TECHNICAL INFORMATION

CITIZEN QUARTZ

Cal. No. 411※

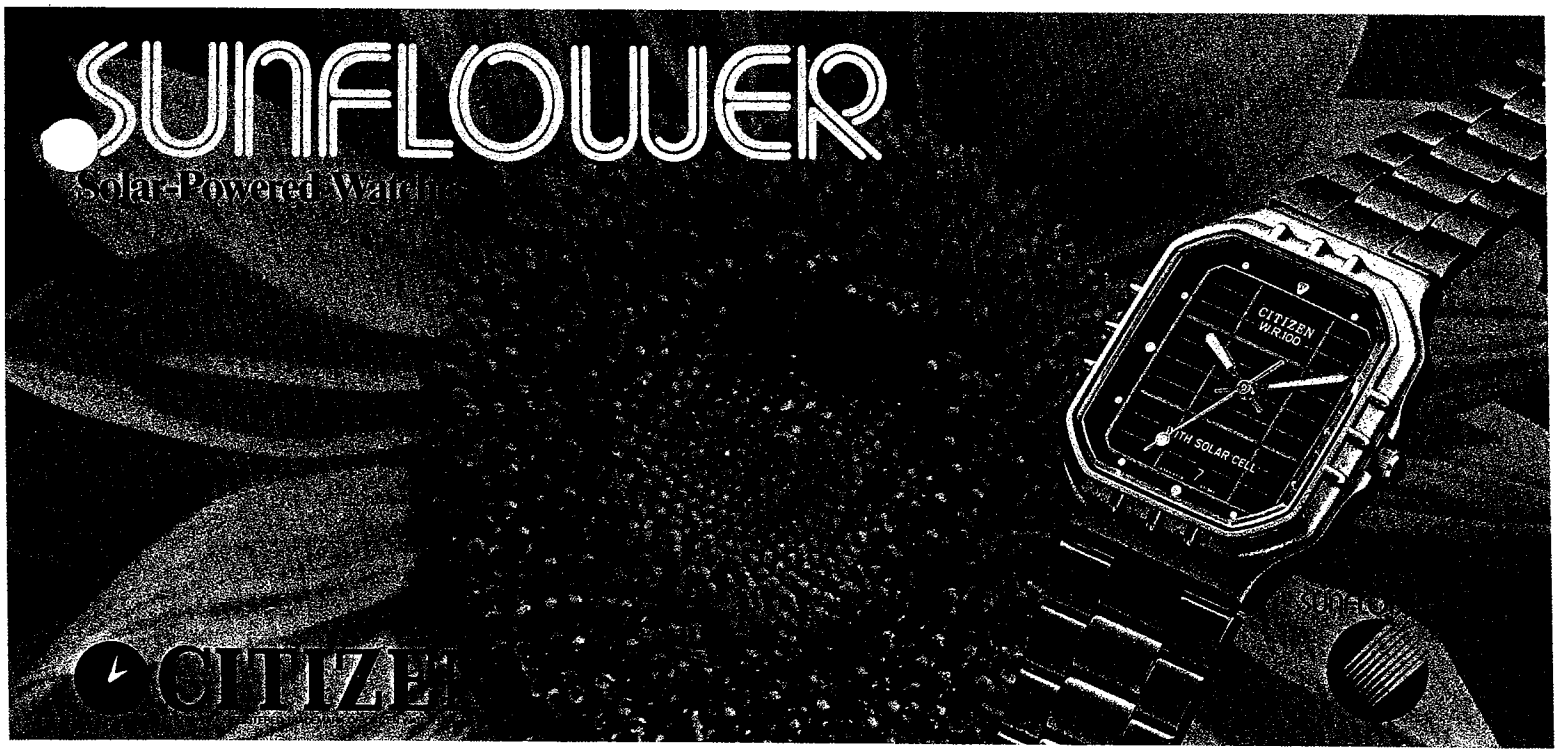
CITIZEN

■1. OUTLINE

This watch is a man's analog quartz watch containing no power cell. It uses amorphous solar cells for the primary power source and an electrolytic capacitor for the secondary power source.

■2. SPECIFICATIONS

Caliber No.		4110A-01
Type		Analog solar cell watch (with second hand)
Module size (mm)		ϕ26.4 x 25.0 Thickness: 3.26^t
Accuracy		±20 sec./month (at normal temperature)
Oscillation		32,768 Hz
Integrated circuit		C-MOS-LSI 1 unit
Effective temp. range		-10°C ~ +60°C (14°F ~ 140°F)
Converter		Bi-polar step motor
Time rate adjustment		DFC (without control terminal)
Time rate measurement		10 seconds
Additional functions		Date (with quick-setting device) Second hand stopping device Quick-start Charge warning Time setting notification (Overcharge prevention)
Capacitor (Double-layer electrolytic capacitor)	Part No. Capacitor code Size	298-182 GC 920 ϕ9.5 x 2.1
Current consumption		Under 1.0 μA (at 1.55V)
Coil resistance		1.8 ~ 2.4 kΩ



■3. CHARACTERISTICS

1) Long duration

Once the watch is fully charged, it will continue running for about 200 hours (190 hours in one-second steps and about 10 hours in two-second steps) without the need for recharging. (Duration varies to some degree, depending on the strength of the light or the characteristics of the capacitor.)

2) Quick-start function

If the watch is illuminated while it is not running, it will start to operate in irregular two-second steps after several seconds. This function is called "quick start."
Although the time required before the watch starts varies depending on the strength of the light, it should start in approximately 10 seconds in a normally illuminated room (about 500 lux).

3) Time setting notification

If the watch stops and then starts again, the second hand runs in irregular steps to indicate that the watch has stopped. This function is unique to CITIZEN.
If, at this time, the crown is pulled out to the second click position, the watch is set to the correct time and when the crown is pushed in, the second hand will begin to run normally (in one-second steps or two-second steps).

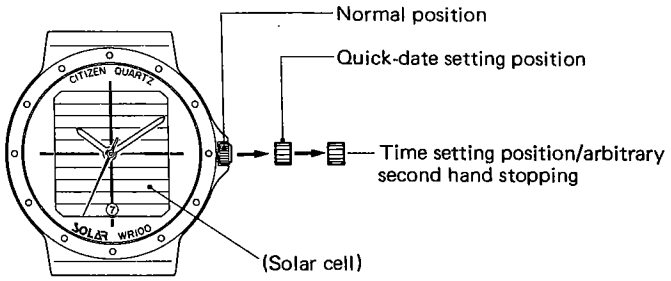
4) Charge warning function

When the voltage of the capacitor (electrolytic double-layer capacitor) drops below 1.3V approx., the second hand reverts to two-second step running to signal that the watch requires charging.
Cal. 41-type watches are designed to stop at voltages lower than 1.15V approx., to run in two-second steps at approx. 1.15 — 1.3V and to run in one-second steps at approx. 1.3 — 2.65V. However, this varies somewhat depending on the watch or the strength of the light.

5) Overcharge prevention function

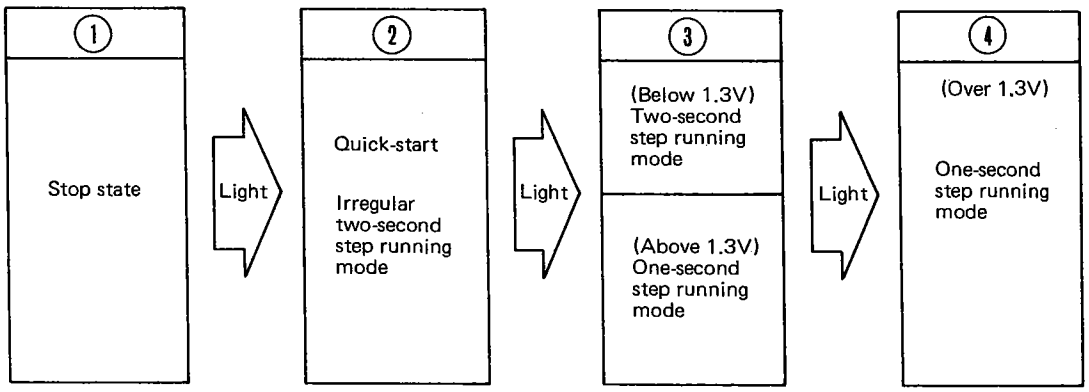
When the capacitor is fully charged a discharge circuit in the IC prevents it from being further charged and prevents further increases in voltage. Therefore, the watch cannot be overcharged even if it is exposed to light for a long period of time.

■4. HANDLING THE WATCH



This watch is operated in the same manner as an ordinary analog watch.
However, since the watch uses light as the source of energy, please use it where sufficient light is available and in the one-second step running mode.

- **Second hand running mode**



(1) If the watch has been stopped for a long period of time due to lack of illumination, and then supplied with light, it will start running in irregular two-second steps after several seconds. (Quick-start function)

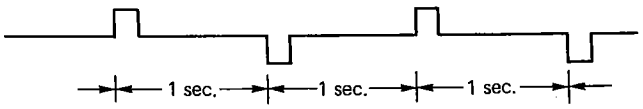
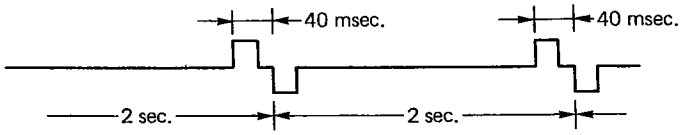
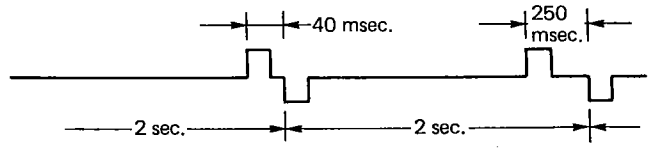
(2) When the watch is in Mode ② , pull out the crown to the second click position and set the watch to the correct time. If the crown is pushed back to the normal position or the date setting position, the watch switches to the normal running mode (two-second step running/ one-second step running mode) (Time setting notification function = irregular two-second step running).

(3) When the watch is in Mode ③ , the second hand runs in one-second steps if the capacitor voltage is higher than approximately 1.3V. But if the capacitor voltage is below 1.3V, the second hand runs in two-second steps to notify the user that the capacitor should be charged by exposing the watch to light. (Charge warning function = two-second step running)

Note: • One-second step running/two-second step running/irregular two-second step running — In any of these modes, the watch is functionning normally. However please use the watch after charging it sufficiently, according to the instructions listed on the attached table: "Table of Charging Time." The energy source is "light".

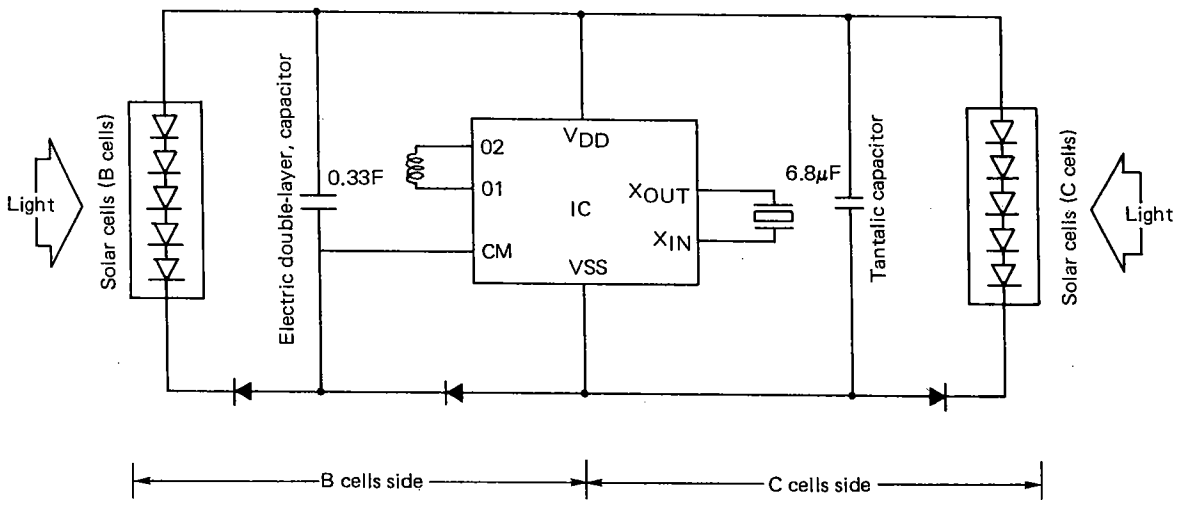
• If the hands are set before quick-start, the watch will experience trouble in starting.

- **Second hand running modes and output pulses**

Second hand running modes			Output pulses
Ordinary running mode	One-second step running mode	(Under normal conditions)	
	Two-second step running mode	(When the charge is insufficient)	
Irregular two-second step running mode		(When the watch requires setting)	

During the irregular two-second step running mode, two pulses occur at an interval of 40 milliseconds, and the second hand appears to run in two seconds steps; but since the next two pulses occur at an interval of 250 milliseconds, the second hand appears to have run two seconds in two steps. This running mode of the second hand is the irregular two-second step running mode.

■5. BASIC CIRCUIT FORMATION



- The watch uses combined amorphous solar cells as the primary power source with a high-capacity electric double-layer capacitor as the secondary power source. It also has installed a tantalic capacitor which is used for quick-start and as an auxiliary power source.
- The C cells form a pair with the tantalic capacitor and cause the hands to start at a certain degree of illumination after intensity has been reached, regardless of the voltage of the electric double-layer capacitor. Since the tantalic capacitor has a small capacity and cannot be charged, the watch will stop as soon as no light is present. Conversely, if the C cells constantly receive light, the watch will continue operating without the electric double-layer capacitor on the B cells side.
- The basic principles of motion of the watch are similar to those of an ordinary analog quartz watch, but please refer to pp. 7 – 11 regarding the basic principles of the solar cell and the electric double-layer capacitor. In general, the solar cells change light into electrical energy, and the energy is stored in the capacitor (electric double-layer capacitor). The capacitor performs the function of the power cells in an ordinary quartz watch and powers the watch.

(5-1) Amorphous Solar Cell

- **Amorphous silicon**

Amorphous silicon is used in the solar cells of this watch. An amorphous substance lacks a crystallized structure. Unlike single-crystal silicon, which is used in transistors and LSI's, amorphous silicon is a new semiconductor material which contains hydrogen atoms etc. and has an irregular atomic arrangement.

- Basic principle of a solar cell

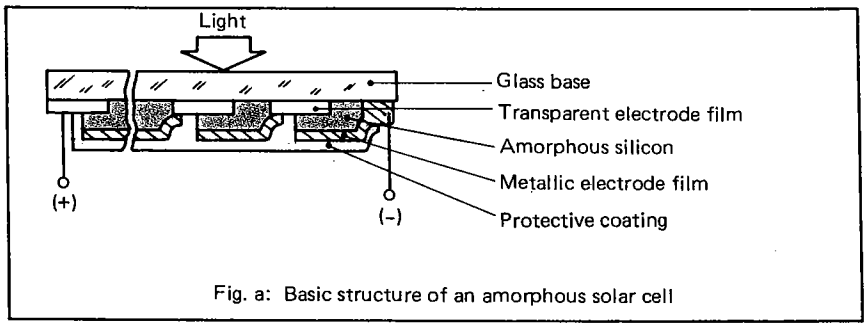


Fig. a: Basic structure of an amorphous solar cell

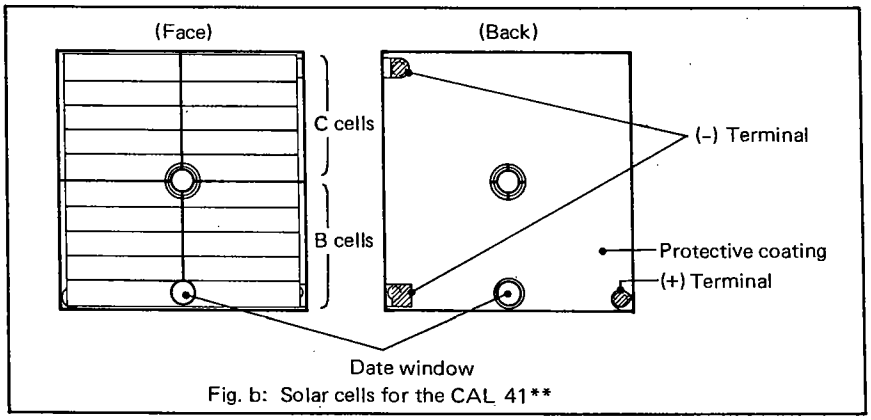


Fig. b: Solar cells for the CAL 41**

1) The light that passes through the transparent electrode is absorbed by the amorphous silicon layer, and then forms pairs of electrical charges, electrons (-) and holes (+), in the amorphous silicon.
   Because of the special structure of the semiconductor, the (-) charges flow to the metallic electrode side and the (+) charges flow to the transparent electrode side, and thereby a potential difference is produced between the two electrodes, causing an electric current to flow.
2) As shown in Fig. b, the solar cells used in a CAL 41-type watch are divided into B cells and C cells, both of which are composed of five cells. B cells are used to charge the electric double-layer capacitor and C cells are used for the quick-start function.
3) The solar cells of a CAL 41-type watch are composed of B cells and C cells, both of which comprise five cells. One cell can produce a voltage of about 0.5V max. Since the voltage is (number in the series) x (voltage of a unit element), a series of five cells, for example, is used as a 2.5V power source. Electric current is proportional to the light-receiving area of the unit elements and the intensity of illumination.

- **Distinctive features of amorphous solar cells**

1) Small, light and durable.
   Amorphous solar cells are small, thin and light. Since they generate electricity from the light they receive, they contain no component which is consumed, and therefore have a long life expectancy.
2) Free design
   The size of the unit elements can be freely designed, and the desired voltage and current are easily obtained. Amorphous solar cells, therefore, can be formed into any desired design.
3) Sensitivity to light
   The sensitivity properties of amorphous solar cells change depending on the wavelength of light. The degree of change is similar to that of the human eye, so they are used as light sensors (as mechanical eyes).
4) Other features
   - Any type of base material can be used.
   - The production process is simple.
   - Normal room light is adequate for their operation.

(Shortcomings)
1) Conversion efficiency in sunlight is low compared with other types of solar cells.
2) Deterioration sometimes occurs in strong light, in high humidity environments and when static electricity is present.

(5-2) Charging the Watch

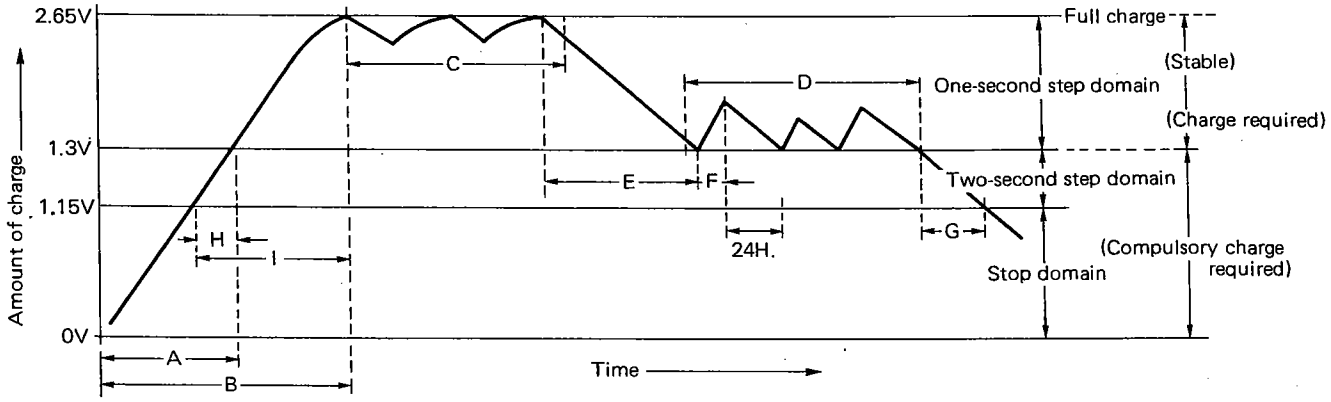
- **Table of Charging Time**

Condition (Intensity of Illumination: Lx)			From stoppage to one-second step running	From stoppage to full charge	Charging time for a day during one-second step running	From shortly before stoppage to one-second step running	From shortly before stoppage to a full charge
1	500 Lx	Fluorescent 60 w • 60 cm	Approx. 12 hours	Approx. 25 hours	Approx. 1.5 hours	Approx. 2 hours	Approx. 15 hours
2	3,000 Lx	Fluorescent 15 w x 2 • 20 cm	2 hours	4 hours	15 minutes	20 minutes	2.3 hours
3	5,000 Lx	Fluorescent 15 w x 2 • 12 cm	1 hour	2.5 hours	10 minutes	12 minutes	1.7 hours
4	10,000 Lx	Sunlight, cloudy	30 minutes	1.5 hours	5 minutes	6 minutes	1.1 hours
5	100,000 Lx	Direct sunlight in the summer	3 minutes	10 minutes	30 seconds	30 seconds	7.5 minutes

Note: This table supplies a general standard, but the charging time may vary depending on the watch, type of light, environment, etc.

Direct sunlight, in the summer

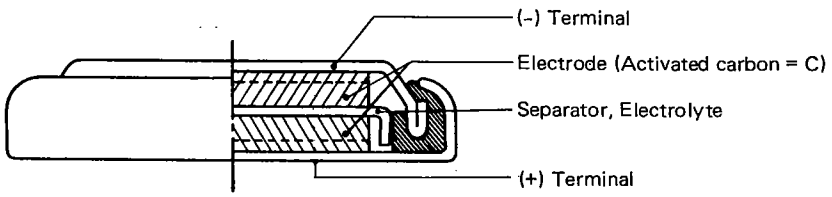
- **Charge and Discharge Graph**



A : Charging time required from stoppage to one-second step running.
B : Charging time required from stoppage to a full charge.
C : The watch is used in a full charge state.
D : The watch is rarely used in a one-second step mode.
E : Duration between a full charge and two-second-step running (approx. 190 hours).
F : Charging time required to operate the watch for one day.
G : Duration between the beginning of two-second step running and stoppage of the watch (approx. 10 hours)
H : Charging time required just prior to stoppage of the watch to one-second step running.
I : Charging time required just prior to stoppage of the watch to full charge.

(5-3) Capacitor (Electric Double-Layer Capacitor)

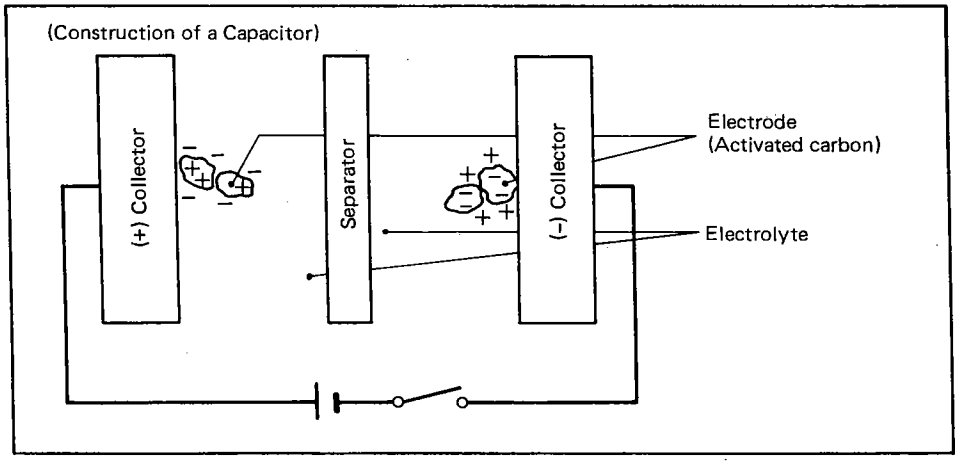
- **Structure**



- **Electric double-layer capacitor**

1) When two different layers come into contact with each other, the positive and negative charges will be distributed on the interface of the layers. The layer on which these charges are distributed is called the electric double-layer.
The electric double-layer capacitor has a structure which accumulates electrical charges by applying an electric field to the electric double-layer.

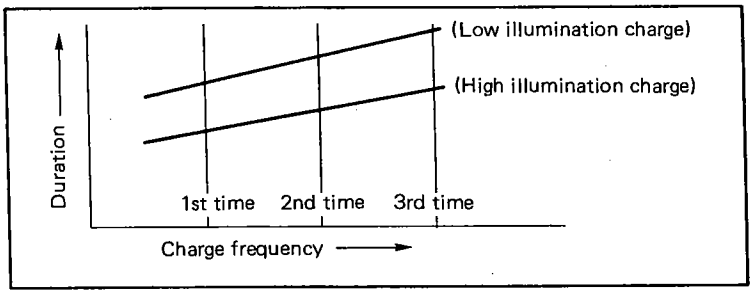
2) The electric double-layer capacitor uses activated carbon (C = activated carbon fiber) in the electrodes. If the voltage produced by the solar cells is supplied to the collectors, as shown in the figure, (+) and (-) ions are collected separately in each electrode. Even if the external voltage is removed thereafter, the (+) and (-) charges will remain and electron ions will flow, consequently the capacitor can be used as a power source.



3) In general, the capacity is dependent on the ion concentration in the electrolyte. Activated carbon is very effective as an electrode because it has a very large surface area.

- **Characteristics of the electric double-layer capacitor**

1) Since only electron ions flow in the capacitor, it is almost free from deterioration caused by constant charging and discharging.
2) Since it uses activated carbon as a component, no pollution is caused.
3) Because the capacitor itself does not generate electricity, no gas is produced through a chemical reaction, and the capacitor will not rupture.
4) Very little leakage occurs.
5) Because no short circuit can occur inside the capacitor, electrical leakage does not occur.
6) If the capacitor is charged slowly in weak light, the charging duration tends to increase. When the capacitor is new, an increase in the frequency of charging will lead to an increase in duration.



■6. NOTES ON DISASSEMBLY AND ASSEMBLY

1) Handling of the solar cells

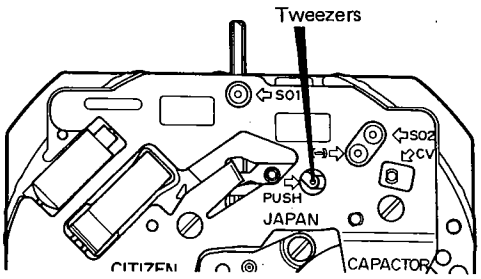
- Solar cells should be treated in the same manner as the dials. This should be noted when placing an order.
- Because the solar cells are thin glass plates, they may be damaged if subjected to a strong force. Extreme care should be taken when mounting and removing the hands or the solar cells.
- Three solar cell-connector springs are placed between the circuit and the solar cells. Confirm that they are correctly in place when mounting the solar cells.
- Damaged solar cells will cause malfunctions such as faulty quick-start and impaired charging ability. In this a case, replace the solar cells.
- If the electrodes on the back (three positions) are stained or have peeled off, the circuit will not function. Since stains on the cell surface are difficult to remove, do not touch the surface of the solar cells directly.
- Solar cells can be deteriorated by static electricity or humidity, therefore care should be taken when they are stored.

2) Handling of the capacitor

- As a safety measure, a connector spring has been welded to the capacitor (so that the circuit cannot be closed if a power cell is installed). Do not detach the connector spring.
- Even if a power cell is installed by mistake, no problem will occur because these is no connector spring. However, if the connector spring and a power cell are installed together, the watch will overcharge and may burst, which can be very dangerous. Therefore, never install a power cell.

(Safety measures)
a) The capacitor has a connector spring welded to it. Therefore, if a power cell is installed in place of the capacitor block, the circuit cannot be closed.
b) The capacity strap is inscribed with the word "CAPACITOR."
c) A seal pasted on the case back states, "Do not put the power cell."

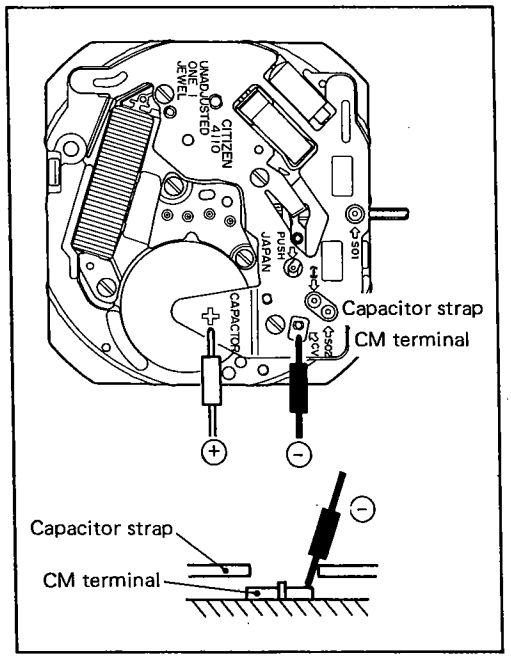
3) Mounting and removal of the winding stem



- When removing the winding stem, press the part marked "PUSH" and remove it, as shown in the figure on the left.
- Remove and mount the winding stem with the crown in its normal position.

4) Mounting of the second hand

If the second hand is mounted while the watch is in the one-second step mode, the second hand may stop at odd-numbered seconds, 57, 59, 1, 3 ..... when the watch is in the two-second step mode.
Therefore, short-circuit the capacitor, as shown in the figure below, to lower the voltage to less than 1.3V, and after confirming that the watch is in the two-second step mode, mount the second hand correctly.
However, there will be no problem in performance or function if the second hand is mounted when the watch is in either the one-second step mode or the two-second step mode.



While placing the ⊖ tester lead pin on the CM terminal, make contact with the capacitor strap. A short circuit will occur and the voltage will gradually fall. Then measure the voltage with the tester. When it is confirmed that the voltage has fallen below 1.3V, mount the second hand so that it stops at even-numbered seconds.
(When the voltage has fallen below 1.3V, pull out the crown to the second click position, then push, it back to the normal position, after the irregular two-second step running mode has stopped.)
the second hand.)

5) Time rate measurement

Since the rate is adjusted by DFC, it cannot be adjusted in the field.
The time rate is measured in a range of 10 seconds.
Because exact measurement may be impossible while the watch is in the two-second step or irregular two-second step mode, expose the watch to light so that the watch is in the one-second step mode before measuring the time rate.

6) Measurement of current consumption

(Refer to the section on trouble-shooting)
Since the voltage of the capacitor varies with the amount of charge, the current consumption is not stabilized. When measuring the current consumption, therefore, insert a silver cell (1.55V) in the adaptor of the tester and measure in the prescribed way.
As a criterion, if the current consumption is below 1.0 μA at 1.55V, the watch is operating normally. The higher the voltage the lower the current consumption value tends to be.

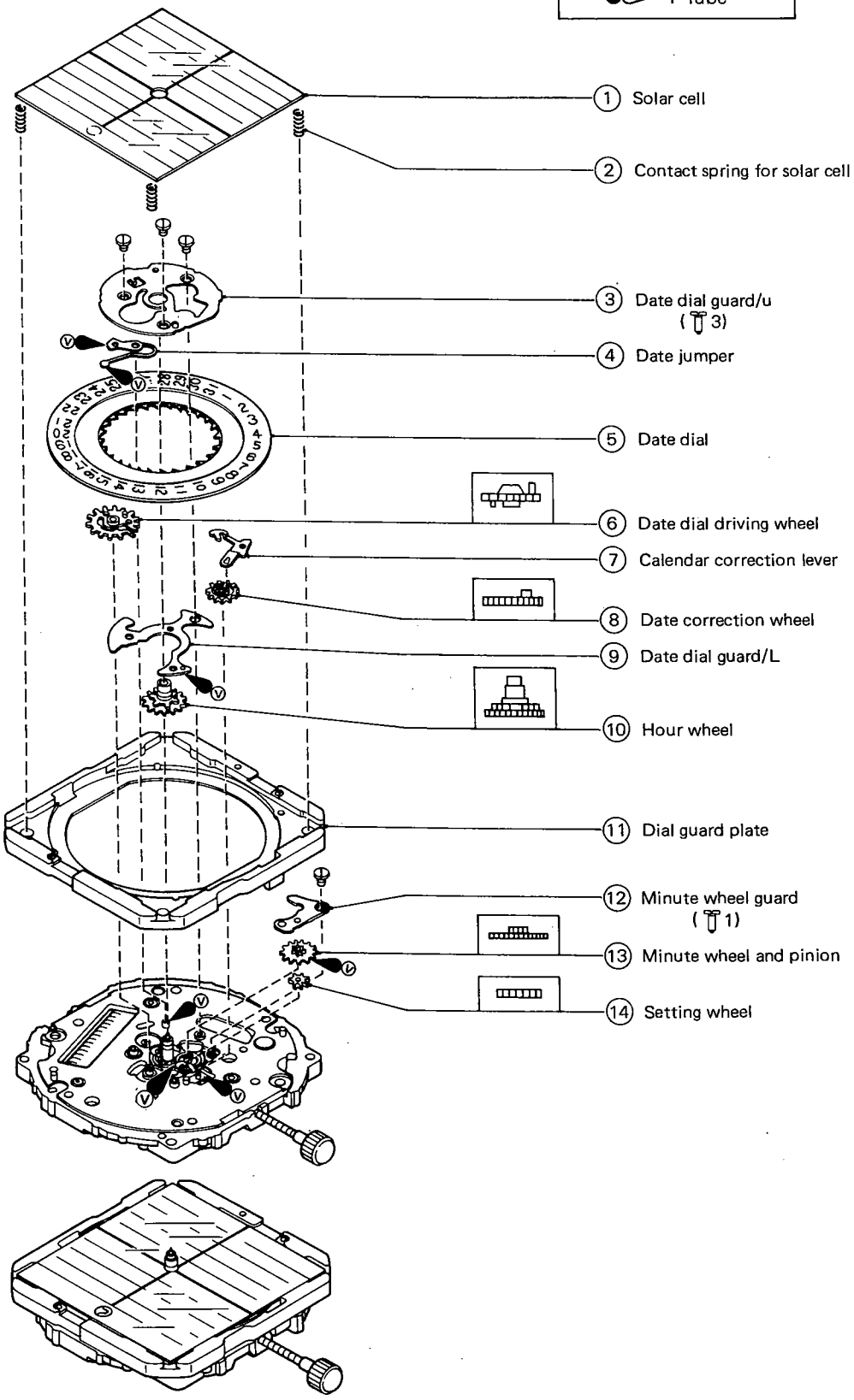
■7. DISASSEMBLY, ASSEMBLY AND LUBRICATION OF THE MODULE

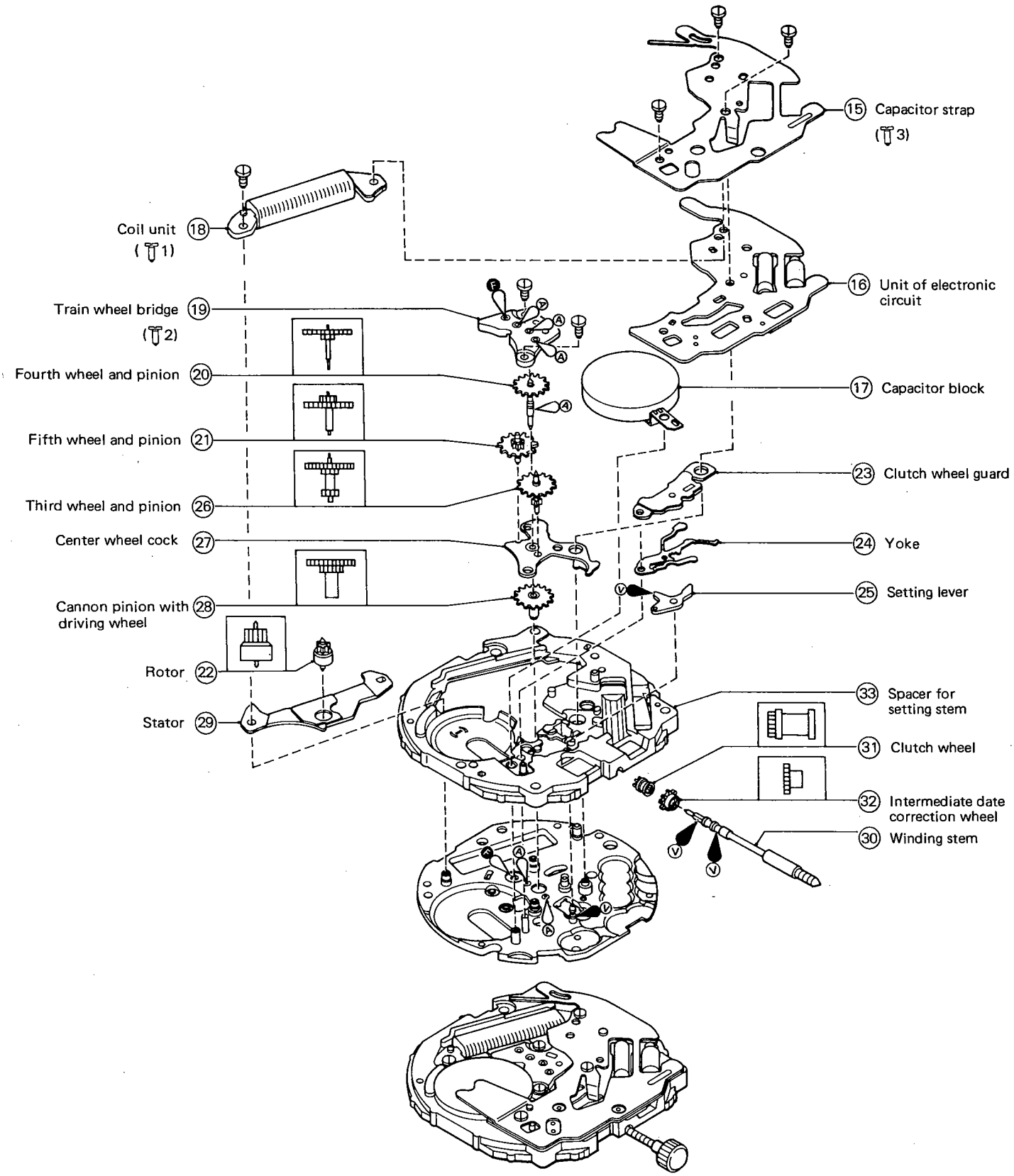
Disassembling procedure : ① → ㉝

Assembling procedure : ㉝ → ①

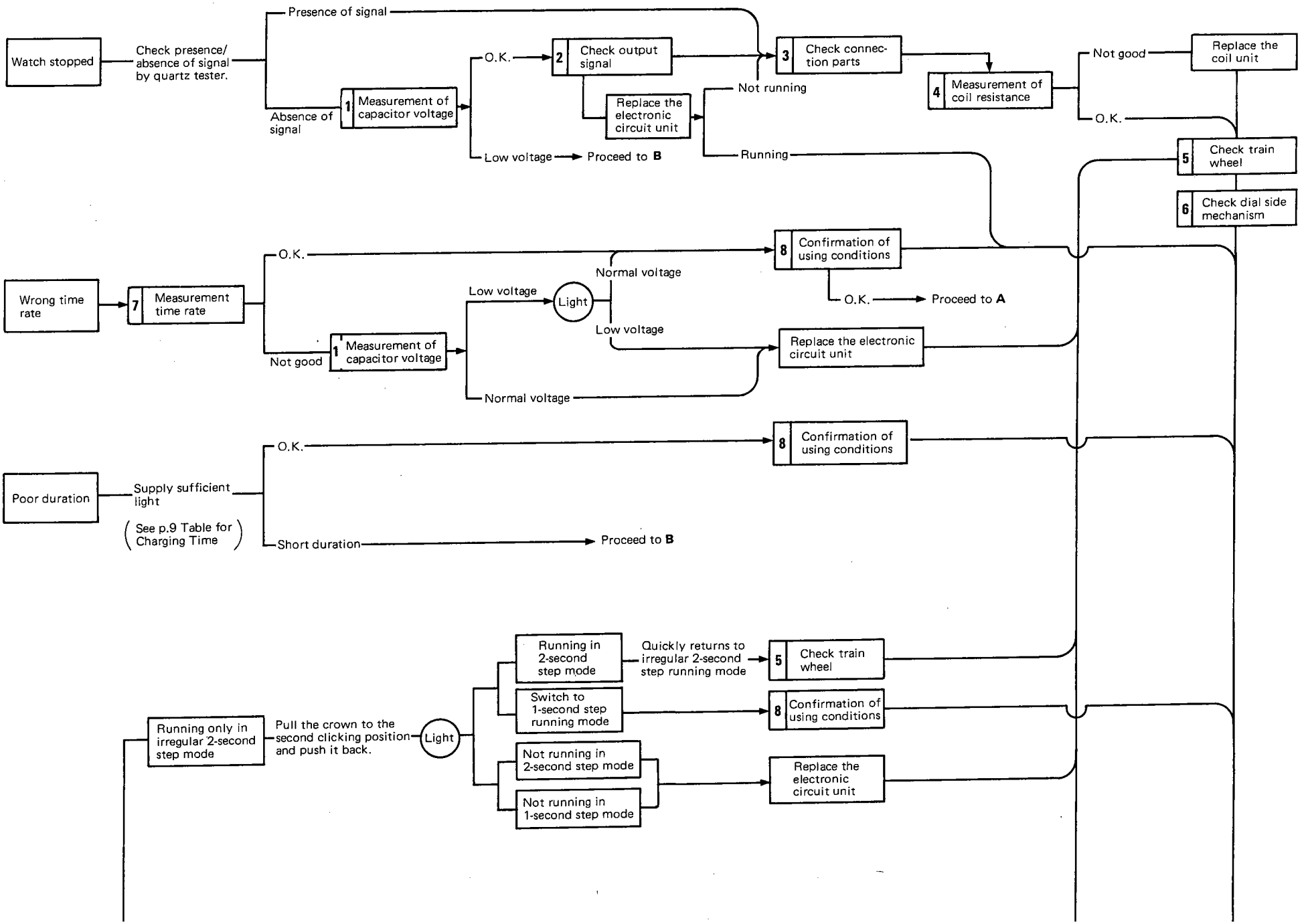
Lubrication markings

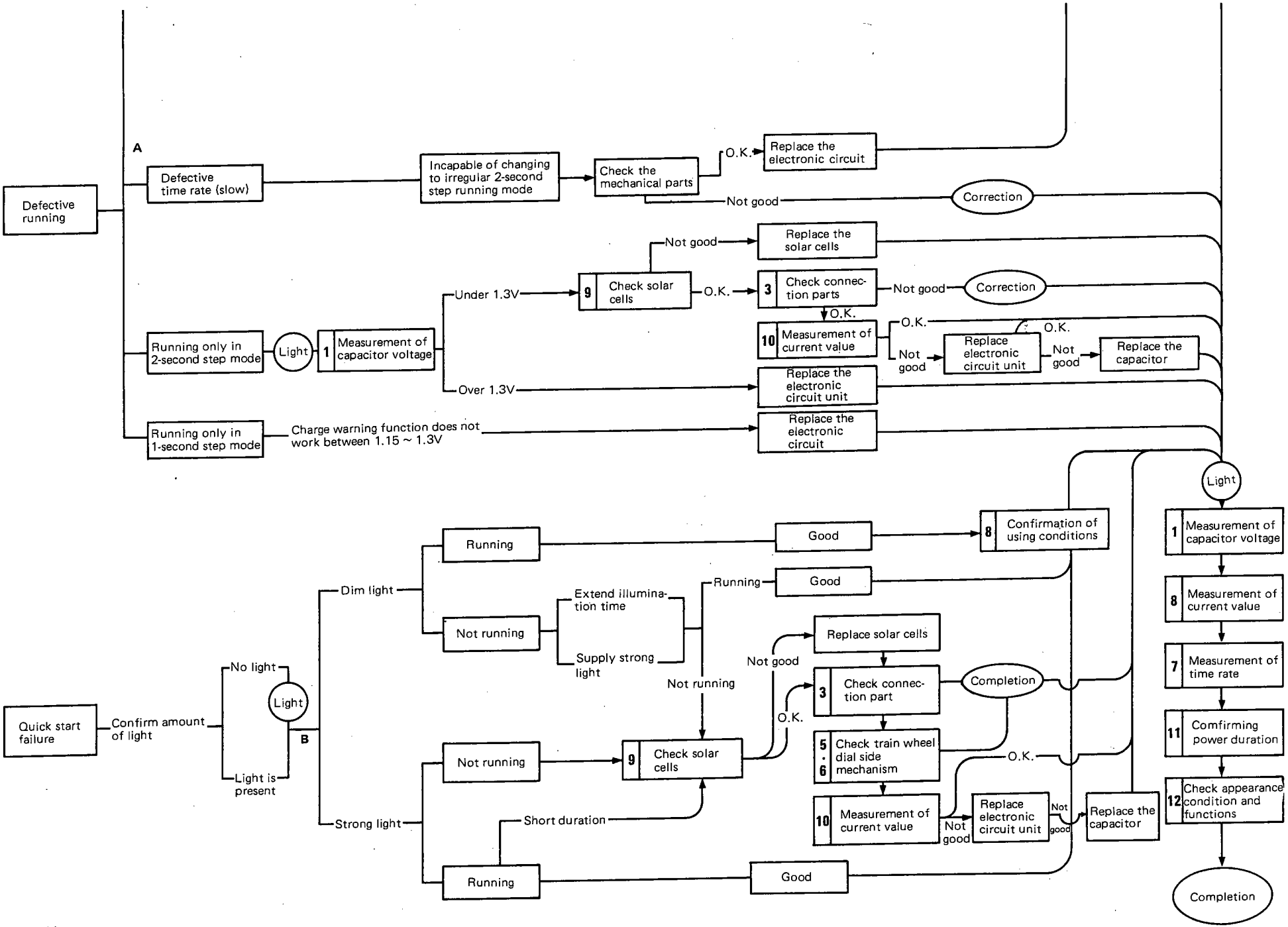
- Ⓐ A lube
- Ⓥ V lube
- Ⓕ F lube




15 Capacitor strap
(3)
Coil unit 18
(1)
16 Unit of electronic circuit
Train wheel bridge 19
(2)
17 Capacitor block
Fourth wheel and pinion 20
Fifth wheel and pinion 21
23 Clutch wheel guard
Third wheel and pinion 26
24 Yoke
Center wheel cock 27
25 Setting lever
Cannon pinion with driving wheel 28
Rotor 22
33 Spacer for setting stem
Stator 29
31 Clutch wheel
32 Intermediate date correction wheel
30 Winding stem

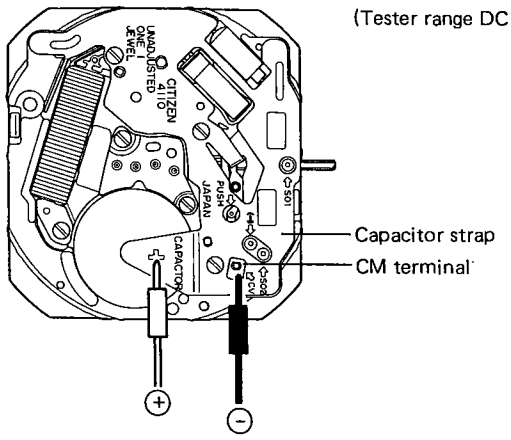
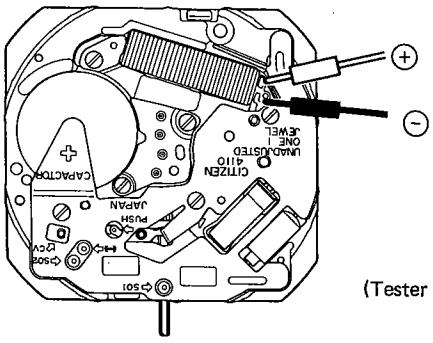
■8. TROUBLE-SHOOTING AND ADJUSTMENT

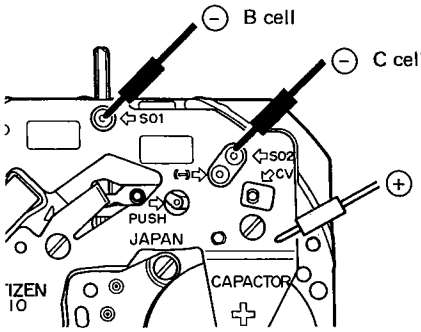
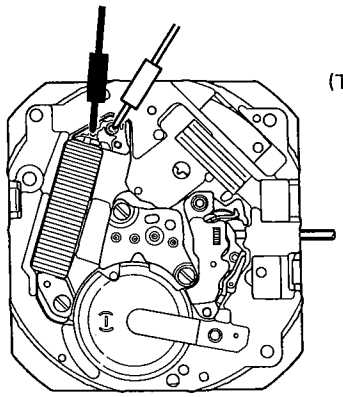


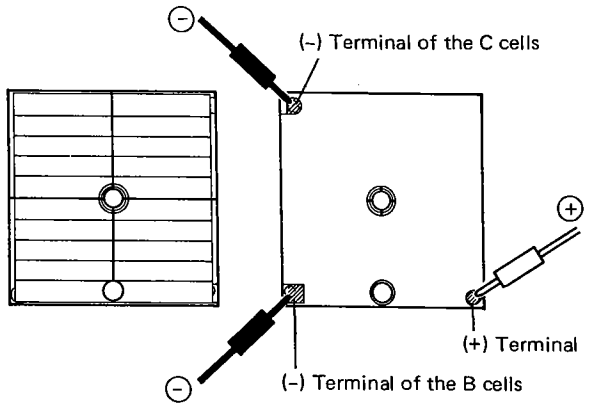


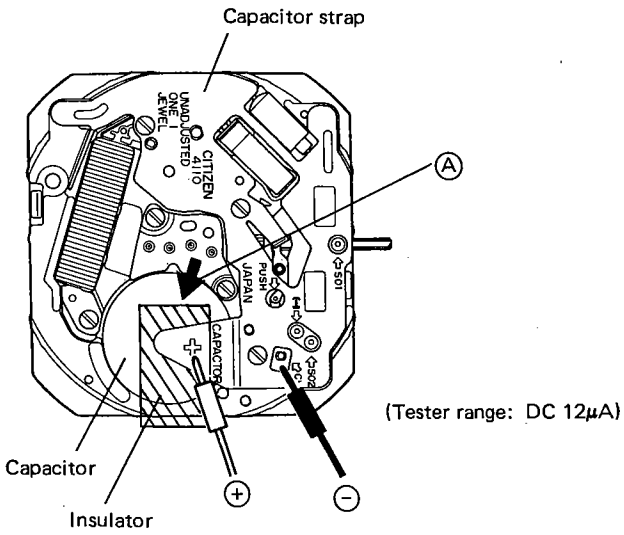
Note:

- Light refers to charging the watch with sufficient light.: (Light)
- It is important to expose the watch to light and then try to determine the problem that is whether the problem is failure to run, defective running or quick-start failure.

Check Items	How to Check	Results and Treatment
(1) Measurement of capacitor voltage	 (Tester range DC 3V) Reference: ●1.15V ~ 1.3V: Two-second step running mode 1.3V ~ 2.65V: One-second step running mode These voltages may vary slightly from watch to watch. ●Irregular two-second step running is a function that signals that the watch has stopped and restarted. This mode will continue until the watch is set to the correct time, irrespective of the voltage. ●A quick-start is activated by the small-capacity tantalic capacitor which has been incorporated in the circuit, in addition to the primary capacitor. After the watch is illuminated (right after it begins running), the capacitor voltage will display an extremely low value because the capacitor has not been fully charged. Caution: When measuring the voltage, be careful not to place the ⊖ tester pin on the capacitor strap (a short circuit will occur).	
(2) Check output signal	[Refer to Technical Manual, Basic Course Ⅱ-1-b]  (Tester range: DC 0.3V) ●During one-second step running, if the tester pointer swings right and left every second, the signals are normal. ●During irregular two-second step running and two-second step running, the tester pointer swings in one direction every two seconds.	The tester pointer does not swing. → Check the connection parts. ⬇ The connections are normal. → Replace the electronic circuit unit.

Check Items	How to Check	Results and Treatment
(3) Check connection parts	[Refer to Technical Manual, Basic Course II-2-a, Analog Part] ●Confirm that there are no loose screws, dust or stains present. ●Check if there are stains on the solar cell pattern (three positions), peeling of the pattern, deformation of the connector springs, peeling of the capacitor welds, or stains on the circuit pattern, also determine whether the contacts of each component are correctly made. (Also refer to Check Item 9)  ●If the tester pointer swings when the B cell and C cell are measured (⊖ and ⊕) at a tester range of DC V 0.3V (DC A 12μA), the cells are connected correctly to the circuit through the connector springs.	Stains on the solar cell pattern or circuit pattern → Remove the stain. Peeling of the solar cell pattern or circuit pattern or peeling of the capacitor welds. → Replace the parts.
(4) Measurement of coil resistance	[Refer to Technical Manual, Basic Course II-1-c]  (Tester range: R x 10Ω) Polarities are disregarded when using the tester lead pins.	1.8 ~ 2.4kΩ → Non-defective Without above resistance value → Replace the coil unit
(5) Check train wheel	[Refer to Technical Manual, Basic Course II-2-b]	
(6) Check dial side mechanism	[Refer to Technical Manual, Basic Course II-2-c]	

Check Items	How to Check	Results and Treatment
(7) Measurement of the time rate	[Refer to Technical Manual Basic Course Ⅱ-2-d] ● Cal No. 411* adopt the DFC and has no control terminals, the time rate cannot be adjusted. (Measurement of time rate: 10 seconds) Accuracy is within ±20 sec./month.	The watch loses or gains substantial time. → Replace electric circuit unit
(8) Confirmation using condition of the watch	[Refer to Technical Manual, Basic Course Ⅱ-2-e] ● This watch uses light as its energy source. Therefore, it is necessary that the watch be used under sufficient light conditions. Example: When the watch is covered by a shirt sleeve or when operated in a dimly lit place, or under similar conditions, it is important that the watch be periodically exposed to light.	
(9) Check solar cells	 ● Confirm whether there are any cracks in the cells. ● Check the (−) terminals of the C and B cells and the (+) terminal for stains, peeling, etc. ● While exposing the solar cells to light, confirm whether the solar cells are functioning using a tester, and determine whether current is generated. (Tester range; DCA, 12μA)	Cracks in the solar cells. → Replace the solar cells. Stains → Remove the stains. Peeling of a terminal → Replace the solar cells. The tester pointer swings. → Non-defective

Check Items	How to Check	Results and Treatment
(10) Measurement of current value	[Refer to Technical Manual, Basic Course II-1-f] Since the watch uses a capacitor in place of a power cell, the circuit construction is different from an ordinary analog quartz watch. For safety reasons, the capacitor cannot be removed separately. Therefore, measure the current value according to the following procedure.  (Tester range: DC 12μA) 1) Referring to the Basic Course in the Technical Manual, set a silver power cell (1.55V) correctly in the adapter of the tester. 2) As shown in the figure above, place an insulator such as vinyl or paper between the capacitor and the strap. 3) Push the capacitor in the direction of arrow A to produce a gap between the capacitor and the train wheel bridge so that no short circuit will occur between them. 4) Pull out the crown to the second click position. 5) Set the (-) tester lead pin, ensuring that it does not touch the strap, and then touch the (+) tester lead pin to the strap or a screw. The value the tester indicates is the **reset current value**, and if it is under **approx. 0.3μA** the watch is operating normally. 6) Push the crown back to the normal position and measure the current consumption in the module. Note: Since the current consumption will show a high value at first, wait until the tester pointer stops fluctuating before making the measurement.	Under 1.0μA → Non-defective

Check Items	How to Check	Results and Treatment
	☆When the tester pointer swings, a short circuit has probably occurred in one of the following parts, ①~③. After checking these items, make the measurement once again according to the procedure described above. ① Short circuit between the tester lead pin and the capacitor strap. ② Short circuit between the capacitor and the capacitor strap. ③ Short circuit between the capacitor and the train wheel bridge. ☆If the measurement is made without pulling out the crown to the second click position, current value in the irregular two-second step running will be measured, therefore a value of **about 2μA** may be indicated. This occurs because the notification function for time setting has been operated as a result of a short circuit. By pulling out the crown to the second click position and then pushing it back to the normal position, the correct curent value can be measured.	
(11) Comfirming power duration	Referring to the Table of Charging Time, confirm power duration. (In general, if the capacitor voltage is 2.1V or over after the watch is illuminated at 3,000 Lx for four hours, the power duration can be considered normal.)	
(12) Check appearance conditions and functions	[Refer to Technical Manual, Basic Course Ⅱ-2-f]	

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