rotation of the minute wheel, an hour wheel (not illustrated) is rotated. An hour hand attached to the hour wheel is constituted to display "hour".

[0067] The barrel complete 120 is supported rotatably by the main plate 102 and a barrel bridge 160. The center wheel & pinion 124, the third wheel & pinion 126, the fourth wheel & pinion 128 and the escape wheel & pinion 130 are supported rotatably by the main plate 102 and a train wheel bridge 162. The pallet fork 142 is supported rotatably by the main plate 102 and a pallet bridge 164.

(4) Constitution of balance with hairspring

[0068] In reference to Fig. 2 and Fig. 3, the balance with hairspring 140 is supported rotatably by the main plate 102 and a balance bridge 166. That is, an upper mortise of the balance stem 140a is supported rotatably by a balance upper bearing 166a fixed to the balance bridge 166. The balance upper bearing 166a includes a balance upper hole jewel and a balance upper cap jewel. The balance upper hole jewel and the balance upper cap jewel are made of an insulating material such as ruby. The balance with hairspring 140 includes a balance stem 140a, a balance wheel 140b and a hairspring 140c.

[0069] A lower mortise of the balance stem 140a is supported rotatably by a balance lower bearing 102b fixed to the main plate 102. The balance lower bearing 102b includes a balance lower hole jewel and a balance lower cap jewel. The balance lower hole jewel and the balance lower cap jewel are made of an insulating material such as ruby.

[0070] The hairspring 140c is a leaf spring in a helical (spiral) shape having a plural turn number. An inner end portion of the hairspring 140c is fixed to a hairspring holder fixed to the balance stem 140a and an outer end portion of the hairspring 140c is fixed by screws via a hairspring stud attached to a stud support 166a rotatably fixed to the balance bridge 166. The balance bridge 166 is made of an electrically conductive material of metal such as brass. The stud support 166a is made of an electrically conductive material of metal such as iron.

[0071] The hairspring 140c is elongated and contracted in the radius direction of the hairspring 140c in accordance with rotational angle of rotating the balance with hairspring 140. For example, in a state shown by Fig. 1, when the balance with hairspring 140 is rotated in the clockwise direction, the hairspring 140c is contracted in a direction toward the center of the balance with hairspring 140 and in contrast thereto, when the balance with hairspring 140 is rotated in the counterclockwise direction, the hairspring 140c is expanded in a direction remote from the center of the balance with hairspring 140.

[0072] The hairspring 140c is made of an elastic material having spring performance such as "elinvar". That is, the hairspring 140c is made of an electricity conductive material of metal.

[0073] A portion proximate to an outer periphery of the hairspring 140c is supported between a hairspring bridge 426 and a hairspring rod 428. Therefore, the effective length of the hairspring 140c is determined by determining positions of the hairspring bridge 426 and the hairspring rod 428 by rotating a regulator 420. Further, when the effective length of the hairspring 140c is determined, the period of the rotational oscillation of the balance with hairspring 140 is determined and the rate of the mechanical timepiece is determined.

(5) Constitution of balance magnet provided at balance with hairspring and coils provided at main plate

[0074] In reference to Fig. 1 through Fig. 3, coils 180, 180a, 180b and 180c are attached to a face on the front side of the main plate 102 to be opposed to a side face of the balance wheel 140b on the side of the main plate. Although the number of the coils is, for example, four as illustrated, the number may be one, may be two, may be three or may be four or more.

[0075] A balance magnet 140e is attached to the side face of the balance with hairspring 140b on the side of the main plate to be opposed to the face on the front side of the main plate 102.

[0076] Although it is preferable that as shown by Fig. 1 and Fig. 2, an interval in a circumferential direction of the coil in the case of arranging the plurality of pieces of coils, is an interval in the circumferential direction of an S pole and an N pole of the balance magnet 140e arranged to be opposed to the coil multiplied by an integer, the interval may not be the same for all of the coils in the circumferential direction. Further, according to such structure of providing the plurality of pieces of coils, wirings among the respective coils may be wired in parallel such that currents generated at the respective coils by electromagnetic induction are not canceled by each other. Alternatively, wiring among the respective coils may be wired in parallel such that currents generated at the respective coils by electromagnetic induction are not canceled by each other.

[0077] In reference to Fig. 4, the balance magnet 140e is provided with a mode in an annular shape (ring-like shape) and along its circumferential direction, for example, there are alternately provided magnet portions comprising 12 pieces of S poles 140s1 through 140s12 and 12 pieces of N poles 140n1 through 140n12 which are polarized in the up and down direction. Although the number of the magnet portions arranged in the annular shape (ring-like shape) in the balance magnet 140e is 12 in the example shown in Fig. 4, the number may be a plural number of 2 or more. In this case, it is preferable that a length of one chord of the magnet portion is substantially equal to an outer diameter of one coil provided to be opposed to the magnet portion.

[0078] In reference to Fig. 3, a gap is provided between the balance magnet 140e and the coils 180, 180a, 180b and 180c. A magnitude STC of the gap between the balance magnet 140e and the coils 180, 180a, 180b and 180c, is determined such that magnetic force of the balance magnet 140e can effect influence on the coils 180, 180a, 180b and 180c when the coils 180, 180a, 180b and 180c are conducted.

[0079] When the coils 180, 180a, 180b and 180c are not conducted, the magnetic force of the balance magnet 140e

does not effect influence on the coils 180, 180a, 180b and 180c. The balance magnet 140e is fixed to a face of the balance ring 140b on the side of the main plate by adhering or the like in a state in which one face of the balance magnet 140e is brought into contact with a ring-like rim portion of the balance wheel 140b and other face thereof is opposed to the face of the main plate 102 on the front side.

[0080] A first lead wire 182 is provided to connect one terminal of the coil 180 and a first coil terminal of IC642. A second lead wire 184 is provided to connect one terminal of the coil 180c and a second coil terminal of IC642.

[0081] Further, although in Fig. 3, the thickness of the hairspring 140c (thickness in radius direction of balance with hairspring) is illustrated to exaggerate, the thickness is, for example, 0.021 millimeter. According to the balance magnet 140e, for example, an outer diameter thereof is about 9 millimeters, an inner diameter thereof is about 7 millimeters, a thickness thereof is about 1 millimeter and a magnetic flux density thereof is about 0.02 tesla. A turn number of each of the coils 180, 180a, 180b and 180c is, for example, 8 turns and the coil wire diameter is about 25 micrometers. The gap STC between the balance magnet 140e and the coils 180, 180a, 180b and 180c is, for example, about 0.4 millimeter.

(6) Constitution and operation of IC

[0082] Next, an explanation will be given of constitution and operation of IC of the mechanical timepiece according to the invention.

[0083] In reference to Fig. 5, a crystal oscillator 210 constitutes an oscillation source of a circuit for counting time. IC642 includes a dividing circuit 214, a corrected pulse comparing circuit 216, a waveform correcting circuit 332, an electromagnetic brake operating circuit 340 and a rectifying circuit 342.

[0084] The dividing circuit 214 inputs an output signal outputted by oscillating the crystal oscillator 210, divides the signal and outputs a signal with respect to time. The waveform correcting circuit 332 corrects a waveform of a detected signal outputted from a rate detecting unit.

[0085] The corrected pulse comparing circuit 216 compares a divided signal outputted from the dividing circuit 214 and a detected signal outputted from the waveform correcting circuit 332.

[0086] The electromagnetic brake operating circuit 340 conducts the coils 180, 180a, 180b and 180c in response to an operational timing signal outputted from the waveform correcting circuit 332 based on a signal outputted from the corrected pulse comparing circuit 216. By conducting the coils 180, 180a, 180b and 180c, inductive current is generated by a change in magnetic flux of the balance magnet 140e. By the inductive current, force for restraining rotational movement of the balance with hairspring 140 is operated on the balance with hairspring 140. Further, by the operation, the swing angle of the balance with hairspring 140 can be reduced by exerting brake force to the balance with hairspring 140 for restraining rotation of the balance with hairspring 140.

[0087] The rectifying circuit 342 is provided for rectifying the inductive current generated by changing the magnetic flux of the balance magnet 140e in a state of conducting the coils 180, 180a, 180b and 180c.

[0088] An electricity storing member, that is, a condenser 352 constitutes a power source for operating IC642. Current rectified by the rectifying circuit 342 is conducted to the condenser 352 and electric energy generated by the inductive current is stored to the condenser 352.

[0089] According to the invention, the electricity storing member may be a chargeable secondary battery or may be a chargeable condenser. Further, according to the invention, the rectifying circuit 342 maybe built in IC642 as illustrated or may be constituted separately from IC642 by using an external element.

[0090] When an external element is used, it is preferable that the rectifying circuit 342 is fabricated by using a Schottky barrier diode (SBD). The reason is that operational speed of a Schottky barrier diode is faster than a PN couple diode and forward direction voltage is low, which is optimum for rectifying low voltage.

[0091] According to the invention, it is preferable to fabricate IC642 by using "SOI technology". The "SOI technology" refers to "silicon on insulator". When the "SOI technology" is used, electrostatic capacitance of a transistor can be reduced, operational speed thereof can be accelerated and current consumption can be reduced.

[0092] A board fabricated by using the "SOI technology" can be obtained from, for example, Komatsu electronic metal under commercial name of "SIMOX".

(7) Constitution and operation of rate detecting unit

[0093] Next, an explanation will be given of constitution and operation of the rate detecting unit of the mechanical timepiece according to the invention.

[0094] Next, in reference to Fig. 1, Fig. 2, Fig. 3 and Fig. 7, a train wheel 224 is rotated with a mainspring 222 as a power source. It is constituted that by rotation of the train wheel 224, a minute hand 226 displays "minute" and an hour hand 228 displays "hour". The minute hand 226 is fixed to the center wheel & pinion 124. The center wheel & pinion 124 is constituted to make one rotation in one hour. By rotation of the train wheel 224, the escape wheel & pinion 130 is rotated. The pallet fork 142 controls rotation of the escape wheel & pinion 130 based on operation of the balance

with hairspring 140.

[0095] A pallet fork detecting piezoelectric element 336 is fixed to the first bank pin 102d of the main plate 102. Therefore, the pallet fork rod portion 142d is constituted to be brought into contact with the pallet fork detecting piezoelectric element 336. At an instance at which the pallet fork rod portion 142d is brought into contact with the pallet fork detecting piezoelectric element 336, the pallet fork detecting piezoelectric element 336 generates voltage (refer to (4) of Fig. 8).

[0096] The pallet fork detecting piezoelectric element 336 constitutes the rate detecting unit 330 for detecting a rotational operation state of the train wheel. Further, it is constituted that when the pallet fork rod portion 142d is brought into contact with the pallet fork detecting piezoelectric element 336, a detected signal is inputted to IC642. The balance with hairspring 140 is oscillated at 3 Hertz and accordingly, the rate detecting unit 330 outputs the detected signal at 3 Hertz.

[0097] The waveform correcting circuit 332 is constituted to input a detected signal outputted from the pallet fork detecting piezoelectric element 336.

[0098] In reference to Fig. 3, the corrected pulse comparing circuit 216 is constituted to compare a period of (1/3) second measured by the escapement & speed control apparatus (refer to (1) of Fig. 6) and a period of (1/3) second measured by IC642 (refer to (2) of Fig. 6).

[0099] The rate detecting unit 330 outputs to IC642, the detected signal of the period of (1/3) second measured by the escapement & speed control apparatus including the escape wheel & pinion 130, the pallet fork 142 and the balance with hairspring 140 by bringing the pallet fork rod portion 142d into contact with the pallet fork detecting piezoelectric element 336.

[0100] That is, the rate detecting unit 330 includes the pallet fork rod portion 142d and the pallet fork detecting piezoelectric element 336.

(8) Operation and constitution of balance power generation control unit

[0101] Next, an explanation will be given of constitution and operation of the balance power generation control unit of the mechanical timepiece according to the invention.

[0102] Further, in reference to Fig. 1, Fig. 2, Fig. 3 and Fig. 9, the dividing circuit 214 is constituted to divide an output signal of 32768 Hertz outputted by oscillating the crystal oscillator 210 and output a divided signal having a period of (1/3) second to the corrected pulse comparing circuit 216.

[0103] The corrected pulse comparing circuit 216 is constituted to compare the detected signal having the period of (1/3) second measured by the escapement & speed control apparatus (refer to (1) of Fig. 6) and the divided signal having the period of (1/3) second outputted by the dividing circuit 214 in IC642 (refer to (2) of Fig. 6) and count a difference therebetween (refer to (3) of Fig. 6). The difference is a time period to be corrected by adjusting the rate in the mechanical timepiece of the invention.

[0104] Further, the electromagnetic brake operating circuit 340 conducts the coils 180, 180a, 180b and 180c based on the signal outputted from the corrected pulse comparing circuit 216. By conducting the coils 180, 180a, 180b and 180c, the balance with hairspring 140 is exerted with brake force for restraining rotation of the balance with hairspring 140 to thereby reduce the swing angle of the balance with hairspring 140.

[0105] Therefore, in the balance power generation control unit, the corrected pulse comparing circuit 216, the electromagnetic brake operating circuit 340, the balance magnet 140e and the coils 180, 180a, 180b and 180c constitute portions for controlling operation of the balance with hairspring 140. Further, the balance power generation control unit is constituted, for example, to normally control operation of the balance with hairspring 140.

[0106] By constituting in this way, the rate of the mechanical timepiece can be adjusted to correspond to the difference shown by (3) of Fig. 6.

[0107] That is, in reference to Fig. 5 and Fig. 7, when contact of the pallet fork is detected by bringing the pallet fork rod portion 142d into contact with the pallet fork detecting piezoelectric element 336, the waveform correcting circuit 332 inputs the detected signal outputted from the pallet fork detecting piezoelectric element 336.

[0108] The waveform correcting circuit 332 inputs the detected signal counted by the pallet fork detecting signal counting unit, shapes the waveform and outputs a corrected signal as shown by (5) of Fig. 8. The dividing circuit 214 outputs the divided signal as shown by (2) of Fig. 6 to the corrected pulse comparing circuit 216.

[0109] Next, the corrected pulse comparing circuit 216 compares the output signal having the period of (1/3) second outputted from the waveform correcting circuit 332 (refer to (1) of Fig. 6) and the divided signal having the period of (1/3) second outputted from the dividing circuit 214 (refer to (2) of Fig. 6) and counts the difference (refer to (3) of Fig. 6).

[0110] Here, by inputting the signal of (5) of Fig. 8 by the corrected pulse comparing circuit 216, a timing of bringing the pallet fork rod portion 142d into contact with the pallet fork detecting piezoelectric element 336 is known and accordingly, a timing of stopping the pallet fork 142 is known. Therefore, from such a timing of stopping the pallet fork 142, rotational direction of rotating the balance with hairspring 140 and a timing of the center of the rotational oscillation

of the balance with hairspring 140 can be detected.

[0111] The corrected pulse comparing circuit 216 determines whether the rate of the timepiece gains or whether the rate of the timepiece loses by comparing the period of (1/3) second measured by the escapement & speed control apparatus and the period of (1/3) second measured by IC642.

[0112] The hairspring 140c is elongated and contracted in the radius direction of the hairspring 140c in accordance with rotational angle of rotating the balance with hairspring 140. For example, in a state shown by Fig. 2, when the balance with hairspring 140 is rotated in the clockwise direction, the hairspring 140c is contracted in the direction toward center of the balance with hairspring 140, in contrast thereto, when the balance with hairspring 140 is rotated in the counterclockwise direction, the hairspring 140c is expanded in the direction remote from the center of the balance with hairspring 140. Here, as described above, the balance power generation control unit 350 of the mechanical timepiece according to the invention is constituted to change the period of the rotational oscillation of the balance with hairspring 140 by controlling the rotation of the balance with hairspring 140 by applying the "Airy's theorem".

[0113] The control of the rotation of the balance with hairspring 140 may be carried out at a time point apart from the center of the rotational oscillation of the balance with hairspring 140 at a certain time period over a constant time interval or may be carried out over a constant time period including the center of the rotational oscillation of the balance with hairspring 140.

[0114] That is, the balance power generation control unit 350 of the mechanical timepiece according to the invention is constituted to brake the rotation of the balance with hairspring 140 at a timing prior to constitute the center of the rotational oscillation of the balance with hairspring 140 (timing of t1 of (5) of Fig. 8) when the rate of the mechanical timepiece gains. Further, the balance power generation control unit 350 of the mechanical timepiece according to the invention is constituted to brake the rotation of the balance with hairspring 140 at a timing which has passed through the center of the rotational oscillation of the balance with hairspring 140 (timing of t2 of (5) of Fig. 8) when the rate of the mechanical timepiece loses.

[0115] That is, the timing of conducting the coils 180, 180a, 180b and 180c by operating the electromagnetic brake operating circuit 340, is determined in response to a signal outputted from the waveform correcting circuit 332. Further, a duration time period of conducting the coils 180, 180a, 180b and 180c by operating the electromagnetic brake operating circuit 340, is determined based on a signal outputted from the corrected pulse comparing circuit 216.

[0116] By the constitution, the rotation of the balance with hairspring 140 can be controlled accurately and the rate of the mechanical timepiece can be adjusted accurately.

[0117] According to the mechanical timepiece of the invention, when the rate of the mechanical timepiece gains, at the timing prior to constitute the center of the rotational oscillation of the balance with hairspring 140 (timing of t1 of (5) of Fig. 8), the coils 180, 180a, 180b and 180c are conducted and the magnetic flux of the balance magnet 140e effects influence on the coils 180, 180a, 180b and 180c. As a result, the period of the rotational oscillation of the balance with hairspring 140 is reduced by operation of the balance magnet 140e and the coils 180, 180a, 180b and 180c.

[0118] Further, according to the mechanical timepiece of the invention, when the rate of the mechanical timepiece loses, at the timing which has passed through the center of the rotational oscillation of the balance with hairspring 140 (timing of t2 of (5) of Fig. 8), the coils 180, 180a, 180b and 180c are conducted and the magnetic flux of the balance magnet 140e effects influence on the coils 180, 180a, 180b and 180c. As a result, the period of the rotational oscillation of the balance with hairspring 140 increases by operation of the balance magnet 140e and the coils 180, 180a, 180b and 180c.

[0119] According to the mechanical timepiece of the invention constituted in this way, the period of the rotational oscillation of the balance with hairspring 140 can efficiently be controlled.

[0120] With regard to a value of time of adjusting the period of the rotational oscillation of the balance with hairspring 140 based on a result of determination of the corrected pulse comparing circuit 216, there may be previously calculated by experiment, a relationship between the rate of the mechanical timepiece and the change in the period of the rotational oscillation of the balance with hairspring 140 by the inductive current generated by the change in the magnetic flux of the balance magnet 140e by conducting the coils 180, 180a, 180b and 180c and stored to the corrected pulse comparing circuit 216.

[0121] As has been explained above, by using the invention, the rate of the mechanical timepiece can be adjusted with high accuracy.

[0122] Further, according to the mechanical timepiece of the invention, the coils 180, 180a, 180b and 180c are conducted, for example, in the constant time interval including the center of the rotational oscillation of the balance with hairspring 140. In the state of conducting the coils 180, 180a, 180b and 180c, the magnetic flux of the balance magnet 140e is changed by the rotational oscillation of the balance with hairspring 140. As a result, the inductive current is generated in the coils 180, 180a, 180b and 180c. The generated inductive current is rectified by the rectifying circuit 342 and is stored to the electricity storing member, that is, the condenser 352. Therefore, the condenser 352 constitutes the power source of operating IC642.

[0123] The "constant time period including the center of the rotational oscillation of the balance with hairspring 140"

can be set, for example, between a time interval in correspondence with a range of plus and minus 30 degrees (when rotation in the right direction constitutes plus and rotation in the left direction constitutes minus) of the swing angle from the center of the oscillation of the balance with hairspring and a time interval in correspondence with a range of plus and minus 120 degrees of the swing angle from the center of the oscillation of the balance with hairspring.

[0124] According to the mechanical timepiece of the invention constituted in this way, in the constant time interval including the center of the rotational oscillation of the balance with hairspring 140, the period of the rotational oscillation of the balance with hairspring 140 can efficiently be controlled by adjusting a power generation amount of the inductive current generated at the coils 180, 180a, 180b and 180c.

(9) Constitution of circuit of mechanical timepiece of the invention

[0125] Further, according to the mechanical timepiece of the invention, circuits for carrying out various functions may be constituted in IC or IC may be PLA-IC including programs for carrying out various operations. Further, according to the mechanical timepiece of the invention, there can be used external elements such as resistor, condenser, coil, diode, transistor and the like along with IC if necessary.

(10) Embodiment

[0126] Next, an explanation will be given of one embodiment of the mechanical timepiece of the invention.

[0127] For example, according to the mechanical timepiece of the invention, mainspring torque of the mainspring is set to 60g·cm. The mechanical timepiece is fabricated such that 5g·cm in the mainspring torque is used for power generation.

[0128] According to the mechanical timepiece of the invention, a reduction ratio of gears from the barrel complete containing the mainspring to the escape wheel & pinion is 1/5040. According to the mechanical timepiece of the invention, synthesized efficiency of the train wheel and the escapement is 30 %. According to the mechanical timepiece of the invention, the radius r of the balance wheel of the balance with hairspring is 0.42 cm, the width of the balance magnet is 0.04 cm and the distance between the balance magnet and the coils is, for example, 0.04 cm.

[0129] According to the mechanical timepiece of the invention, the torque of the balance wheel is as follows.

$$T = (5/5040) \times 0.3 = 2.98 \times 10^{-4} \text{ [gf·cm]}$$

[0130] The force of the outer ring portion of the balance wheel is as follows.

$$F = T/r = (2.98 \times 10^{-4}) / 0.42 \text{ [gf·cm/mm]}$$

$$= 7.09 \times 10^{-4} \text{ [gf]}$$

$$= (7.09 \times 10^{-4}) \times (9.8 \times 10^{-3}) \text{ [N]}$$

$$= 6.95 \times 10^{-6} \text{ [N]}$$

[0131] The distance of moving the balance magnet by transmitting the torque to the balance magnet in one second is as follows when the rotational angle of the balance with hairspring from start of impact to the first stop is set to 40 degrees.

$$2\pi r \times (40/360) \times 6 = 1.76 \times 10^{-2} \text{ [m]}$$

[0132] The energy ΔE generated in the coil in one second is as follows.

$$\Delta E = 6.95 \times 10^{-2} \times 1.76 \times 10^{-2} \text{ [N} \cdot \text{m/S]}$$

$$= 1.22 \times 10^{-7} \text{ [J/S]}$$

$$= 0.12 \text{ [}\mu\text{W]}$$

[0133] Further, the power necessary for driving the quartz unit and IC in one second is as follows in IC including the dividing unit when the board fabricated by the SOI technology is used.

$$0.06[\mu\text{A}] \times 1.5[\text{V}] = 0.09[\mu\text{W}]$$

[0134] Therefore, the power necessary for driving the quartz unit and IC in one second is 0.09 [μW], the energy ΔE generated in the coil in one second is 0.12 [μW] and accordingly, it has been confirmed that the embodiment of the mechanical timepiece according to the invention is operated firmly.

[0135] According to the embodiment of the mechanical timepiece of the invention, a step-up circuit is not used. Further, according to the embodiment of the mechanical timepiece of the invention, when the rectifier is constituted by using a Schottky barrier diode, 0.2 [V] is needed for the rectifier and 1.5 [V] is needed for IC. Therefore, 2 [V] is needed for the maximum voltage generated in the coil.

[0136] An example of using the coil satisfying such conditions is as follows.

Residual magnetic flux density $B_r = 10$ [KiroGauss]

Radius of magnet $R = 1$ [mm]

Length of magnet $L = 0.5$ [mm]

Distance between magnet and coil $X = 0.5$ [mm]

Density of magnet $\rho = 8.5$ [cm^3]

Outer diameter of coil $D_{c2} = 4$ [mm]

Inner diameter of coil $D_{c1} = 0.5$ [mm]

Thickness of coil $t_c = 0.5$ [mm]

Conductor diameter of coil $d_{c1} = 0.0135$ [mm]

Finish diameter of coil $d_{c2} = 0.0165$ [mm]

[0137] According to the embodiment of the mechanical timepiece of the invention, four pieces of the coils having the above-described specification are prepared and wired in series. Further, the balance with hairspring is fabricated by iron.

[0138] According to the embodiment of the mechanical timepiece of the invention fabricated in this way, voltage generated at the coil is about 2.36 [V]. Therefore, according to the embodiment of the mechanical timepiece of the invention, it has been confirmed that the condenser can be charged without using a step-up circuit.

[Industrial Applicability]

[0139] The mechanical timepiece of the invention is suitable for fabricating a mechanical timepiece having high accuracy.

[0140] According to the mechanical timepiece of the invention, the rate can accurately be adjusted by controlling the period of the rotational oscillation of the balance with hairspring by using the balance magnet.

Claims

1. A mechanical timepiece **characterized in** a mechanical timepiece having a movement constituted to include a mainspring constituting a power source of the mechanical timepiece, a front train wheel rotated by a rotational force in rewinding the mainspring and an escapement & speed control apparatus for controlling rotation of the front train wheel, said escapement & speed control apparatus including a balance with hairspring alternately repeating right rotation and left rotation, an escape wheel & pinion rotated based on rotation of the front train wheel and a pallet fork for controlling rotation of the escape wheel & pinion based on an operation of the balance with hairspring and said balance with hairspring including a hairspring, a balance stem and a balance wheel, said mechanical

timepiece comprising:

a crystal oscillator (210) constituting an oscillation source;
 IC (642) including a dividing unit (214) for outputting a signal with respect to time by inputting an output signal
 outputted by oscillating the crystal oscillator (210) and dividing the output signal;
 an electricity storing member (352) for operating IC (642);
 a rate detecting unit (330) for detecting a rate of the mechanical timepiece; and
 a balance power generation control unit (350) constituted to control a period of rotational oscillation of the
 balance with hairspring (140) based on a divided signal divided by the dividing unit (214) and an operational
 state signal indicating the rate detected by the rate detecting unit (330) and generate power by the rotational
 oscillation of the balance with hairspring (140).

2. The mechanical timepiece according to Claim 1, **characterized in that** the balance power generation control unit (350) includes a balance magnet (140e) provided at the balance with hairspring (140) and coils (180, 180a, 180b, 180c) arranged to be capable of exerting magnetic force to the balance magnet (140e);

wherein the coils (180, 180a, 180b, 180c) are constituted to be capable of controlling the period of the rotational oscillation of the balance with hairspring (140) by exerting the magnetic force to the balance magnet (140e) based on the divided signal divided by the dividing unit (214) and the operational state signal indicating the rate detected by the rate detecting unit (330).

3. The mechanical timepiece according to Claim 1 or Claim 2, **characterized in that** the balance power generation control unit (350) is constituted such that current generated by the rotational oscillation of the balance with hairspring (140) is rectified by a rectifying circuit and is stored to an electricity storing member (352).

4. The mechanical timepiece according to any one of Claim 1 through Claim 3, **characterized in that** the balance power generation control unit (350) is constituted such that the rotation of the balance with hairspring (140) is braked at a timing prior to constituting a center of the rotational oscillation of the balance with hairspring (140) when the rate of the mechanical timepiece gains and is constituted to brake the rotation of the balance with hairspring (140) after passing through the center of the rotational oscillation of the balance with hairspring (140) when the rate of the mechanical timepiece loses.

5. The mechanical timepiece according to any one of Claim 1 through Claim 4, **characterized in that** the rate detecting unit (330) includes a pallet fork detecting piezoelectric element (336) provided at a bank pin (102d) for detecting operation of the pallet fork (142) and a pallet fork detecting signal counting unit for counting a pallet fork detecting signal outputted from the pallet fork detecting piezoelectric element (336).

6. The mechanical timepiece according to Claim 3, **characterized in that** the rectifying circuit is constituted by using a Schottky barrier diode.

7. The mechanical timepiece according to any one of Claim 1 through Claim 6, **characterized in that** the IC is constituted by using an SOI technology.

8. The mechanical timepiece according to any one of Claim 1 through Claim 7, **characterized in that** the balance power generation control unit (350) is constituted to generate inductive current in the coils (180, 180a, 180b, 180c) by the rotational oscillation of the balance with hairspring (140) by conducting the coils (180, 180a, 180b, 180c) in a constant time interval including the center of the rotational oscillation of the balance with hairspring (140).

FIG.1

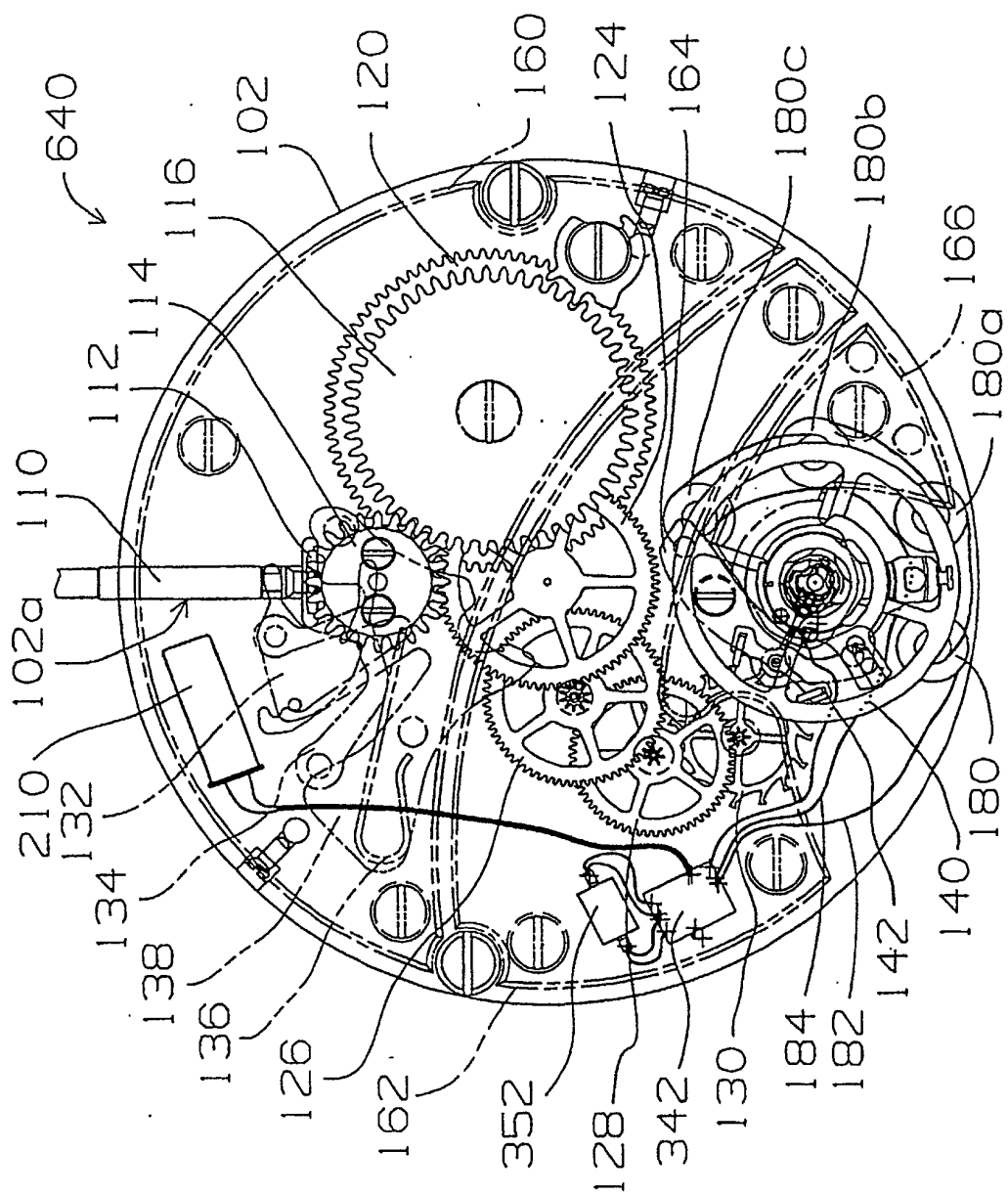


FIG. 2

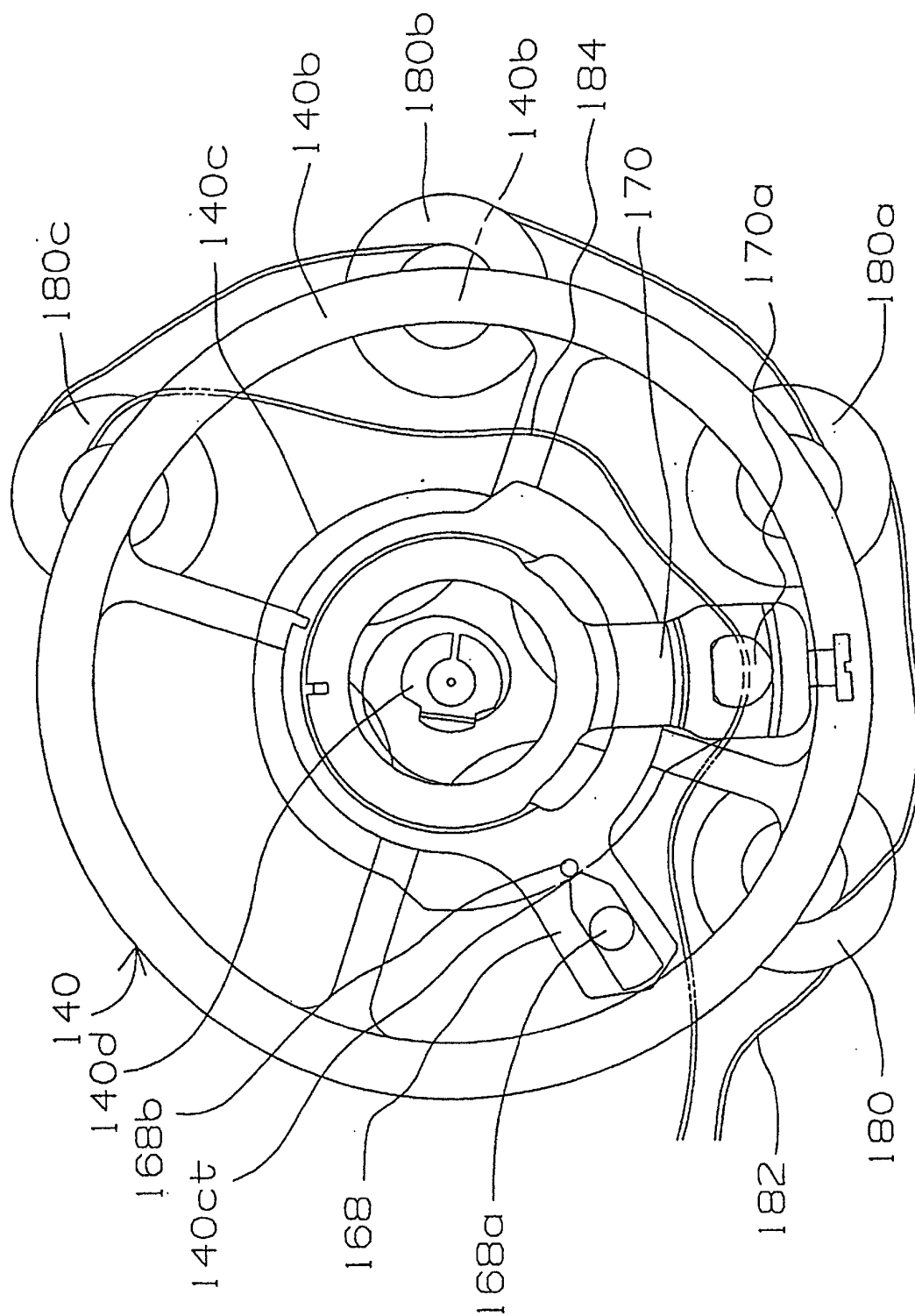


FIG. 3

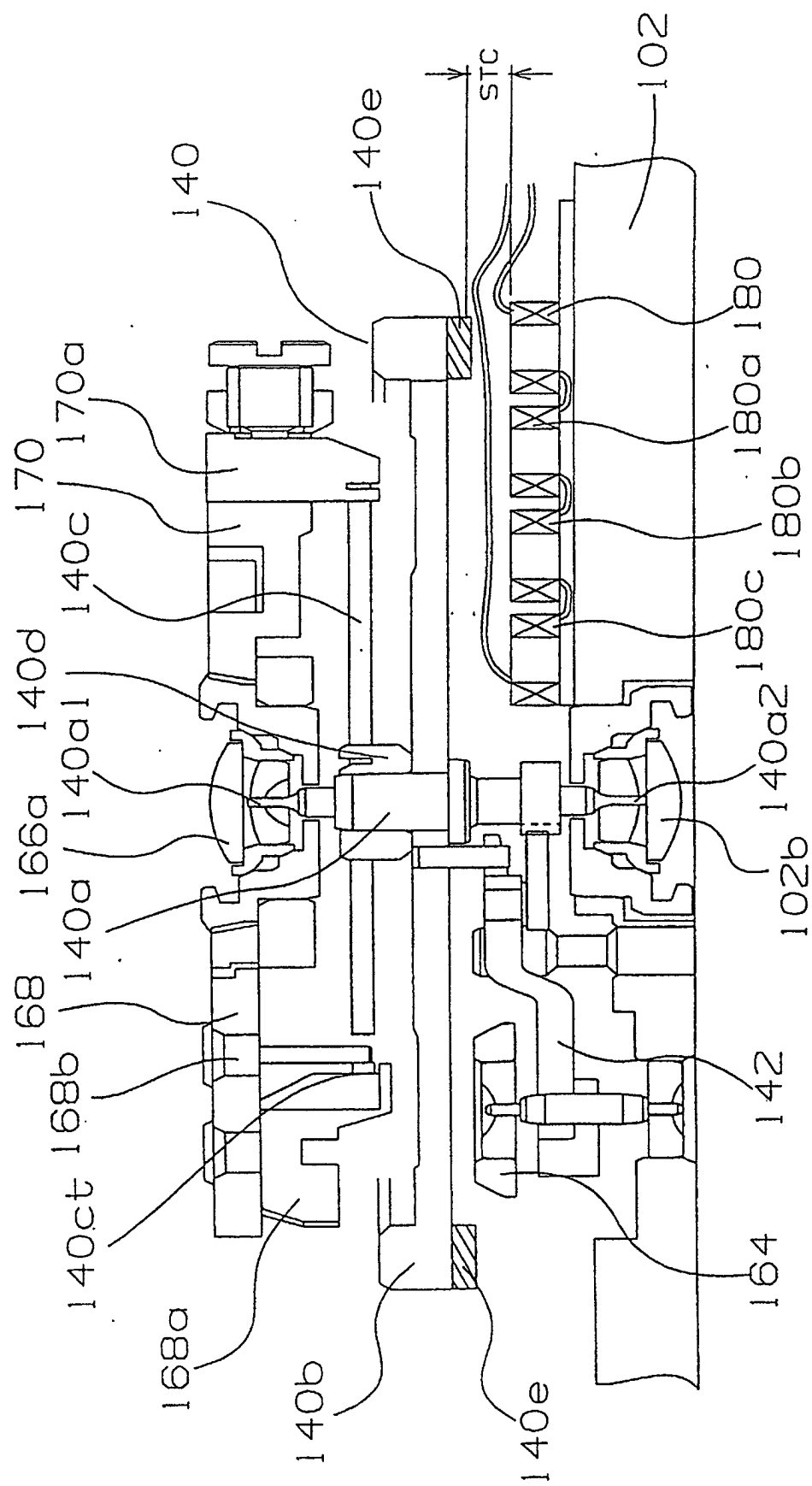
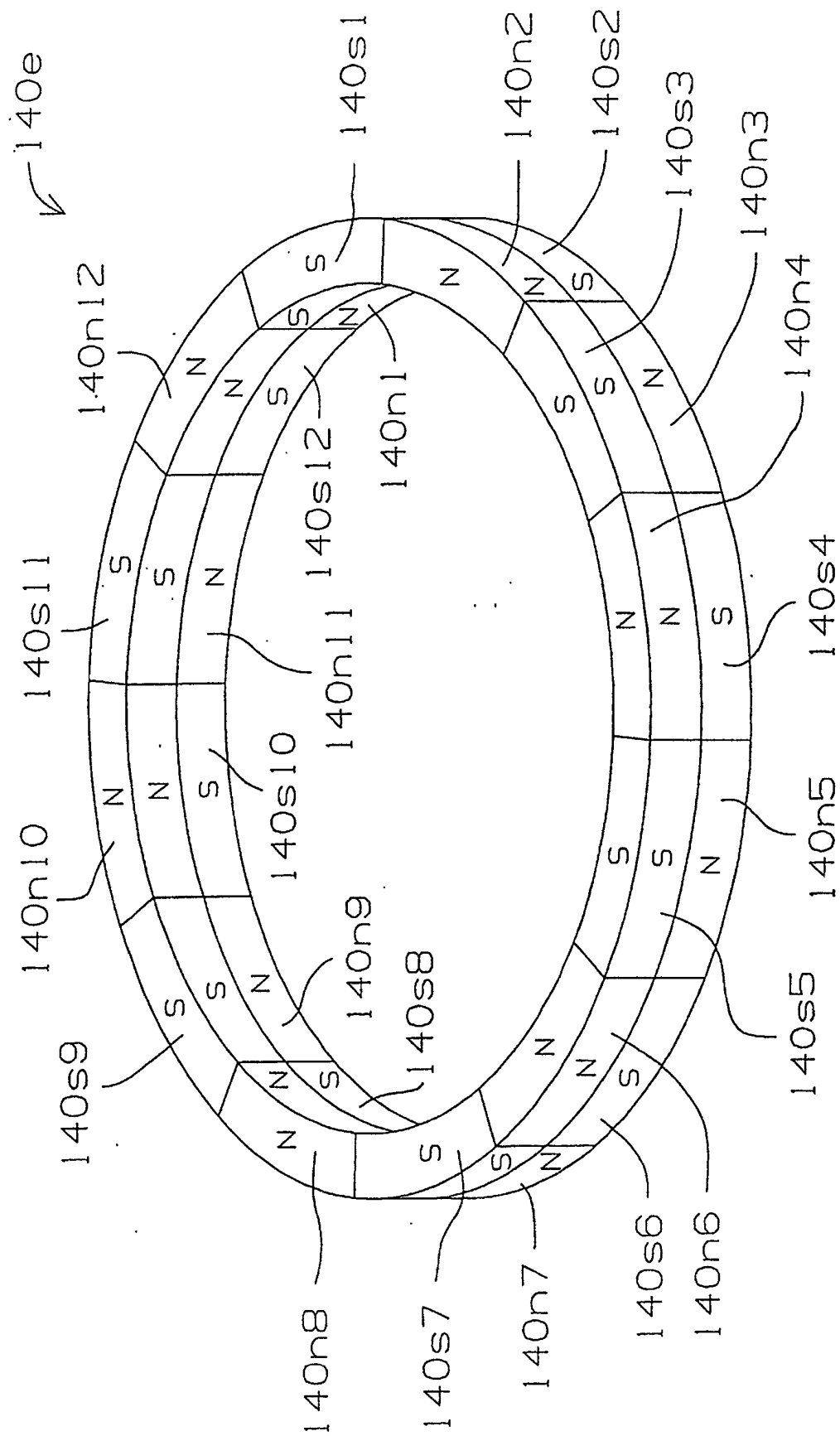


FIG. 4



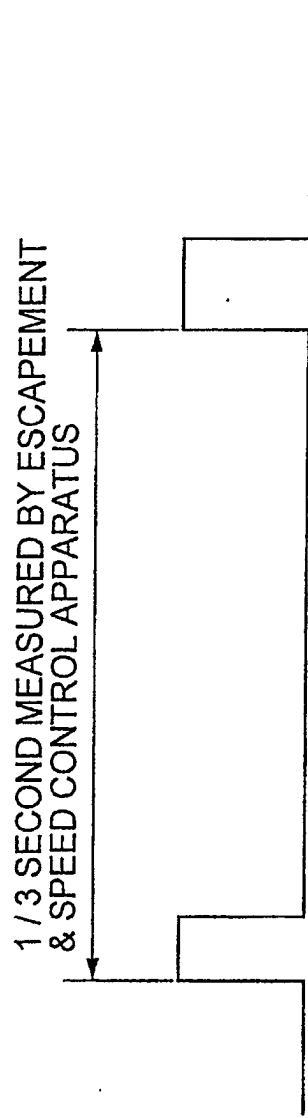


FIG. 6(1)

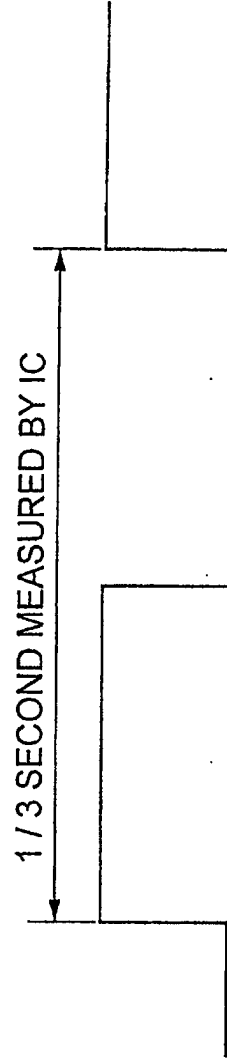
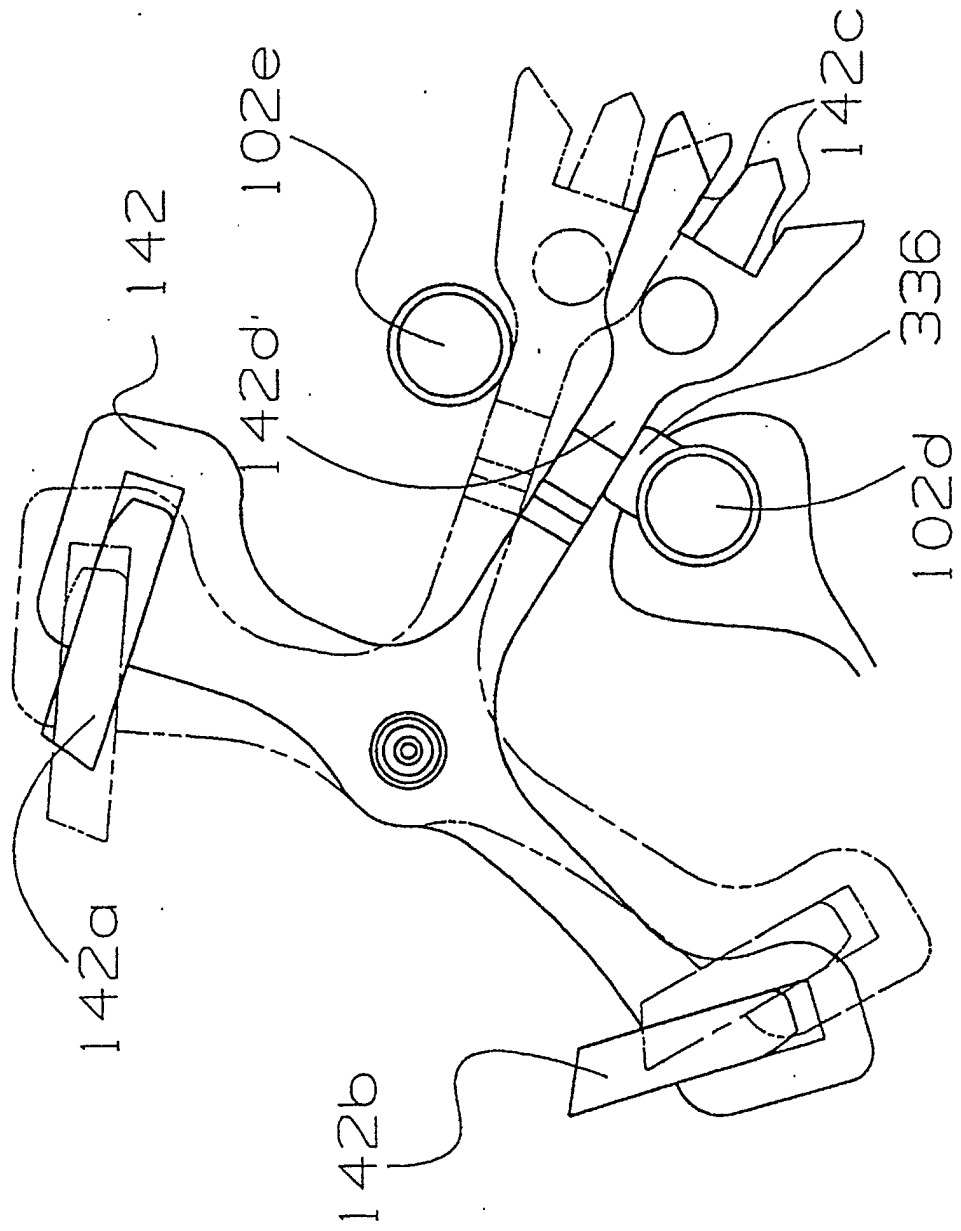


FIG. 6(2)



FIG. 6(3)

FIG. 7



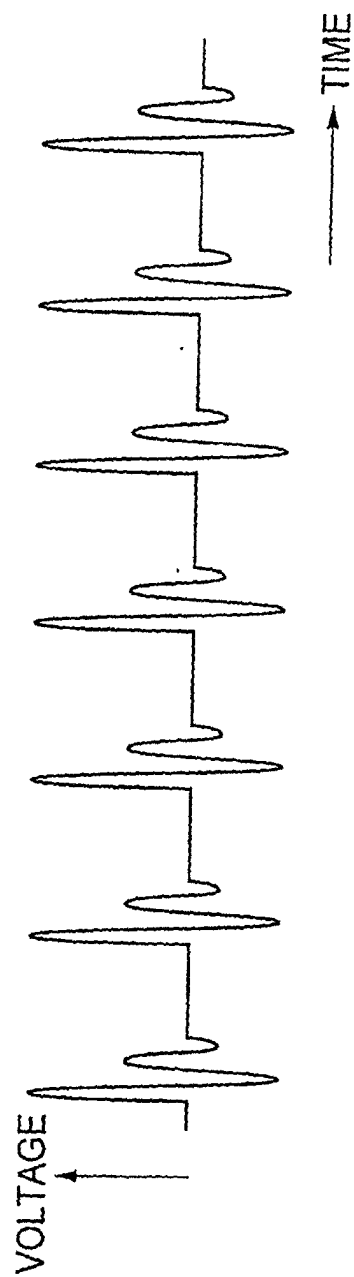


FIG. 8(4)

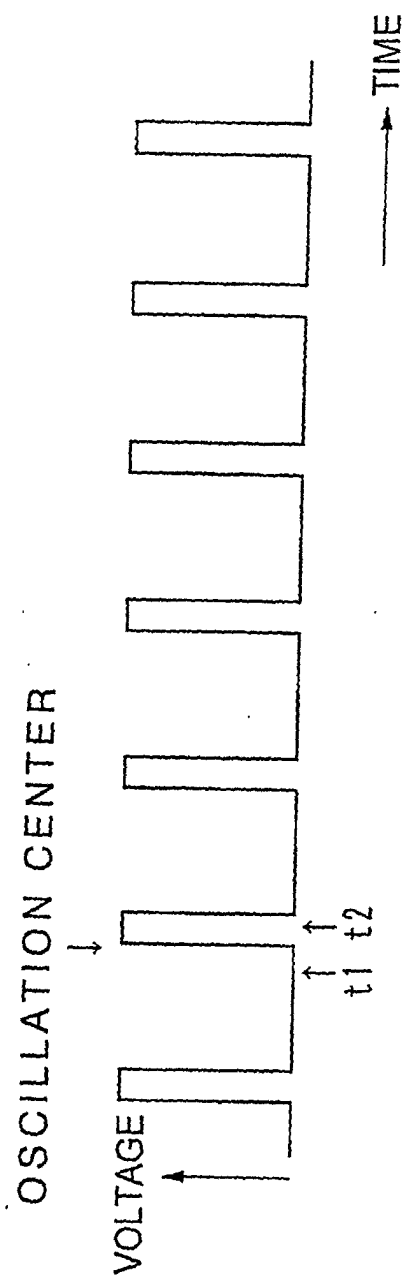


FIG. 8(5)

FIG.9

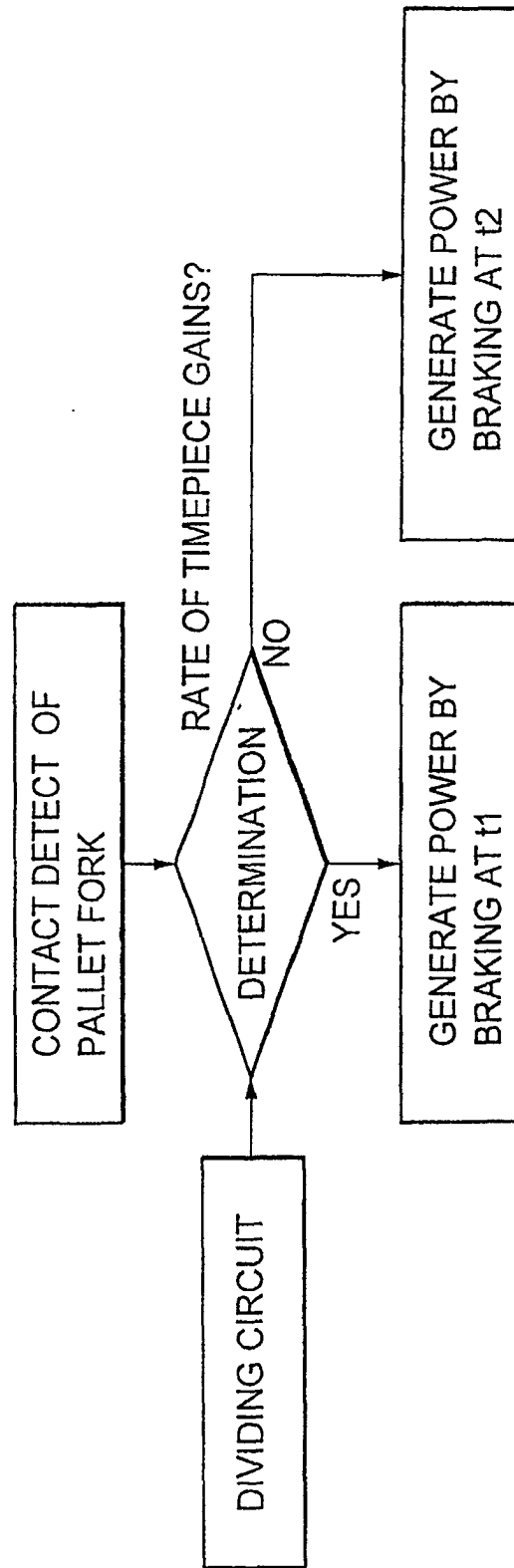


FIG. 10

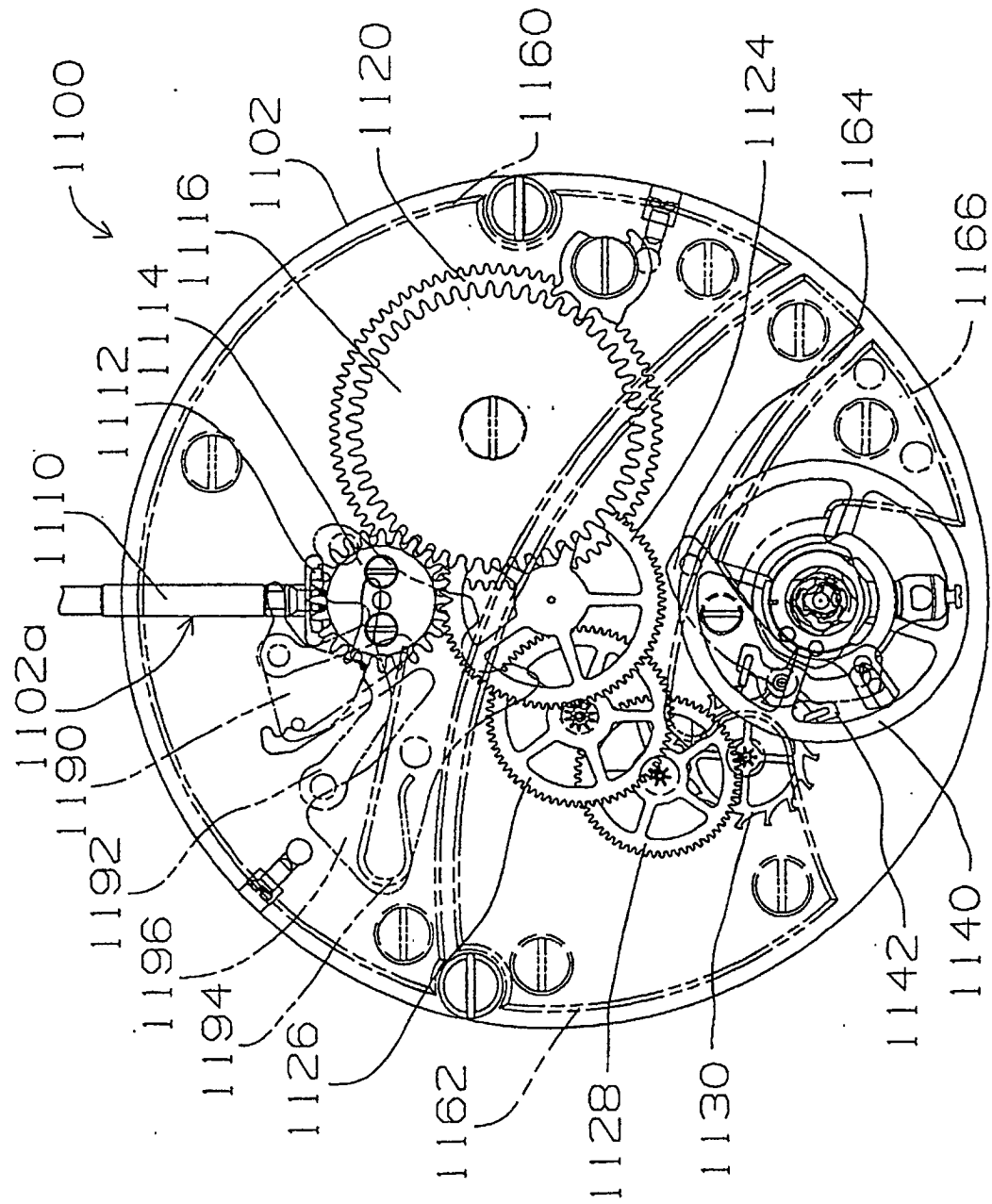


FIG. 11

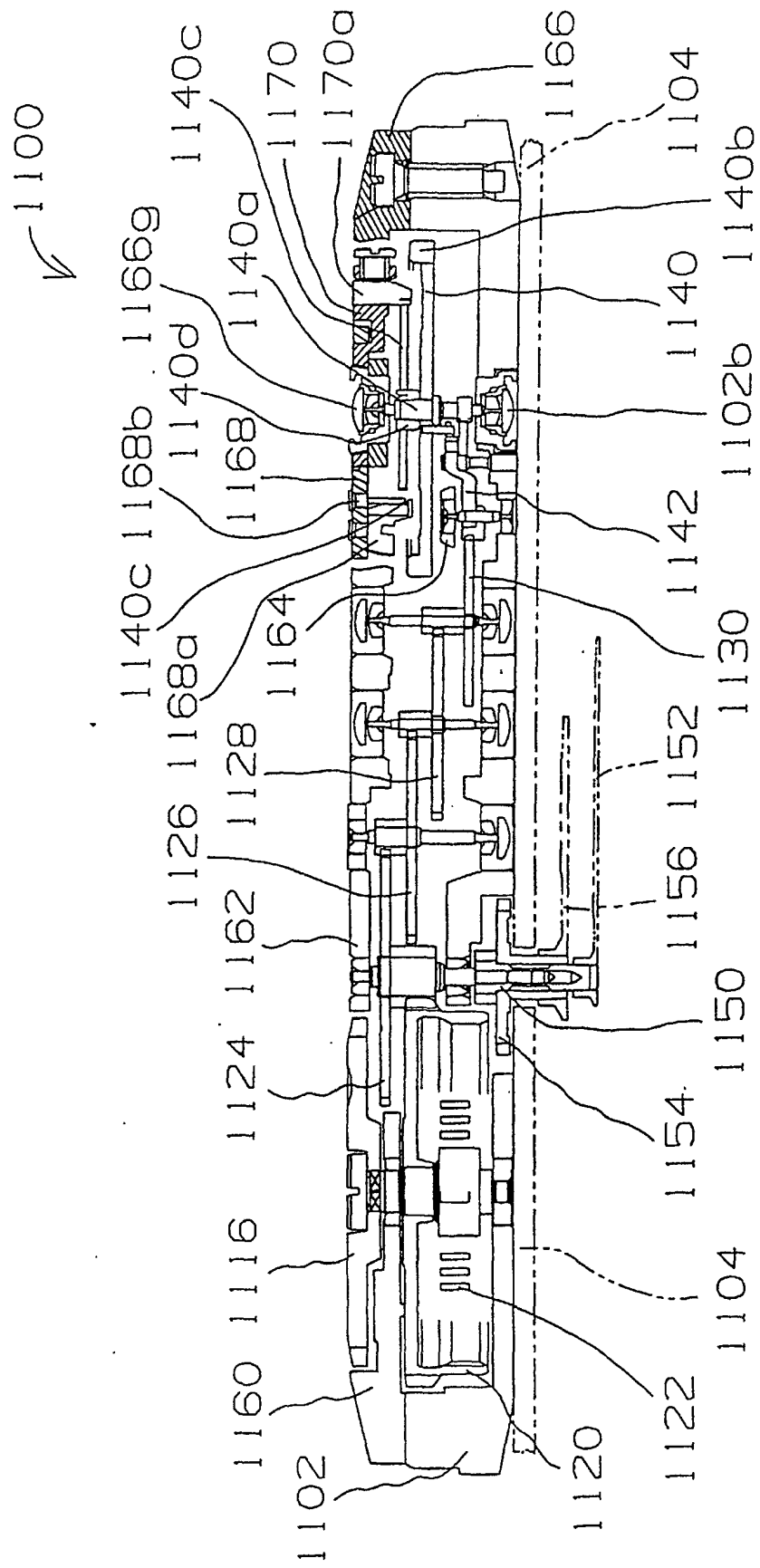


FIG.12

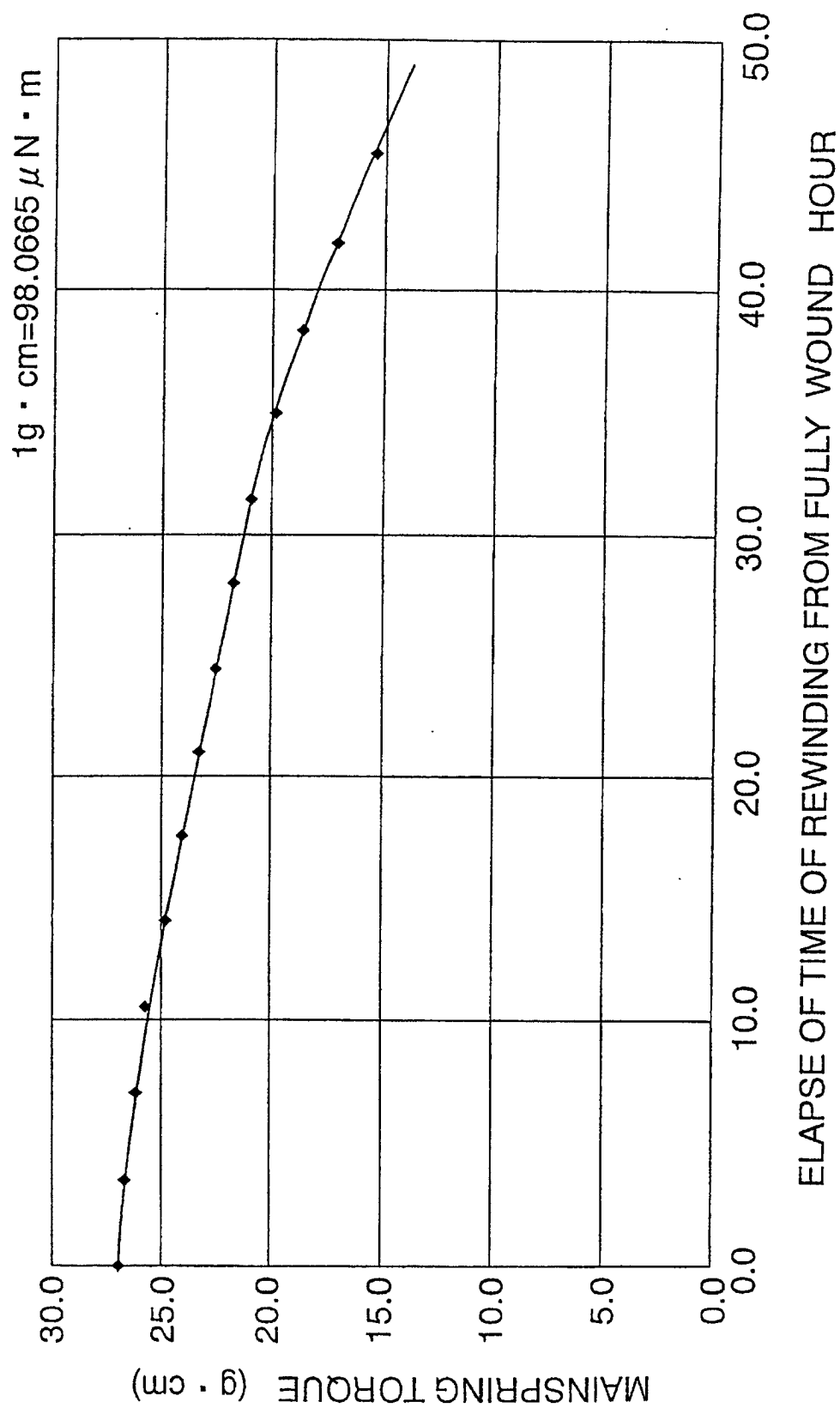


FIG.13

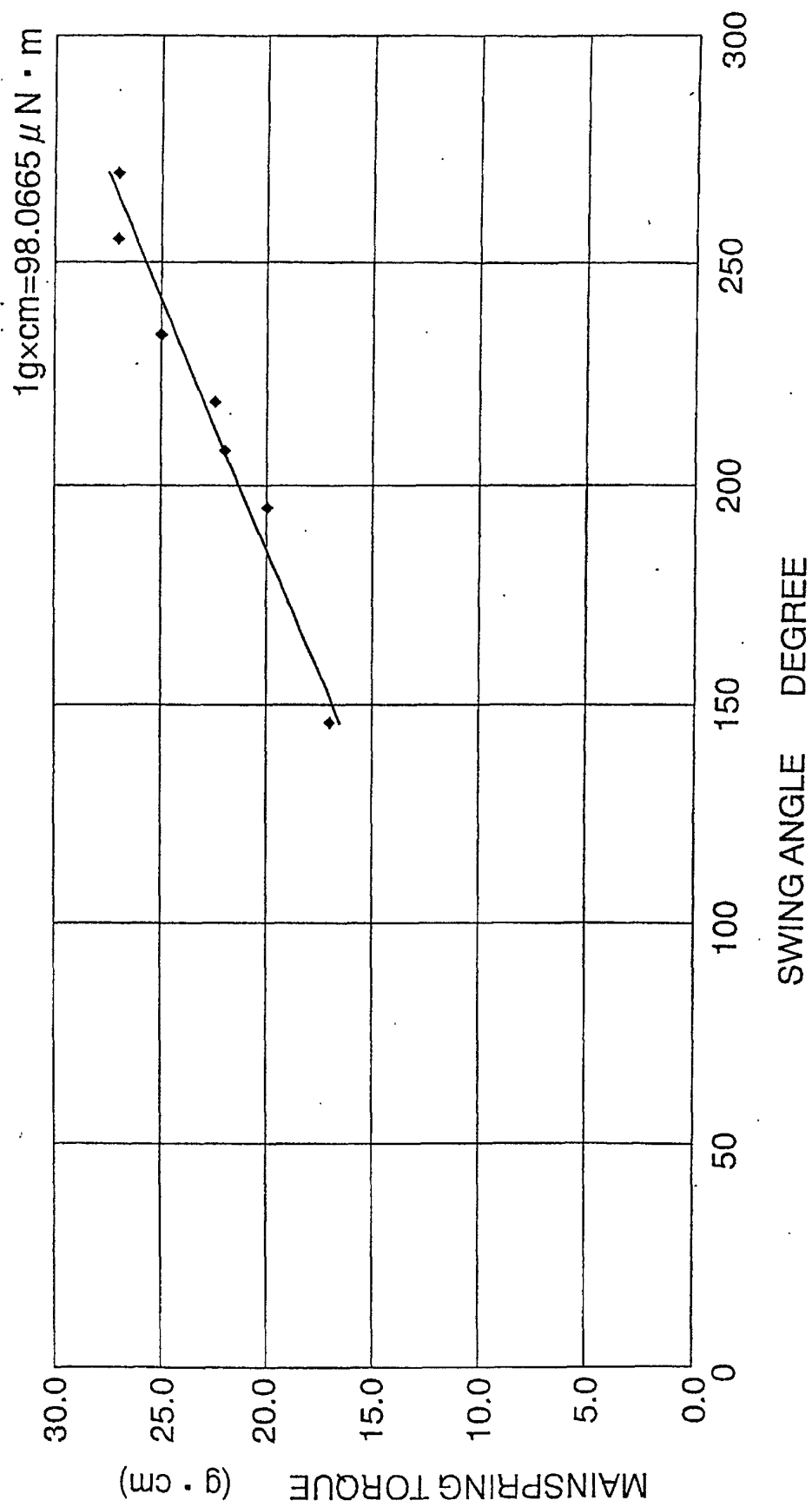


FIG.14

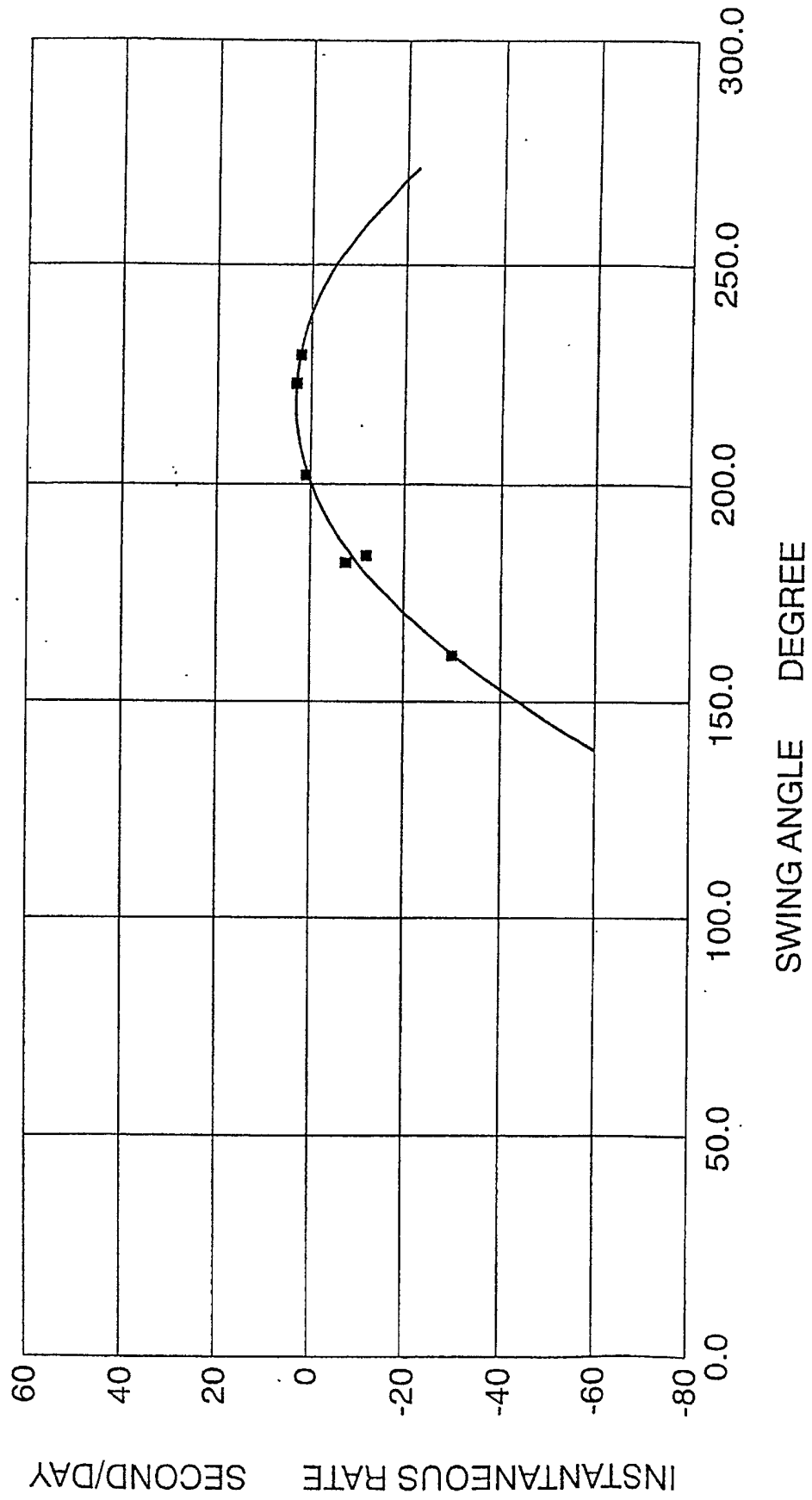
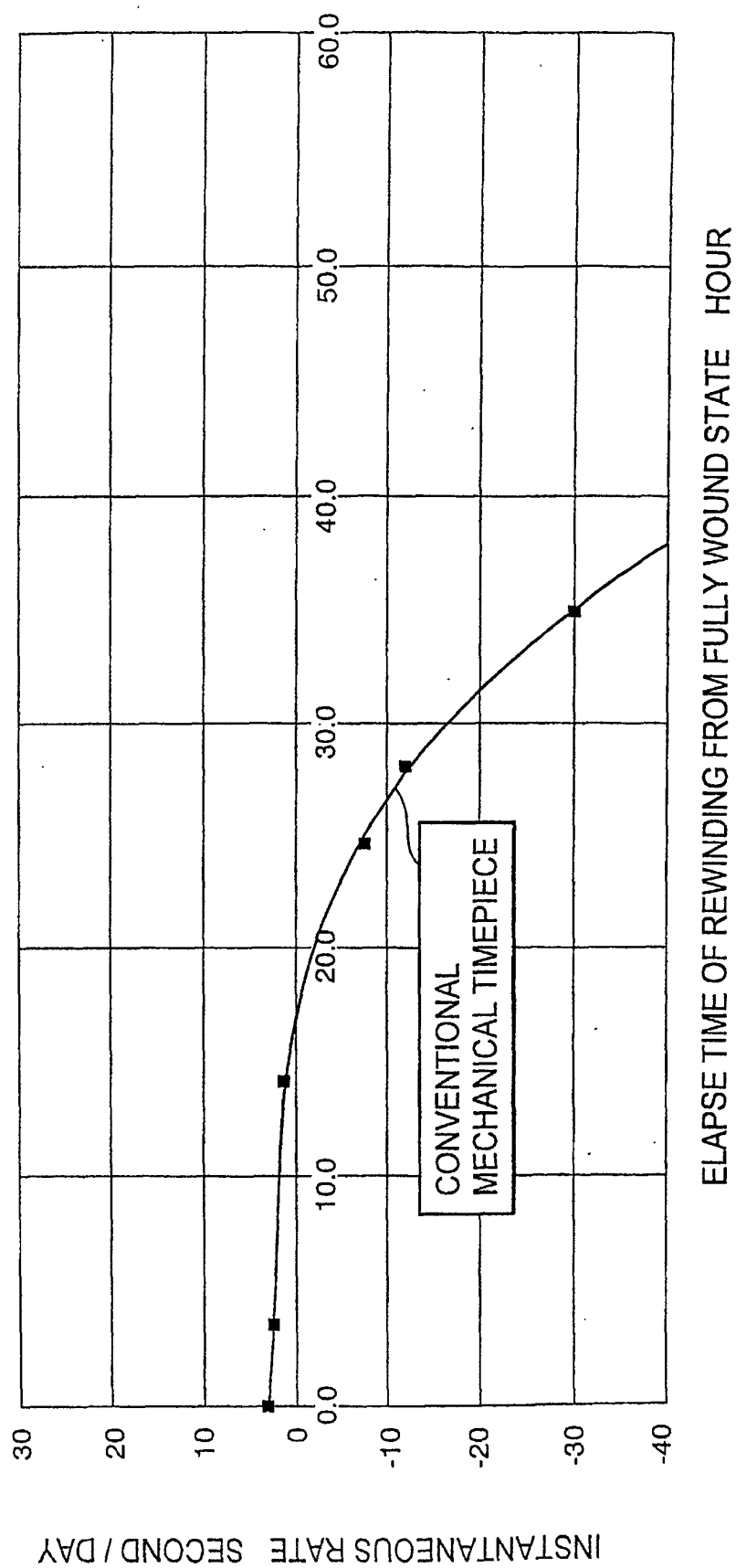


FIG.15



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP00/00679

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl ⁷ G04B17/20, 17/00, G04C3/04, 10/00		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) Int.Cl ⁷ G04B17/00-18/00, G04C3/04-3/06, 9/00-10/00		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1992-1996 Toroku Jitsuyo Shinan Koho 1994-2000 Kokai Jitsuyo Shinan Koho 1971-2000 Jitsuyo Shinan Toroku Koho 1996-2000		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) JICST FILE (JOIS)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP, 58-179379, A (Shiojiri Kogyo K.K., Kabushiki Kaisha Suwa Seikosha), 20 October, 1983 (20.10.83), Full text; all drawings (Family: none)	1-4, 8 6, 7 5
X Y A	US, 3937001, A (Jean-Claude Berney), 10 February, 1976 (10.02.76), Full text; Figs. 3 to 6 & JP, 50-6373, A & DE, 2357244, A1 & GB, 1425908, A & FR, 2207303, A & IT, 1001847, A & CH, 1691872, A	1-4, 8 6, 7 5
X Y A	US, 3952497, A (Heinz Jauch), 27 April, 1976 (27.04.76), Full text; Figs. 3 to 9 & JP, 50-79366, A & DE, 2353200, A1 & IL, 45886, A & LU, 71113, A & NO, 743796, A & SE, 7413174, A & NL, 7413926, A & FR, 2249378, A & DK, 553474, A & BR, 7408767, A & DD, 114694, C & ZA, 7406384, A & AU, 7440744, A & ES, 430659, A	1-4, 8 6, 7 5
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
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Date of the actual completion of the international search 04 April, 2000 (04.04.00)		Date of mailing of the international search report 18 April, 2000 (18.04.00)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)