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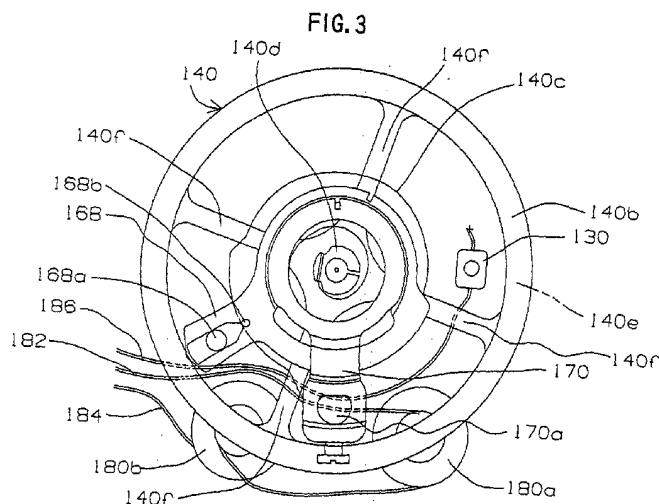
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(54) **MECHANICAL TIMEPIECE WITH OPTICAL DETECTING PART AND BRAKING PART**

(57) According to a mechanical timepiece of the invention, a movement 100 includes a barrel complete 120, a center wheel & pinion 124, a third wheel & pinion 126, a fourth wheel & pinion 128, a balance with hairspring 140, an escape wheel & pinion 130 and a pallet fork 142. Coils 180a, 180b are attached to a face of a main plate 102 on a front side to be opposed to a face of a balance wheel 140b on a side of the main plate. A balance magnet 140e is attached to a face of the balance wheel 140b on the side of the main plate to be op-

posed to the face of the main plate 102 on the front side.

The mechanical timepiece of the invention includes a detecting unit 176 provided for detecting a swing angle of the balance with hairspring by detecting an operational state of the balance with hairspring 140 by using light and a braking unit 146 constituted to exert force for restraining rotation of the balance with hairspring 140 to the balance with hairspring 140 when the swing angle of the balance with hairspring 140 detected by the detecting unit 176 is equal to or larger than a previously set angle.



Description

[Technical Field]

[0001] The present invention relates to a mechanical timepiece having an optical detecting unit and a braking unit constituted such that force of restraining rotation of a balance with hairspring is exerted to the balance with hairspring based on a result of detecting a swing angle of the balance with hairspring.

[Background of the Invention]

[0002] According to a conventional mechanical timepiece, as shown in Fig. 8 and Fig. 9, 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. 9 by an imaginary line) is attached to the movement 1100.

[0003] 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".

[0004] 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.

[0005] 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".

[0006] 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.

[0007] 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.

[0008] 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.

[0009] Generally, according to a conventional representative mechanical timepiece, as shown by Fig. 10, 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. 10, the mainspring torque is about 27 gácm in the fully wound state, becomes about 23 gácm after elapse of 20 hours from the fully wound state and becomes about 18 gácm after elapse of 40 hours from the fully wound state.

[0010] Generally, according to a conventional representative mechanical timepiece, as shown by Fig. 11, when the mainspring torque is reduced, the swing angle of the balance with hairspring is also reduced. For example, in the case of Fig. 11, when the mainspring torque is 25 to 28 gácm, the swing angle of the balance with hairspring is about 240 to 270 degrees and when the mainspring torque is 20 to 25 gácm, the swing angle of the balance with hairspring is about 180 to 240 degrees.

[0011] In reference to Fig. 12, 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" is defined as "a value in-

dicating gain or loss of a mechanical timepiece after elapse of one day when 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. 12, 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.

[0012] For example, according to a conventional representative timepiece, as shown by Fig. 12, 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).

[0013] In reference to Fig. 13, 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 obtained 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. 12 by an extremely slender line, over 24 hours.

[0014] 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.

[0015] For example, according to the conventional representative timepiece, as shown by the extremely slender line in Fig. 13, 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).

[0016] Further, as a conventional apparatus of adjusting a swing angle of a balance with hairspring, there is disclosed a constitution having a swing angle adjusting

plate generating eddy current and exerting braking force to a balance with hairspring at every time of pivotal approach of a magnet of the balance with hairspring in, for example, Japanese Utility Model Laid-Open No. 41675/1979.

[0017] Further, it is an object of the invention to provide an accurate mechanical timepiece having an inconsiderable change in rate even after elapse of time from a fully wound state.

[Disclosure of the Invention]

[0018] The invention is characterized in that in a mechanical timepiece comprising a mainspring constituting a power source of the mechanical timepiece, a front train wheel rotated by a rotational force when the mainspring is rewound and an escapement & speed control apparatus for controlling rotation of the front train wheel in which the escapement & speed control apparatus is constituted to include a balance with hairspring alternately repeating right rotation and left rotation, an escape wheel & pinion rotated based on the rotation of the front train wheel and a pallet fork for controlling rotation of the escape wheel & pinion based on operation of the balance with hairspring, the mechanical timepiece further comprising a detecting unit provided for detecting a swing angle of the balance with hairspring by detecting an operational state of the balance with hairspring by using light, and a braking unit constituted such that when the swing angle of the balance with hairspring detected by the detecting unit is equal to or larger than a previously set angle, a force of restraining rotation of the balance with hairspring is exerted to the balance with hairspring.

[0019] According to the mechanical timepiece of the invention, it is preferable that the detecting unit includes a light emitting portion for irradiating a balance arm portion and a light receiving portion for receiving light which has irradiated the balance arm portion.

[0020] Further, according to the mechanical timepiece of the invention, it is preferable that the braking unit includes coils arranged to be capable of braking motion of a balance magnet.

[0021] By using the detecting and the braking unit constituted in this way, the rotational angle of the balance with hairspring of the mechanical timepiece can effectively be controlled, thereby, accuracy of the mechanical timepiece can be promoted.

[0022] Further, according to the mechanical timepiece of the invention, it is preferable to include a balance rotation detecting circuit constituted to control light emitted by the light emitting portion and a balance rotation controlling circuit constituted to measure operation of the balance arm portion and calculate the swing angle of the balance with hairspring, and wherein the balance rotation controlling circuit does not conduct the coils when the swing angle of the balance with hairspring is less than a constant threshold and conducts the coils

when the swing angle of the balance with hairspring is equal to or larger than the constant threshold.

[0023] Further, according to the mechanical timepiece of the invention, it is preferable to further include an electricity storing unit for operating the balance rotation detecting circuit and the balance rotation controlling circuit.

[0024] Further, according to the mechanical timepiece of the invention, it is preferable to further include an electricity generating unit for charging the electricity storing unit.

[0025] Further, according to the invention, in a mechanical timepiece comprising a mainspring constituting a power source of the mechanical timepiece, a front train wheel rotated by a rotational force when the mainspring is rewound and an escapement & speed control apparatus for controlling rotation of the front train wheel in which the escapement & speed control apparatus includes a balance with hairspring alternately repeating right rotation and left rotation, an escape wheel & pinion rotated based on the rotation of the front train wheel and a pallet fork for controlling rotation of the escape wheel & pinion based on operation of the balance with hairspring, the mechanical timepiece further comprises an electricity storing unit constituting a power source, an electricity generating unit for charging the electricity storing unit, a speed control unit including the balance with hairspring and a balance magnet provided to the balance with hairspring, a detecting unit including a light emitting portion for irradiating a balance arm portion and a light receiving portion for receiving light which has irradiated the balance arm portion.

[0026] The mechanical timepiece of the invention further includes a braking unit including coils arranged to be capable of braking motion of the balance magnet provided at the balance with hairspring, an IC including a balance rotation detecting circuit constituted to control light emitted by the light emitting portion and a balance rotation controlling circuit constituted to measure operation of the balance arm portion and calculate a swing angle of the balance with hairspring.

[0027] The balance rotation controlling circuit of the mechanical timepiece of the invention is constituted not to conduct the coils when the swing angle of the balance with hairspring is less than a constant threshold and conduct the coils when the swing angle of the balance with hairspring is equal to or larger than the constant threshold.

[0028] By constituting in this way, there can be provided the mechanical timepiece having small change in the rate even when the elapse time period has passed from the fully wound state and having excellent accuracy.

[Brief Description of the Drawings]

[0029] Fig. 1 is a plane view showing an outline shape of a front side of a movement according to an embodi-

ment of the mechanical timepiece of the invention (in Fig. 1, portions of parts are omitted and bridge members are indicated by imaginary lines).

[0030] Fig. 2 is a sectional view of an enlarged portion showing an outline shape of portions of train wheels and an escapement & speed control apparatus according to the embodiment of the mechanical timepiece of the invention.

[0031] Fig. 3 is a plane view of an enlarged portion showing an outline shape of a portion of a balance with hairspring according to the embodiment of the mechanical timepiece of the invention.

[0032] Fig. 4 is a sectional view of an enlarged portion showing an outline shape of the portion of the balance with hairspring according to the embodiment of the mechanical timepiece of the invention.

[0033] Fig. 5 is a perspective view showing an outline shape of a balance magnet used in the mechanical timepiece of the invention.

[0034] Fig. 6 is a block diagram showing an outline constitution of the mechanical timepiece according to the invention.

[0035] Fig. 7 is a flowchart showing operation of the mechanical timepiece according to the invention.

[0036] Fig. 8 is a plane view showing an outline shape of a front side of a movement of a conventional mechanical timepiece (in Fig. 8, portions of parts are omitted and bridge members are indicated by imaginary lines).

[0037] Fig. 9 is an outline partial sectional view of the movement of the conventional mechanical timepiece (in Fig. 8, portions of parts are omitted).

[0038] Fig. 10 is a graph showing an outline relationship between an elapse time period and mainspring torque when the mainspring is rewound from a fully wound state in a mechanical timepiece.

[0039] Fig. 11 is a graph showing an outline relationship between a swing angle of a balance with hairspring and mainspring torque in a mechanical timepiece.

[0040] Fig. 12 is a graph showing an outline relationship between a swing angle of a balance with hairspring and an instantaneous rate in a mechanical timepiece.

[0041] Fig. 13 is a graph showing an outline relationship between an elapse time period and an instantaneous rate when a mainspring is rewound from a fully wound state in a mechanical timepiece according to the invention and the conventional mechanical timepiece.

[Best Mode for Carrying Out the Invention]

[0042] An explanation will be given of embodiments of a mechanical timepiece according to the invention in reference to the drawings as follows.

(1) Constitution of switch apparatus and wind up unit

[0043] In reference to Fig. 1 and Fig. 2, according to an embodiment of a mechanical timepiece of the invention, a movement (machine body) 100 of the mechanical

timepiece is provided with a main plate 102 constituting a base plate of the movement. A winding stem 110 is rotatably integrated to a winding stem guide hole 102a of the main plate 102. A dial 104 is attached to the movement 100.

[0044] 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. 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.

[0045] The movement 100 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 190, a yoke 192, a yoke spring 194 and a setting lever jumper 196. Based on rotation of the setting lever, the position in the rotational axis line of the winding stem 110 is determined. Based on rotation of the yoke, a position in the rotational axis line direction of the clutch wheel is determined. Based on rotation of the setting lever, the yoke is positioned to two positions in the rotational direction.

[0046] 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 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 constituted to rotate by rotation of the crown wheel 114.

(2) Constitution of power source and train wheel

[0047] The movement 100 is provided with a mainspring 122 contained in a barrel complete 120 as its power source. The mainspring 122 is made of an elastic material having spring performance such as iron. By rotating the ratchet wheel 116, the mainspring 122 is constituted to be capable of being wound up.

[0048] 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.

(3) Constitution of escapement & speed control apparatus

[0049] In reference to Fig. 1 through Fig. 4, the movement 100 is provided 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.

[0050] The balance with hairspring 140 includes a balance stem 140a, a balance wheel 140b and a hairspring 140c. There are provided four of balance arm portions 140f (referred to as "amida") for connecting the balance stem 140a and the balance wheel 140b. The number of the balance arm portions 140f may be two, may be three or may be four or more.

[0051] The hairspring 140c is made of an elastic material having spring performance such as "elinbar". That is, the hairspring 140c is made of an electrically conducting material of metal.

[0052] Based on rotation of the center wheel & pinion 124, a cannon pinion 150 is simultaneously rotated. A minute hand 152 attached to the cannon pinion 150 is constituted to display "minute". The cannon pinion 150 is provided with a slip mechanism having a predetermined slip torque relative to the center wheel & pinion 124.

[0053] Based on rotation of the cannon pinion 150, a minute wheel (not illustrated) is rotated. Based on rotation of the minute wheel, an hour wheel 154 is rotated. An hour hand 156 attached to the hour wheel 154 is constituted to display "hour".

[0054] 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.

[0055] The balance with hairspring 140 is supported rotatably by the main plate 102 and a balance bridge 166. That is, an upper mortise 140a1 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.

[0056] A lower mortise 140a2 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.

[0057] 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 140d fixed to the balance stem 140a and an outer end portion of the hairspring 140c is fixed by screws via a hairspring stud 170a attached to a stud support 170 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 170 is made of an electrically conductive material of metal such as iron.

(4) Constitution of detecting unit

[0058] An explanation will be given of a constitution of a detecting unit of the mechanical timepiece according to the invention as follows.

[0059] In reference to Fig. 1 through Fig. 4 and Fig. 6, in order to measure rotational operation of the balance arm portion 140f of the balance with hairspring 140, a phototransistor 130 is arranged at the balance bridge 166 to irradiate the balance arm portion 140f. That is, the phototransistor 130 constitutes a light emitting portion.

[0060] In order to receive light irradiated to the balance arm portion 140f, a photodiode 132 is provided at the main plate 102. That is, the photodiode 132 constitutes a light receiving portion. The light receiving portion can be constituted by, for example, photodiode, optical fiber, CCD or the like.

[0061] The phototransistor 130 (light emitting portion) and the photodiode 132 (light receiving portion) constitute a detecting unit 176.

[0062] A speed control unit 144 includes the balance with hairspring 140 and a balance magnet 140e. A description will be given later of details of the balance magnet 140e.

[0063] Further, the balance arm portion 140f of the balance with hairspring 140 is operated to rotate between the phototransistor 130 and the photodiode 132.

[0064] When the balance arm portion 140f is disposed between the phototransistor 130 and the photodiode 132, light emitted by the phototransistor 130 is constituted to be blocked by the balance arm portion 140f and not incident on the photodiode 132. By contrast, when the balance arm portion 140f is not disposed between the phototransistor 130 and the photodiode 132, light emitted by the phototransistor 130 is constituted to reach the photodiode 132.

[0065] The photodiode 132 is connected to IC 134. IC 134 includes a balance rotation detecting circuit 172 and a balance rotation controlling circuit 174. The balance rotation detecting circuit 172 is constituted to control light emitted by the phototransistor 130. The balance ro-

tation controlling circuit 174 is constituted to calculate the swing angle of the balance with hairspring 140 by measuring operation of the balance arm portion 140f.

[0066] The balance rotation controlling circuit 174 is previously stored with a relationship between a period of light incident on the photodiode 132 and a swing angle of the balance with hairspring. Therefore, calculation of the swing angle of the balance with hairspring 140 can be carried out by using the period of light incident on the photodiode 132.

(5) Constitution of electricity generating unit and electricity storing unit

[0067] Next, an explanation will be given of a constitution of an electricity generating unit and an electricity storing unit of the mechanical timepiece according to the invention.

[0068] A secondary battery 136 for operating IC 134 is fixed to the main plate 102. The secondary battery 136 constitutes an electricity storing unit 137. That is, the electricity storing unit 137 constitutes a power source for operating IC 134. The electricity storing unit 137 may be constituted by the secondary battery or may be constituted by a condenser. Or, in place of the electricity storing unit 137, a primary battery can also be utilized.

[0069] In order to charge the electricity storing unit 137, an electricity generating unit 150 is provided. The electricity generating unit 150 may be a hand-winding power generating mechanism for generating voltage by rotation of the barrel complete 102 or may be an automatic-winding power generating mechanism for generating voltage by rotation of an oscillating weight.

[0070] The electricity generating unit 150 may be arranged on the "back side" of the movement 100 or may be arranged on the "front side" of the movement 100.

[0071] As structure of the electricity generating unit 150, a structure similar to a conventional structure can be used and therefore, the structure is not illustrated in Fig. 1.

[0072] Fig. 6 shows an outline constitution when the electricity generating unit 150 is constituted by a hand-winding power generating mechanism. In reference to Fig. 6, the electricity generating unit 150 includes a wind up mechanism 152 operated by rotation of the barrel complete 102, an accelerating train wheel 154 for accelerating and transmitting rotation of the wind up mechanism 152, a rotor 156 rotated by rotation of the accelerating train wheel 154, a stator 157 having a rotor hole opposed to a rotor magnet of the rotor 156, a power generating coil 158 for generating electromotive force by rotation of the rotor 156 and a rectifying circuit 160 for rectifying current generated at the power generating coil 158. Current rectified by the rectifying circuit 160 flows to the secondary battery 136 constituting the electricity storing unit 137. A condenser may be used in place of the secondary battery 136. Rectifying operation carried

out by the rectifying circuit 160 may be half-wave rectifying operation or full-wave rectifying operation. The rectifying circuit can be built in IC 134 or may be provided separately from IC 134.

[0073] When the electricity generating unit is constituted by an automatic-winding power generating mechanism, the electricity generating unit includes an oscillating weight, an accelerating train wheel for accelerating and transmitting rotation of the oscillating weight, a rotor rotated by rotation of the accelerating train wheel, a stator having a rotor hole opposed to a rotor magnet of the rotor, a power generating coil for generating electromotive force by rotation of the rotor and a rectifying circuit for rectifying current generated at the power generating coil. Current rectified by the rectifying circuit is constituted to flow to the secondary battery 136.

[0074] For example, an electronic wrist watch having a power generating apparatus is disclosed in Japanese Patent Laid-Open No. 266989/1986 or Japanese Patent Laid-Open No. 293143/ 1986 and a portable timepiece having charging function is disclosed in Japanese Patent Laid-Open No. 288192/1986.

[0075] A modified example can be constituted without using an electricity generating mechanism by using a battery (primary battery) such as silver battery, lithium battery or the like.

(6) Constitution of braking unit

[0076] Next, an explanation will be given of a constitution of a braking unit of the mechanical timepiece according to the invention.

[0077] Coils 180a and 180b are attached to a face of the main plate 102 on the front side to be opposed to a side face of the balance wheel 140b on the side of the main plate. The coils 180a and 180b constitute the braking unit 146. Although the number of the coils is, for example, two as shown by Fig. 1 through Fig. 4, the number may be one, may be two, may be three, or may be four or more.

[0078] The balance magnet 140e is attached to a side face of the balance wheel 140b on the side of the main plate to be opposed to a face of the main plate 102 on the front side.

[0079] Although it is preferable that as shown by Fig. 1 and Fig. 3, an interval between the coils 180a and 180b in the circumferential direction in the case of arranging pluralities of the coils 180a and 180b, is equal to an interval between an S pole and an N pole of the balance magnet 140e arranged to be opposed to the coils 180a and 180b multiplied by an integer, all of the coils may not be disposed at equal intervals in the circumferential direction. Further, according to such a constitution having the pluralities of coils, wirings among the respective coils may be wired in series such that currents generated at the respective coils by electromagnetic induction are not canceled by each other. Or, the wirings among the respective coils may be wired in parallel

such that currents generated at the respective coils are not canceled by each other by electromagnetic induction.

[0080] In reference to Fig. 5, the balance magnet 140e is provided with an annular (ring-like) shape and along the circumferential direction, magnet portions comprising, for example, 12 pieces of S poles 140s1 through 140s12 and 12 pieces of N poles 140n1 through 140n12 polarized in the up and down direction are alternately provided. 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 of Fig. 5, the number may be a plural number of 2 or more. In this case, it is preferable that a length of a chord of the magnet portion is substantially equal to an outer diameter of the coil provided to be opposed to the magnet portion.

[0081] A clearance is provided between the magnet 140e and the coils 180a and 180b. The clearance between the balance magnet 140e and the coils 180a and 180b is determined such that when the coils 180a and 180b are conducted, magnetic force of the balance magnet 140e effects influence on the coils 180a and 180b.

[0082] When the coils 180a and 180b are not conducted, the magnetic force of the balance magnet 140e does not effect influence on the coils 180a and 180b. The balance magnet 140e is fixed by adhesion or the like to a face of the balance wheel 140b on the side of the main plate in a state in which one face thereof 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.

[0083] A first lead wire 182 is provided to connect one terminal of the coil 180a and a first coil terminal of IC 134. A second lead wire 184 is provided to connect one terminal of the coil 180b and a second coil terminal of IC 134.

[0084] Further, a thickness of the hairspring 140c (thickness in the radius direction of the balance with hairspring) is, for example, 0.021 millimeter. With regard 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 magnetic flux density thereof is about 0.02 tesla. With regard to the coils 180a and 180b, respective turn number is, for example, 8 turn and a coil wire diameter thereof is about 25 micrometers. The clearance between the balance magnet 140e and the coils 180a and 180b is, for example, about 0.4 millimeter.

(7) Operation of detecting unit and braking unit

[0085] Next, an explanation will be given of operation of the detecting unit and the braking unit of the mechanical timepiece according to the invention.

[0086] An explanation will be given of operation of the

balance with hairspring 140 when the coils 180a and 180b are not conducted, that is, when circuits including the coils 180a and 180b are open in reference to Fig. 1 through Fig. 4.

[0087] The hairspring 140c is elongated and contracted in the radius direction of the hairspring 140c in accordance with a rotational angle of rotating the balance with hairspring 140. For example, in a state shown by Fig. 3, 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, 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.

[0088] When the rotational angle (swing angle) of the balance with hairspring 140 is less than a constant threshold, for example, 180 degree, by operation of the balance rotation controlling circuit 174, the coils 180a and 180b are constituted not to be conducted.

[0089] Next, an explanation will be given of operation of the balance with hairspring 140 when the coils 180a and 180b are conducted, that is, when the circuits including the coils 180a and 180b are closed. That is, when the swing angle of the balance with hairspring 140 becomes equal to or larger than 180 degrees, the coils 180a and 180b are constituted to conduct.

[0090] When the swing angle of the balance with hairspring 140 becomes equal to or larger than 180 degree, by operation of the balance rotation controlling circuit 174, the coils 180a and 180b are conducted and by induction current generated by a change in magnetic flux of the balance magnet 140e, force of restraining the rotational motion of the balance with hairspring 140 is exerted to the balance with hairspring 140. Further, by operation of the balance rotation control circuit 174, the coils 180a and 180b and the balance magnet 140e, the swing angle of the balance with hairspring 140 is constituted to reduce by exerting braking force for restraining rotation of the balance with hairspring 140 to the balance with hairspring 140.

[0091] Further, when the swing angle of the balance with hairspring 140 is reduced to a range of the swing angle of the balance with hairspring 140 exceeding 0 degrees and less than 180 degrees, by operation of the balance rotation controlling circuit 174, the coils 180a and 180b are constituted not to be conducted. Therefore, in the range of the swing angle of the balance with hairspring 140 exceeding 0 degrees and less than 180 degrees, the coils 180a and 180b are not conducted and the force of restraining the rotational motion of the balance with hairspring 140 is not exerted to the balance with hairspring 140.

[0092] Next, an explanation will be given of operation of the detecting unit and the braking unit according to the mechanical timepiece of the invention.

[0093] In reference to Fig. 6 and Fig. 7, by operation

of the balance rotation detecting circuit 172, rotation of the balance with hairspring is started to detect (step S1 of Fig. 7).

[0094] The balance rotation detecting circuit 172 determines a detection time period (step 2 of Fig. 7). Determination of the detection time period is carried out by, for example, a counter. A set time period for detecting rotation of the balance with hairspring is previously stored in the balance rotation detecting circuit 172.

[0095] The set time period for detecting rotation of the balance with hairspring is, for example, about 1 hour. The set time period for detecting rotation of the balance with hairspring is preferably about 0.25 through 6 hours, further preferably, about 0.5 through 3 hours and further preferably, about 1 through 2 hours.

[0096] When the balance rotation detecting circuit 172 determines elapse of the set time period, the balance rotation detecting circuit 172 makes ON the phototransistor 130 (step S3 of Fig. 7). When the balance rotation detecting circuit 172 determines that the set time period has not elapsed, the operation returns to step S2 of Fig. 7 and operation of determining the detection time period is repeated.

[0097] When the balance rotation detecting circuit 172 makes ON the phototransistor 130, the balance rotation controlling circuit 174 determines the swing angle of the balance with hairspring 140 (step S4 of Fig. 7).

[0098] That is, the balance rotation controlling circuit 174 measures the operational state of the balance arm portion 140f by using light incident on the photodiode 132 and calculates the swing angle of the balance with hairspring 140. The balance rotation controlling circuit 174 is previously stored with the relationship between the period of light incident on the photodiode 132 and the swing angle of the balance with hairspring and therefore, calculation of the swing angle of the balance with hairspring 140 is carried out by using the period of light incident on the photodiode 132.

[0099] When the balance rotation controlling circuit 174 determines that the swing angle of the balance with hairspring 140 is equal to or larger than the set angle, the balance rotation detecting circuit 172 makes OFF the phototransistor 130 (step S5 of Fig. 7). In this case, the balance rotation controlling circuit 174 conducts the coils 180a and 180b (step S6 of Fig. 7). When the coils 180a and 180b are conducted, induction current is generated by the change in the magnetic flux of the balance magnet 140e and force of restraining the rotational motion of the balance with hairspring 140 is exerted to the balance with hairspring 140. Further, by exerting the braking force for restraining rotation of the balance with hairspring 140 to the balance with hairspring 140, the swing angle of the balance with hairspring 140 is reduced. When the balance rotation controlling circuit 174 conducts the coils 180a and 180b and the swing angle of the balance with hairspring 140 is reduced, the operation returns to step S2 of Fig. 7 and operation of determining the detection time period is repeated.

[0100] The relationship between the time period which the balance rotation controlling circuit 174 is to conduct the coils 180a and 180b and the swing angle of the balance with hairspring 140 is previously calculated by experiment and a result thereof is stored to the balance rotation controlling circuit 174.

[0101] The set angle of the swing angle of the balance with hairspring 140 is previously stored to the balance rotation controlling circuit 174. The set angle of the swing angle of the balance with hairspring 140 is, for example, 180 degrees. The set angle of the swing angle of the balance with hairspring 140 is preferably about 150 through 210 degrees and further preferably 180 degrees.

[0102] When the balance rotation controlling circuit 174 determines that the swing angle of the balance with hairspring 140 is less than the set angle, the balance rotation detecting circuit 172 makes OFF the phototransistor 130 (step S7 of Fig. 7). In this case, the balance rotation controlling circuit 174 does not conduct the coils 180a and 180b (step S8 of Fig. 7).

[0103] Further, the operation returns to step S2 of Fig. 7 and repeats operation of determining the detection time period.

[0104] A modified example may be constituted such that when the balance rotation controlling circuit 174 determines that the swing angle of the balance with hairspring 140 is equal to or larger than the set angle, the balance rotation detecting circuit 172 makes OFF the phototransistor 130, the balance rotation controlling circuit 174 conducts the coils 180a and 180b, the force of restraining the rotational motion of the balance with hairspring 140 for conducting the coils 180a and 180b is exerted to the balance with hairspring 140 and thereafter, the rotation controlling circuit 174 determines again the swing angle of the balance with hairspring 140. That is, in Fig. 7, a loop of returning to step S4 by a constant number of times after step S6 may be provided in Fig. 7.

[0105] According to the constitution, by providing the feedback loop, the swing angle of the balance with hairspring 140 can further accurately be adjusted.

[0106] Therefore, according to the mechanical timepiece of the invention, the swing angle of the balance with hairspring 140 can be controlled accurately and efficiently.

(8) Constitution of circuits used in mechanical timepiece of the invention

[0107] Further, according to the embodiment of the mechanical timepiece of the invention, circuits for carrying out various functions may be constituted in IC or IC may be PLA-IC incorporating programs for carrying out various operations.

[0108] Further, in the embodiment of the mechanical timepiece of the invention, there can be used external elements of resistors, condensers, coils, diodes, transistors and so on along with IC, depending on necessity.

(9) Effect of the Invention

[0109] According to the invention, as has been explained above, in the mechanical timepiece constituted such that the escapement and speed control apparatus includes the balance with hairspring repeating right rotation and left rotation, the escape wheel & pinion rotated 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, there is constructed the constitution including the detecting unit for detecting the swing angle of the balance with hairspring and the braking unit for controlling the rotational angle of the balance with hairspring and accordingly, accuracy of the mechanical timepiece can be promoted without reducing the duration time period of the mechanical timepiece.

[0110] That is, according to the present invention, attention is paid to the correlation between the instantaneous rate and the swing angle, by maintaining the swing angle constant, the change in the instantaneous rate is restrained and gain or loss of the timepiece per day is adjusted to reduce.

[0111] By contrast, according to the conventional mechanical timepiece, by the relationship between the duration time period and the swing angle, the swing angle is changed with elapse of time. Further, by the relationship between the swing angle and the instantaneous rate, the instantaneous rate is changed with elapse of time. Therefore, it has been difficult to prolong the duration time period of the timepiece capable of maintaining constant accuracy.

(10) Simulation with regard to instantaneous rate

[0112] Next, an explanation will be given of a result of a simulation with regard to instantaneous rate which is carried out with regard to the mechanical timepiece of the invention developed for resolving the problem of the conventional mechanical timepiece.

[0113] In reference to Fig. 13, according to the mechanical timepiece of the invention, initially, as shown by plots of x marks and a slender line in Fig. 13, the timepiece is adjusted to a state of gaining the instantaneous rate of the timepiece.

[0114] That is, according to the mechanical timepiece of the invention, as shown by the plots of x marks and the slender line in Fig. 13, in a state of completely winding up the mainspring, the rate is about 18 seconds / day (gain of about 18 seconds per day), after elapse of 20 hours from the fully wound state, the instantaneous rate becomes about 13 seconds / day (gain of about 13 seconds per day) and with elapse of 30 hours from the fully wound state, the instantaneous rate becomes about -2 seconds / day (loss of about 2 seconds per day).

[0115] According to the mechanical timepiece of the invention, when the braking unit is operated, as shown

by plots of black circles and an extremely bold line, in a state of operating the braking unit, that is, until elapse of 27 hours from the state of completely winding up the mainspring, the instantaneous rate can be maintained at about 5 seconds / day (maintaining state of gaining about 5 seconds per day) and when 30 hours has elapsed from the fully wound state, the instantaneous rate becomes about -2 seconds / day (loss of about 2 seconds per day).

[0116] According to the mechanical timepiece having the mechanism of controlling the rotational angle of the balance with hairspring of the invention, by controlling the swing angle of the balance with hairspring, the change in the instantaneous rate of the timepiece is restrained and accordingly, in comparison with the conventional mechanical timepiece shown by plots of squares and the imaginary line in Fig. 13, the elapse time period from the fully wound state at which the instantaneous rate is about 0 through 5 seconds / day can be prolonged.

[0117] That is, according to the mechanical timepiece of the invention, the duration time period in which the instantaneous rate falls within plus and minus 5 seconds / day is about 32 hours. The value of the duration time period is about 1.45 times as large as the duration time period in which the instantaneous rate falls within plus and minus 5 seconds / day, or about 22 hours in the conventional mechanical timepiece.

[0118] Therefore, there is provided the result of the simulation in which the accuracy of the mechanical timepiece of the invention is very excellent in comparison with that of the conventional mechanical timepiece.

[Industrial Applicability]

[0119] The mechanical timepiece of the invention is suitable for realizing a mechanical timepiece having a simple structure and having an excellent accuracy.

[0120] Further, the mechanical timepiece of the invention is provided with the optical detection type detection unit of the swing angle of the balance with hairspring and accordingly, fabrication and rate adjustment of the mechanical timepiece are extremely facilitated.

Claims

1. A mechanical timepiece **characterized in that** in a mechanical timepiece comprising a mainspring constituting a power source of the mechanical timepiece, a front train wheel rotated by a rotational force when the mainspring is rewound and an escapement & speed control apparatus for controlling rotation of the front train wheel in which the escapement & speed control apparatus is constituted to include a balance with hairspring alternately repeating right rotation and left rotation, an escape wheel & pinion rotated based on the rotation of the front

train wheel and a pallet fork for controlling rotation of the escape wheel & pinion based on operation of the balance with hairspring, said mechanical timepiece further comprising:

a detecting unit (176) provided for detecting a swing angle of the balance with hairspring by detecting an operational state of the balance with hairspring (140) by using light; and a braking unit (146) constituted such that when the swing angle of the balance with hairspring (140) detected by the detecting unit (176) is equal to or larger than a previously set angle, a force of restraining rotation of the balance with hairspring (140) is exerted to the balance with hairspring (140).

2. The mechanical timepiece according to Claim 1, **characterized in that** the detecting unit (176) includes a light emitting portion (130) for irradiating a balance arm portion (140f) and a light receiving portion (132) for receiving light which has irradiated the balance arm portion (140f).
3. The mechanical timepiece according to Claim 1 or Claim 2, **characterized in that** the braking unit (146) includes coils (180a, 180b) arranged to be capable of braking motion of a balance magnet (140e) provided to the balance with hairspring (140).
4. The mechanical timepiece according to Claim 3, **characterized in** further including a balance rotation detecting circuit (172) constituted to control light emitted by the light emitting portion (130) and a balance rotation controlling circuit (174) constituted to measure operation of the balance arm portion (140f) and calculate the swing angle of the balance with hairspring (140); and wherein the balance rotation controlling circuit (174) does not conduct the coils (180a, 180b) when the swing angle of the balance with hairspring (140) is less than a constant threshold and conducts the coils (180a, 180b) when the swing angle of the balance with hairspring (140) is equal to or larger than the constant threshold.
5. The mechanical timepiece according to Claim 4, **characterized in** further including an electricity storing unit (137) for operating the balance rotation detecting circuit (172) and the balance rotation controlling circuit (174).
6. The mechanical timepiece according to Claim 5, **characterized in** further including an electricity generating unit (150) for charging the electricity storing unit (137).
7. A mechanical timepiece **characterized in that** in a

mechanical timepiece comprising a mainspring constituting a power source of the mechanical timepiece, a front train wheel rotated by a rotational force when the mainspring is rewound and an escapement & speed control apparatus for controlling rotation of the front train wheel in which the escapement & speed control apparatus includes a balance with hairspring alternately repeating right rotation and left rotation, an escape wheel & pinion rotated based on the rotation of the front train wheel and a pallet fork for controlling rotation of the escape wheel & pinion based on operation of the balance with hairspring, said mechanical timepiece further comprising:

an electricity storing unit (137) constituting a power source;
 an electricity generating unit (150) for charging the electricity storing unit (137);
 a speed control unit (144) including the balance with hairspring (140) and a balance magnet (140e) provided to the balance with hairspring (140);
 a detecting unit (176) including a light emitting portion (130) for irradiating a balance arm portion (140f) and a light receiving portion (132) for receiving light which has irradiated the balance arm portion (140f);
 a braking unit (146) including coils (180a, 180b) arranged to be capable of braking motion of the balance magnet (140e) provided at the balance with hairspring (140);
 IC (134) including a balance rotation detecting circuit (172) constituted to control light emitted by the light emitting portion (130) and a balance rotation controlling circuit (174) constituted to measure operation of the balance arm portion (140f) and calculate a swing angle of the balance with hairspring (140); and
 wherein the balance rotation controlling circuit (174) is constituted not to conduct the coils (180a, 180b) when the swing angle of the balance with hairspring (140) is less than a constant threshold and conduct the coils (180a, 180b) when the swing angle of the balance with hairspring (140) is equal to or larger than the constant threshold.

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FIG.1

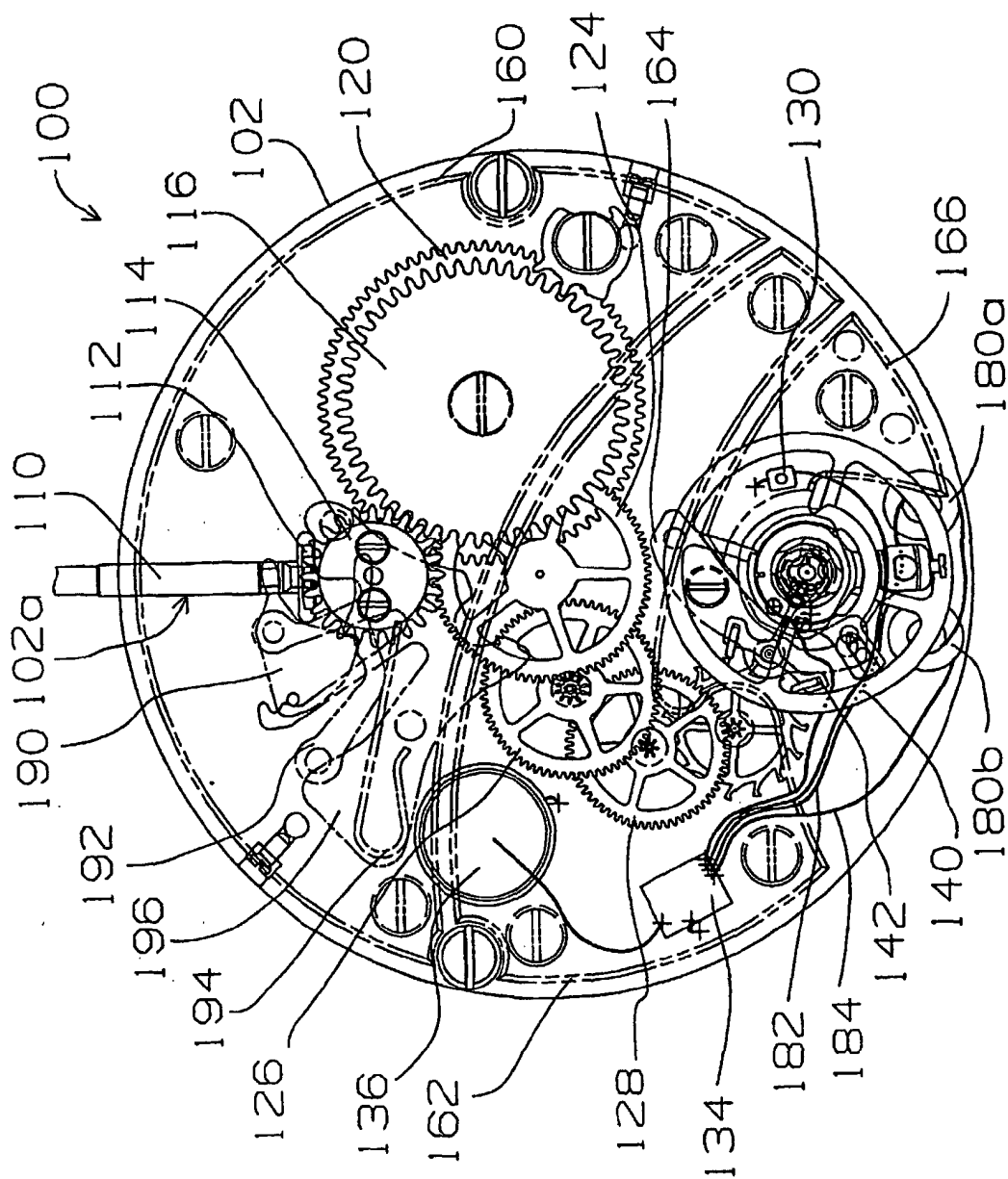


FIG. 2

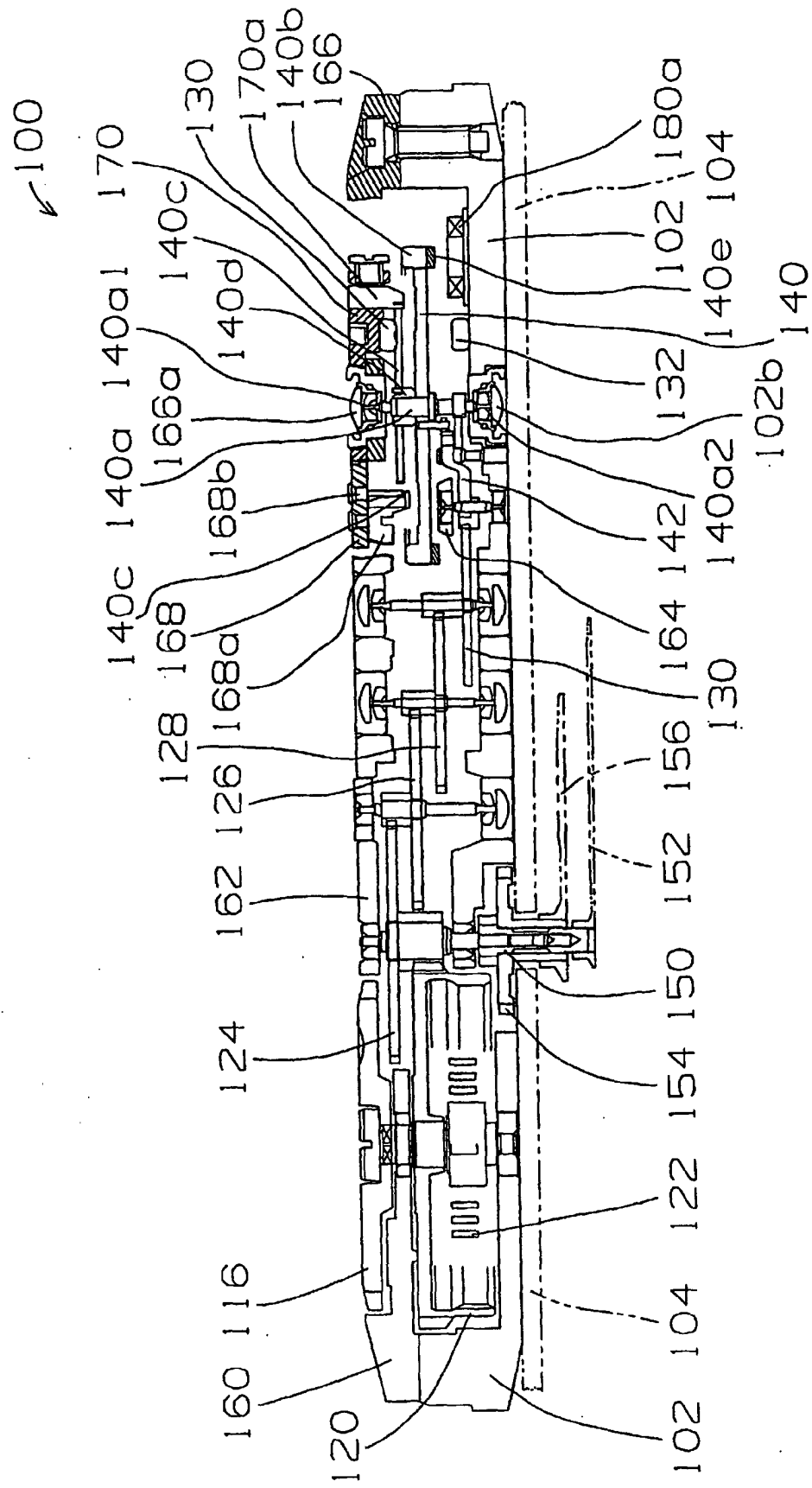


FIG. 3

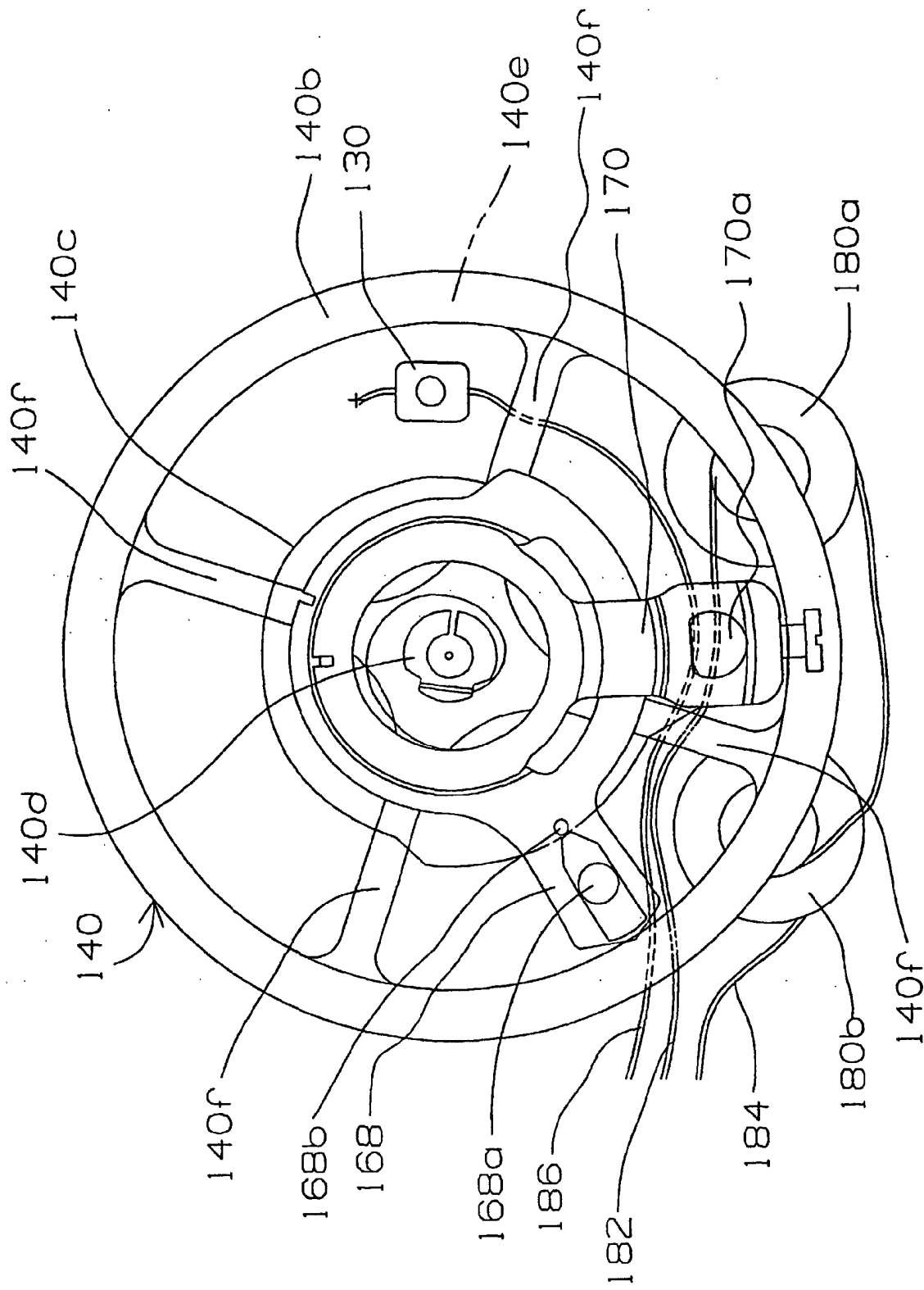


FIG. 4

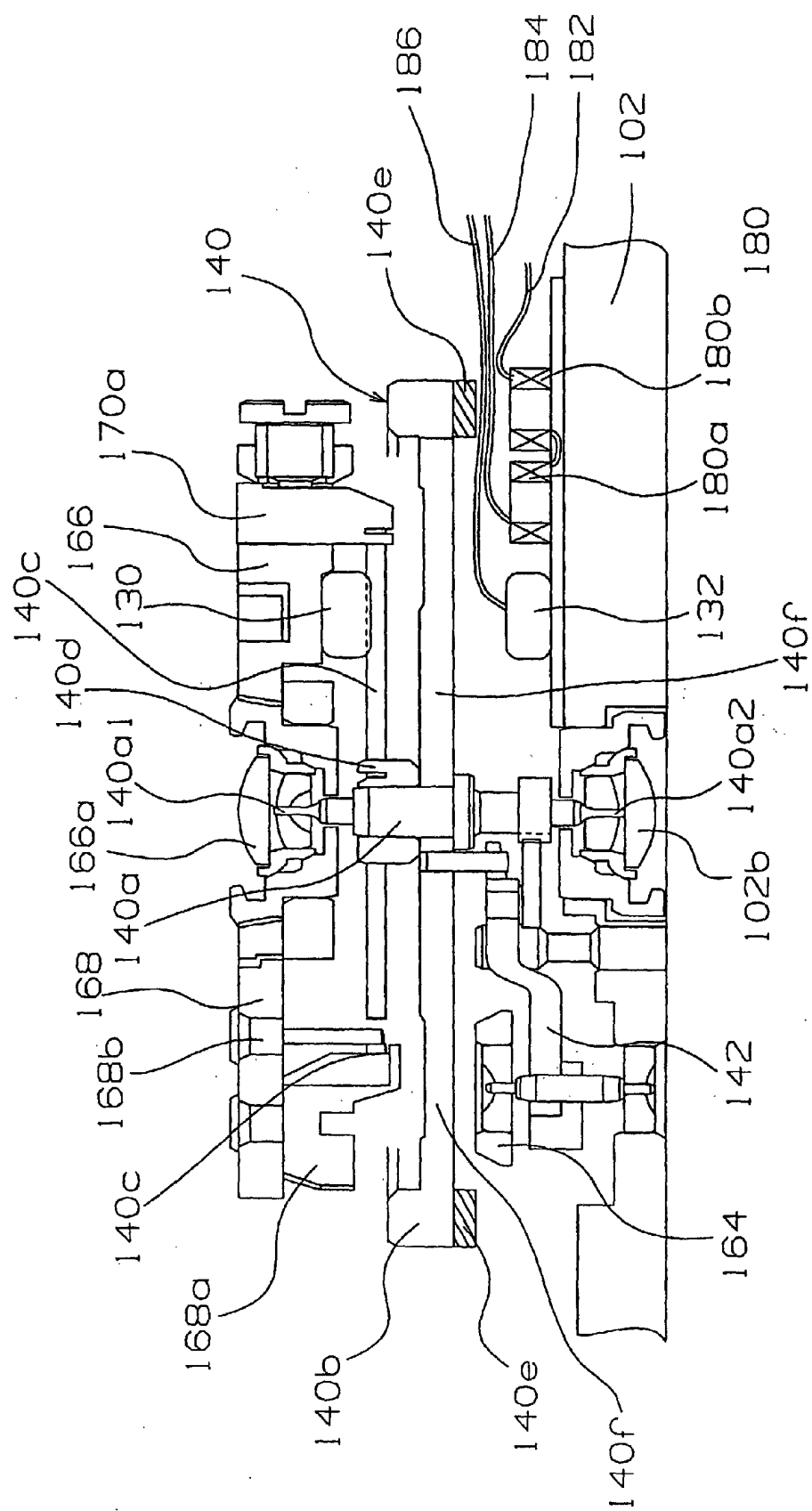


FIG. 5

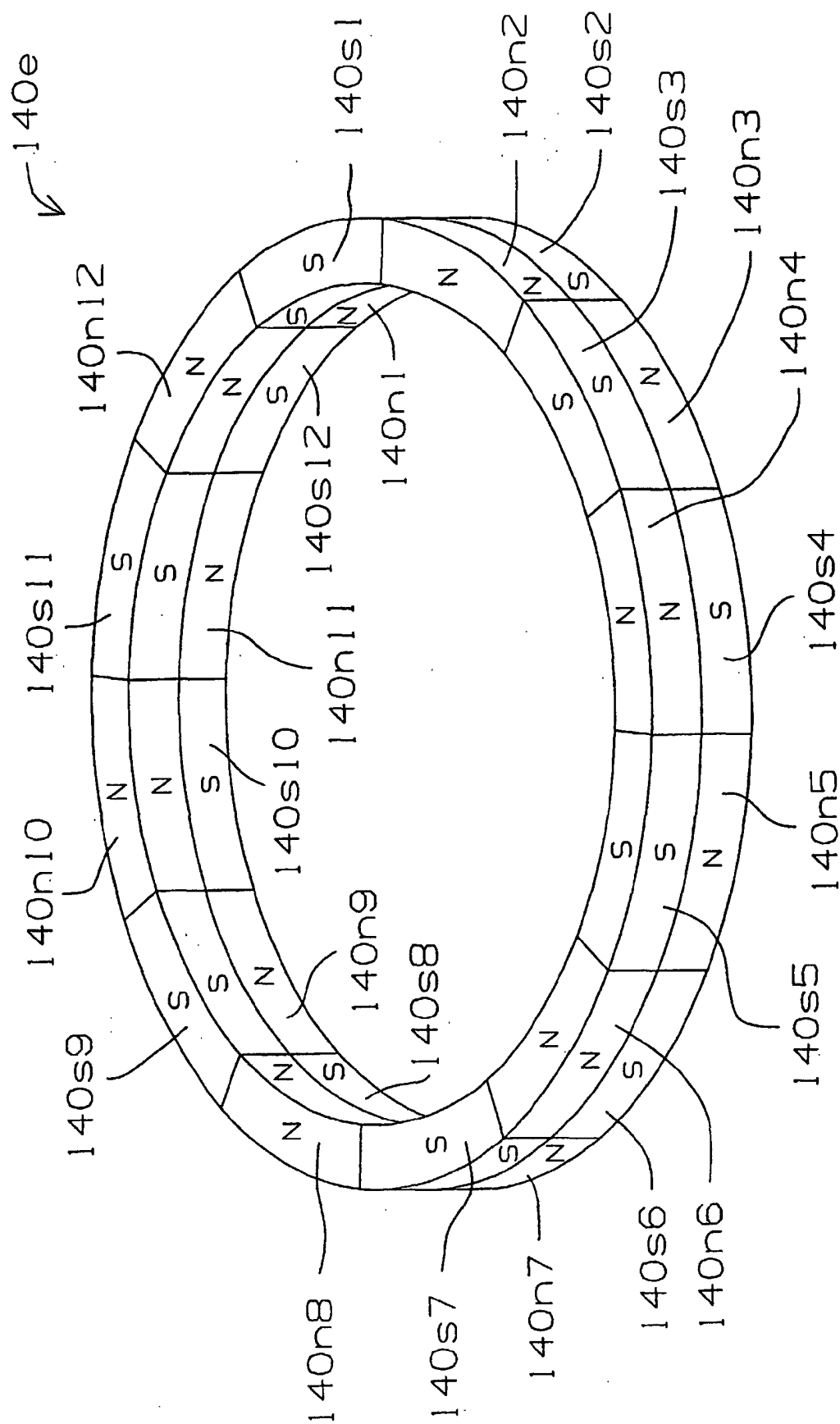


FIG. 6

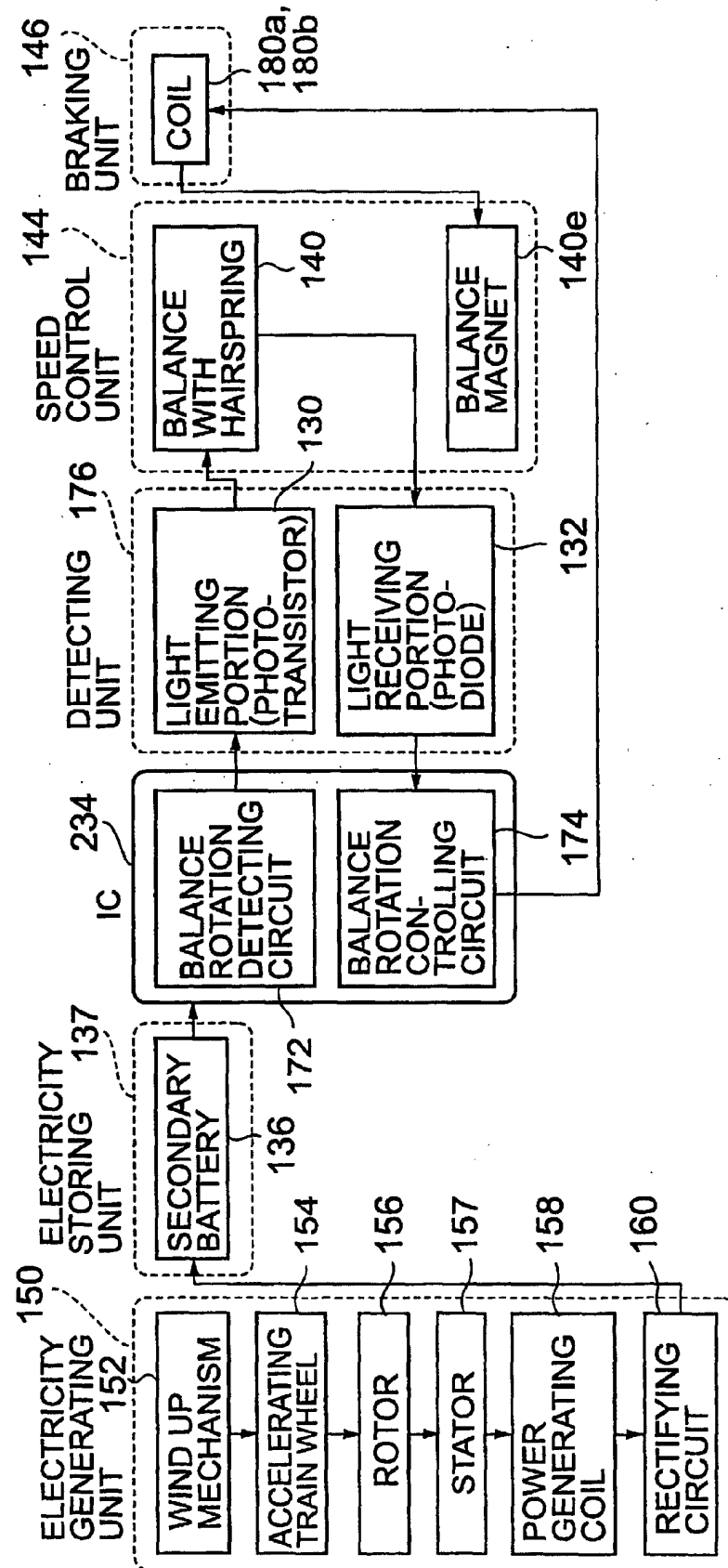


FIG. 7

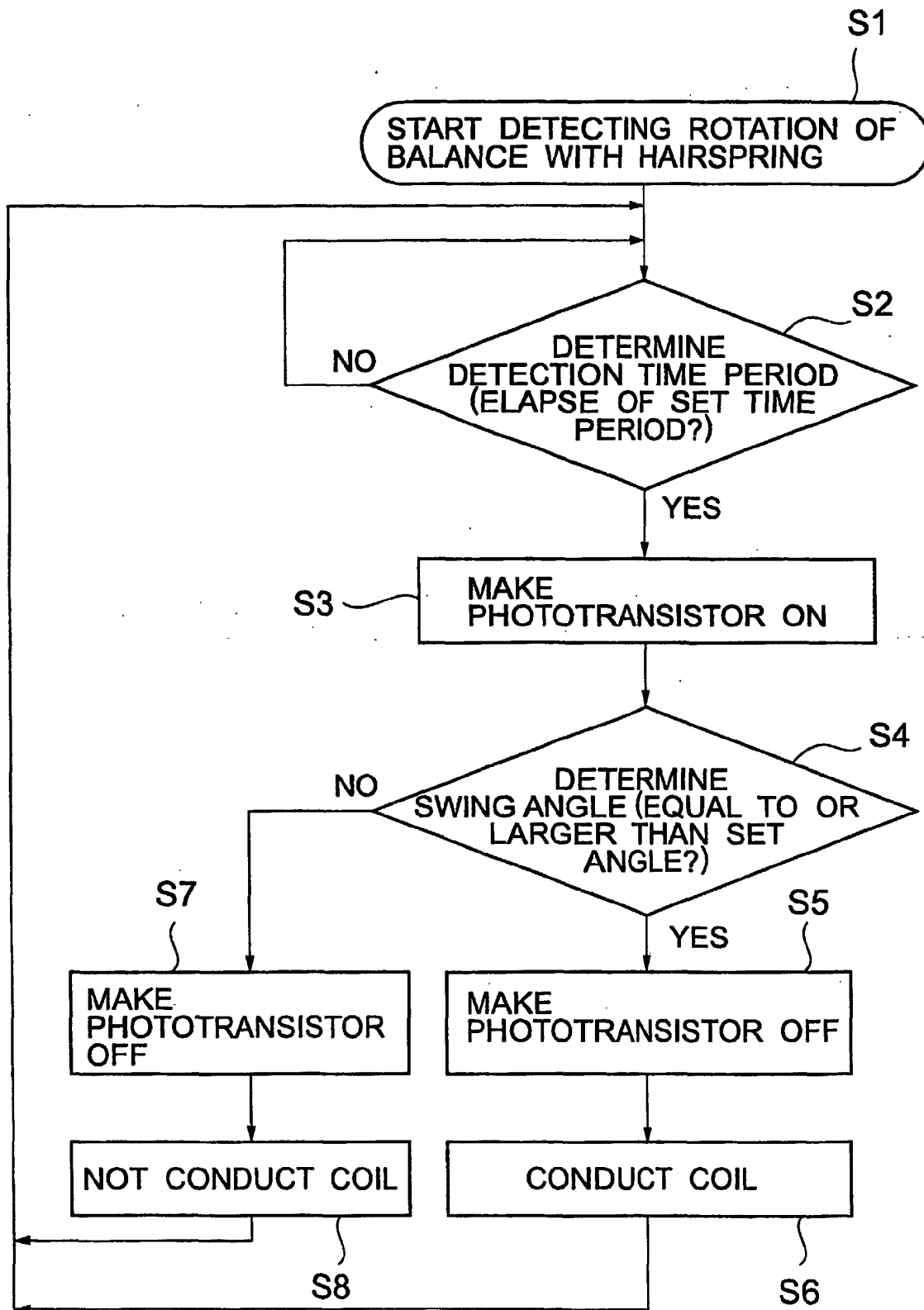


FIG. 8

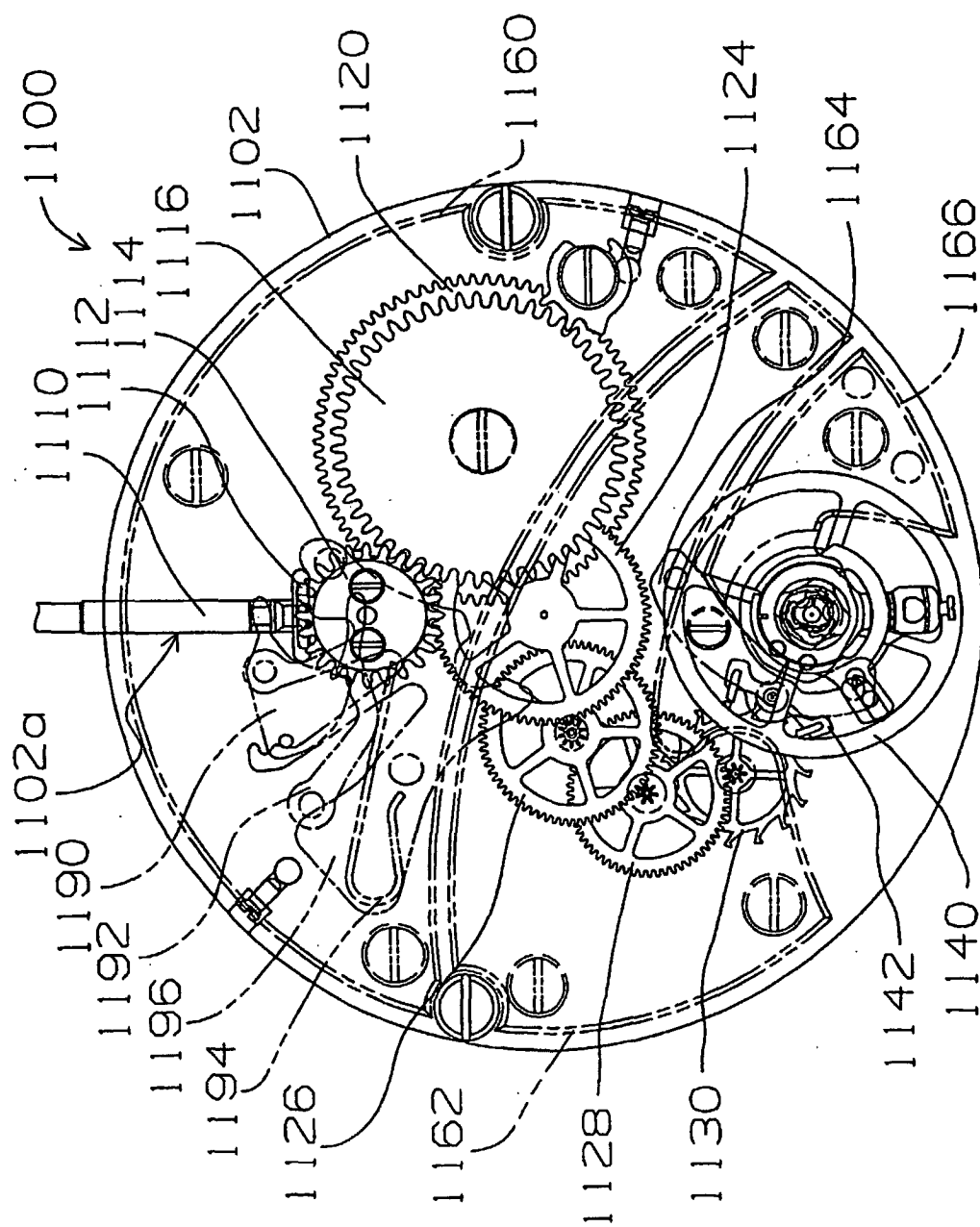


FIG. 9

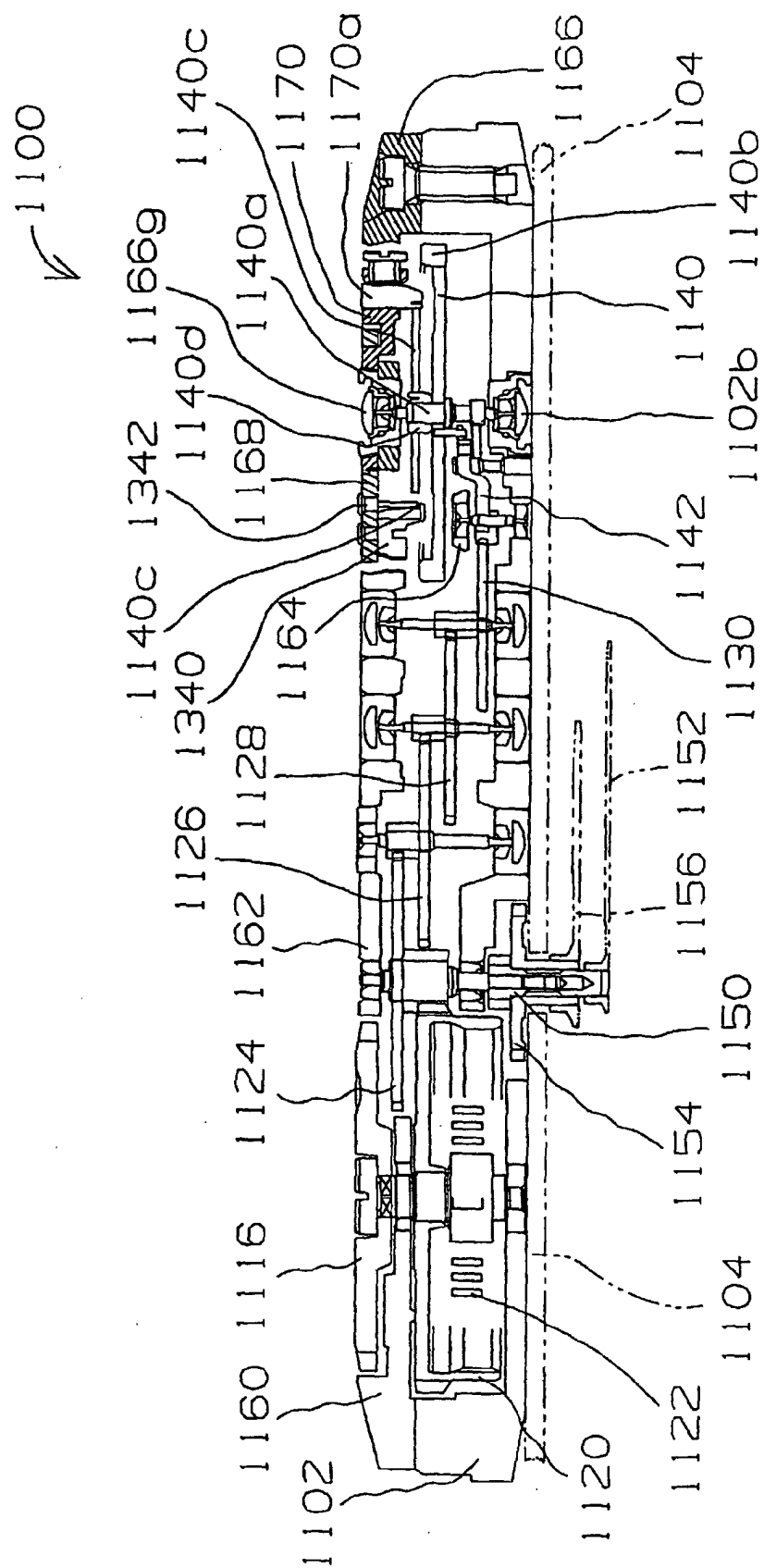


FIG.10

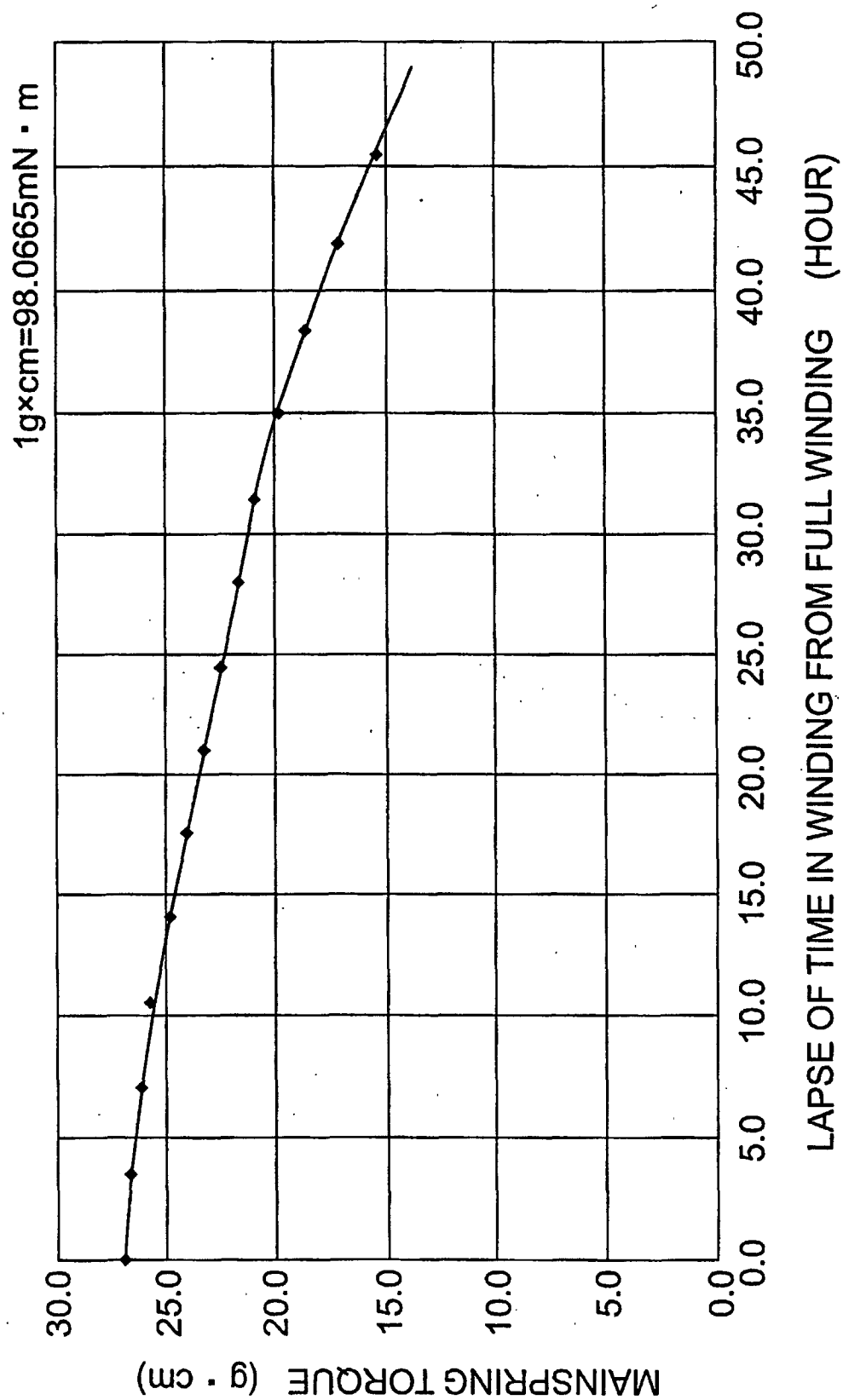


FIG.11

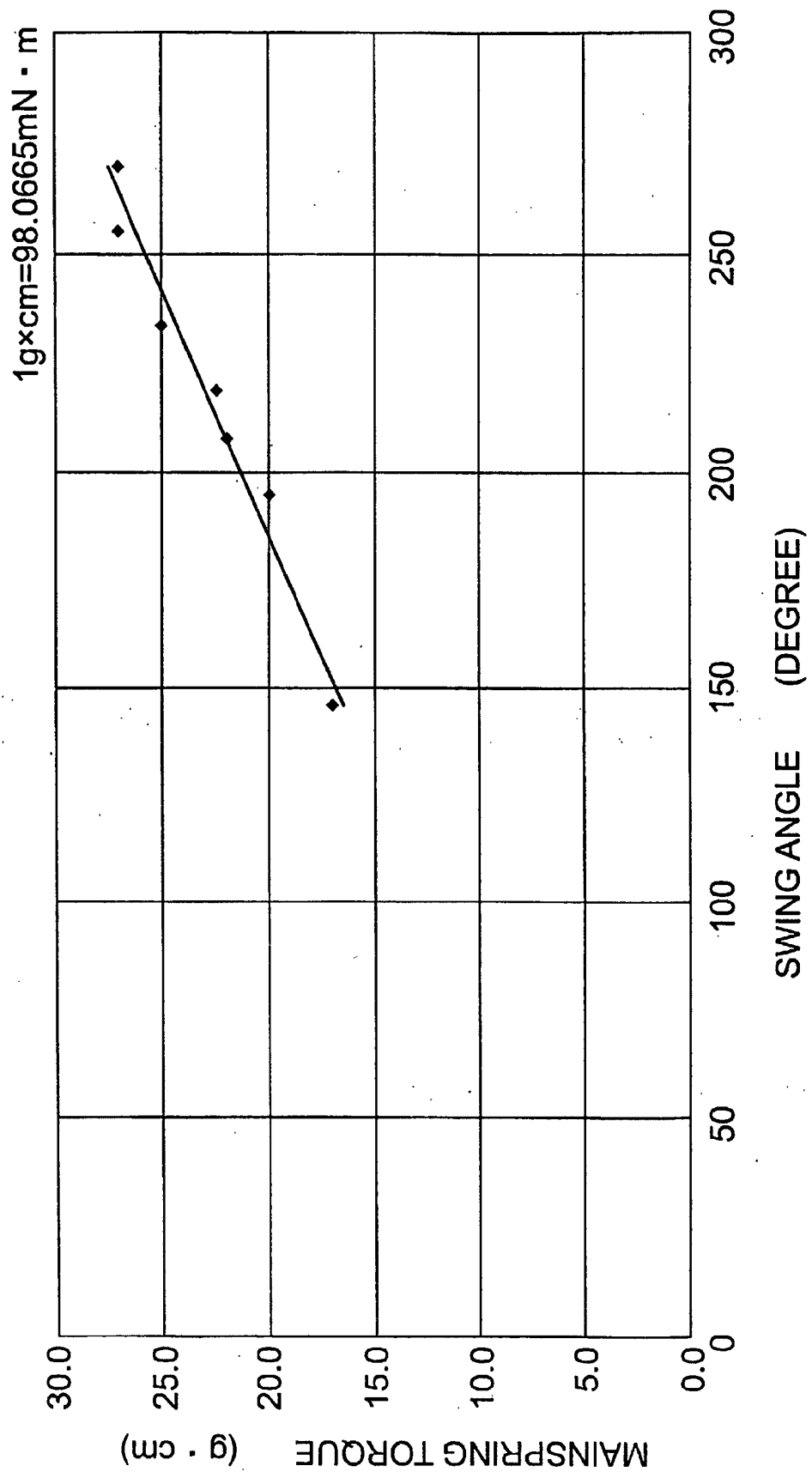


FIG.12

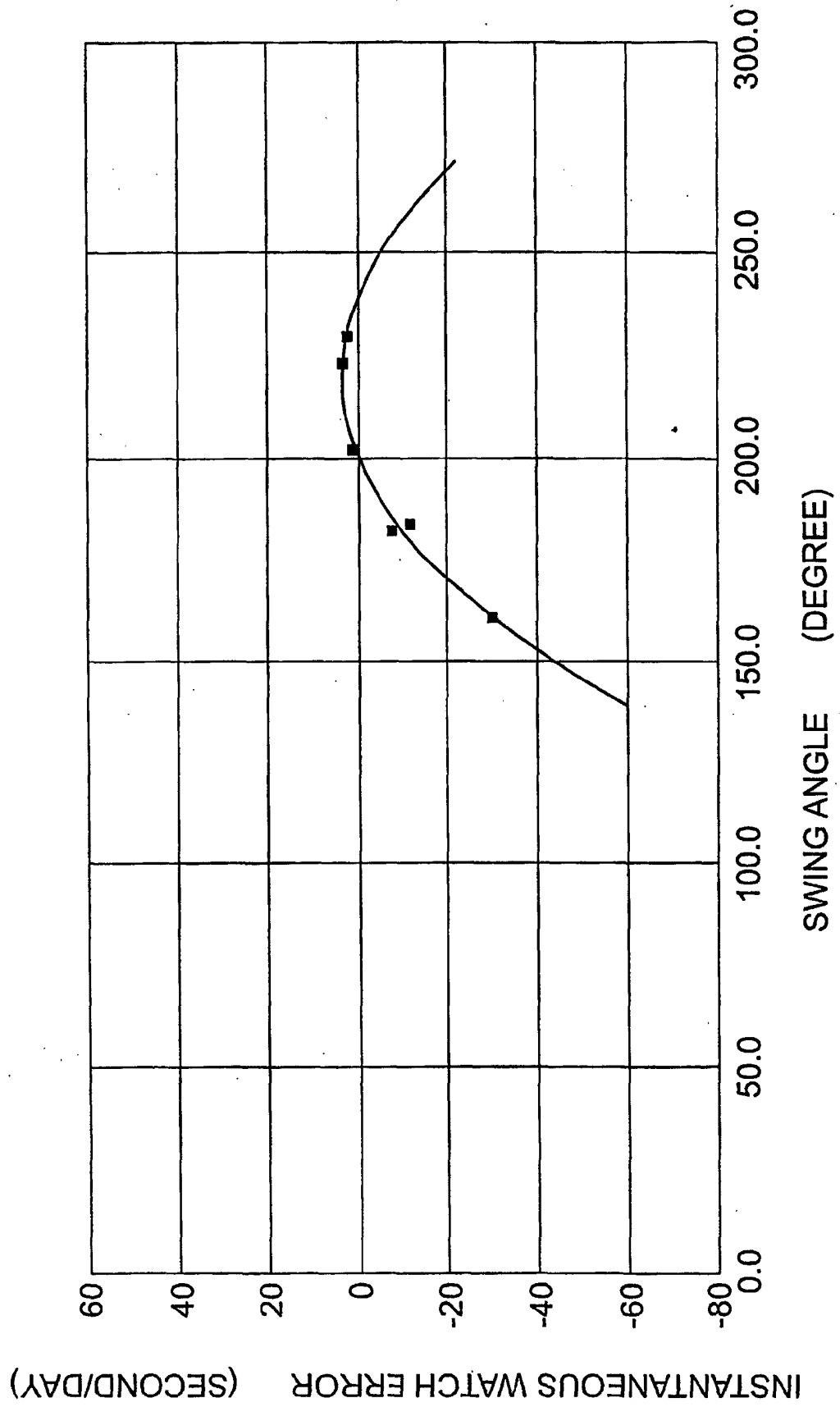
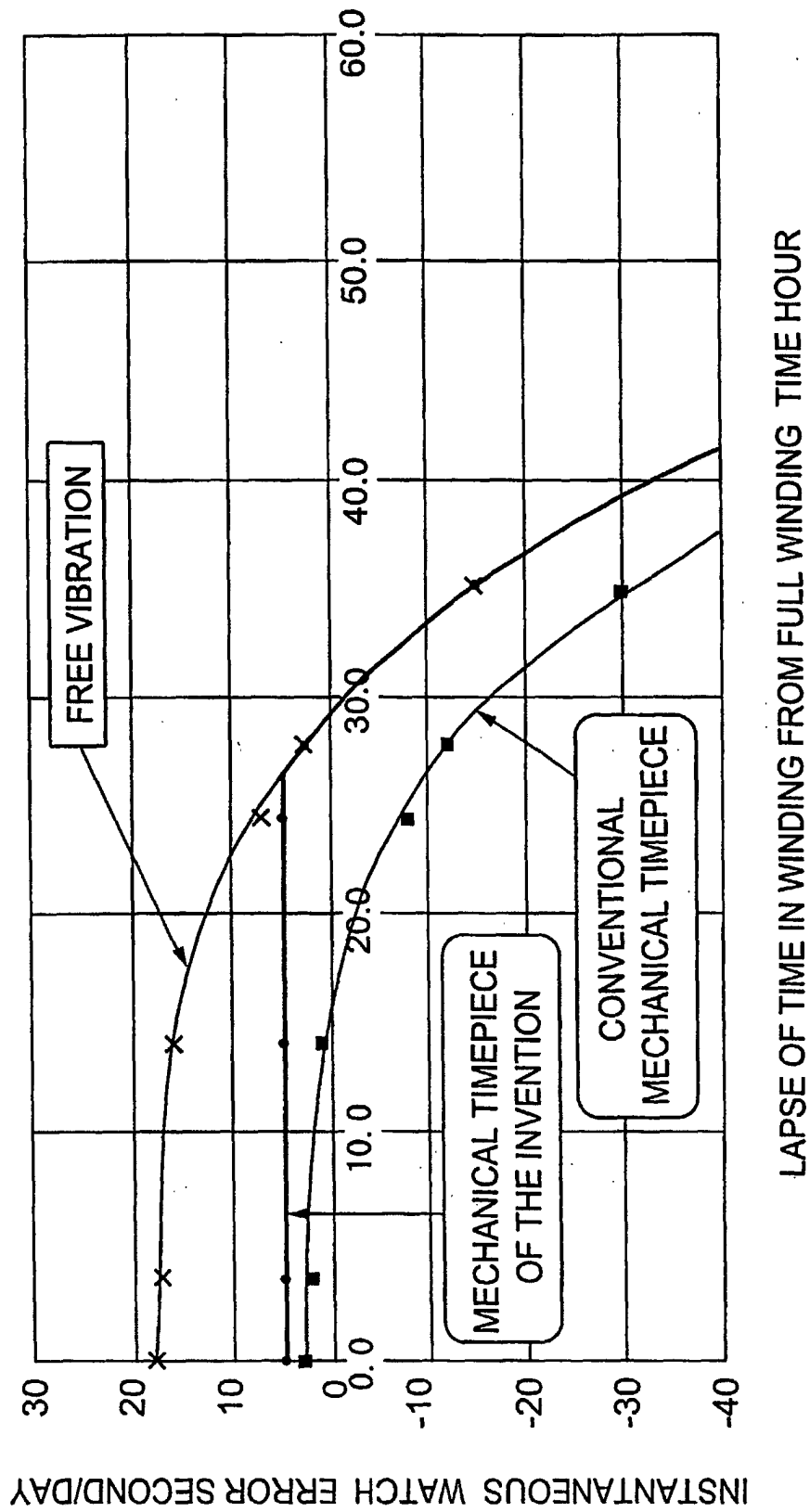


FIG.13



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP00/01164

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl ⁷ G04B17/06, 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 G04B17/06, 17/20, G04B18/00, G04C3/04, 10/00, G04D7/12		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 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)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 39-7098, Y1 (Kabushiki Kaisha Hattori Tokeiten), 23 March, 1964 (23.03.64), Full text; Figs. 1 to 2 (Family: none)	1-7
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No.115366/1977 (Laid-open No.41675/1979) (Kabushiki Kaisha Seikosha), 20 March, 1979 (20.03.79), page 2, lines 1 to 5; page 3, lines 1 to 14; Figs. 1 to 2 (Family: none)	1-7
A	US, 3714773, A (TIMEX CORP.), 06 February, 1973 (06.02.73), Full text; Figs. 1 to 7 & JP, 48-58876, A & AU, 4831372, A & BE, 790818, A & CA, 956015, A & CH, 1594972, A & DE, 2252883, A1 & FR, 2158373, A & GB, 1358657, A & IT, 966866, A & NL, 7214761, A	1-7
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 11 May, 2000 (11.05.00)		Date of mailing of the international search report 23 May, 2000 (23.05.00)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

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

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP00/01164

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 51-34762, A (Kabushiki Kaisha Dai 2 Seikosha), 24 March, 1976 (24.03.76), Full text; all drawings	1-7

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