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(54) IMPROVEMENTS IN OR RELATING TO WATCHES AND OTHER TIME-PIECES

(71) We, KABUSHIKI KAISHA SUWA SEIKOSHA, a Japanese company, of 3-4, 4-chome, Ginza, Chuo-ku, Tokyo, Japan, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to watches and other time-pieces and more specifically to time-pieces of the kind in which a solar battery is provided to charge a secondary battery (which may also be called a charge battery) which provides the operating voltage for the time-piece.

Table clocks and other clocks for domestic and office use inside rooms have been provided with solar batteries but, so far as the present applicants are aware, wrist watches have not been fitted with such batteries. Now these two types of use of time-pieces namely (a) as a clock in a room, and (b) as a wrist watch, differ in an important respect. In the case of a clock for room use there is a maximum intensity of illumination to which it can reasonably be expected to be subjected—this is about 1000 lux—and overcharge and resultant damage from this cause can be easily guarded against, a single protecting resistance being usually all that is necessary. In the case of a wrist watch however, if it were to be fitted with a solar battery to constitute an electric current supply, difficulties would arise because the watch is liable to be exposed directly to the sun. It would be necessary, therefore, to limit the maximum charging current supplied by the solar battery to the watch's operating battery (hereinafter called the "charge" battery to distinguish it from the solar battery). The charge battery is a secondary battery and is preferably a Ni Cd battery or a silver battery. There is a correct maximum charging current for any charge battery (especially a silver battery or a Ni Cd battery) and if this value of current is exceeded

the charge battery deteriorates more or less quickly depending upon how great the excess current is and how often charging at an excess rate occurs. Since a wrist watch is covered by clothing (a sleeve) for a good deal of the time and, in any case, a solar battery will not effect charging of the charge battery in the night hours of darkness, the charge battery of a wrist watch having a solar battery for charging the said charge battery would have to be designed to take a charge at a low rate, i.e. when the light intensity is only 50 lux or thereabouts. However, in practice, the solar battery may be exposed, at times, to much greater light intensity reaching tens of thousands or even hundreds of thousands of lux. The useful life of the charge battery in such a watch may therefore be much shorter than it should be, for if the watch is much used outdoors the life will be very much shorter than if it were used entirely, or nearly entirely, indoors.

The present invention seeks to overcome the foregoing difficulties and to provide an improved wrist watch or similar time-piece likely to be used outdoors (hereinafter called, simply, an "outdoor time-piece") and having a charged battery charged by a solar battery, which shall be such that the charged battery will have an acceptably long useful life despite that the time-piece may be subjected, at different times, to widely different values of light intensity.

According to this invention a time-piece includes a secondary or chargeable battery supplying operating voltage thereto, a solar battery for charging said secondary or chargeable battery and a transistor, the state of conductivity of which is controlled directly or indirectly by the output voltage of the solar battery and which is connected to act as a limiting resistance limiting the charging current to a pre-determined maximum.

The invention is illustrated in and further explained in connection with the accompanying drawings, in which Figures 1, 2, 3, 5 and 7 show diagrammatically different embodi-

ments of the invention and Figures 4 and 6 are explanatory graphical figures.

Referring to Figure 1, 1 represents the solar battery of an outdoor time-piece and 3 is a diode through which it charges a secondary battery 4, the said diode serving to prevent reverse current discharge of the charge battery 4 when the voltage of the solar battery 1 becomes low (in darkness). The block 5 represents the electrical load presented by the watch (not otherwise represented) to its operating battery namely, the secondary battery 4. A transistor 2 has its emitter-collector circuit connected across the solar battery 1 and its emitter-base circuit connected across the diode 3 all as shown. When the output from the solar battery 1 is low, little or no base current flows and the circuit between the emitter and collector electrodes of the transistor is cut off. When, however, the output battery of the solar battery 1 becomes large, the base current of the transistor 2 increases, the circuit between the emitter and collector electrodes becomes conductive, and transistor acts as a device limiting the charging current to the secondary battery.

Figure 2 shows an embodiment differing from Figure 1 only in the provision of the resistance 6 in the base circuit of transistor 2 while the embodiment of Figure 3 differs from that of Figure 2 by the substitution of a second diode 7, poled as shown, for the resistance 6.

The limiting effect produced is least in Figure 3 and most in Figure 1.

Figure 4 is a typical set of characteristics showing charging current I plotted against intensity of illumination L . Curve A is drawn for a case (not illustrated and not in accordance with this invention) in which the transistor 2 and its circuitry is not provided, there being no overcharge prevention means. Curves B, C and D are the corresponding curves for circuit as shown in Figures 3, 2 and 1 respectively. There is no limit of charge current in the case of curve A but, as will be seen, the maximum charging current is limited to I_1 , I_2 and I_3 in the case of curves B, C and D respectively.

In the circuit of Figure 1, a pn connection provided by the emitter and base electrodes of the transistor 2 is in parallel with the diode 3, so that the diode 3 could, in principle, be omitted. However, the provision of the diode 3 is preferred because it enables a better charging current to be obtained when the intensity of illumination is low.

The diodes 3 and 7 can be germanium or silicon diodes, the values of the maximum limited charging currents I_1 , I_2 and I_3 depending, of course, upon which types are used. The transistor 2 may be either of the pnp or the npn type.

In the embodiment of Figure 5 the solar

battery (represented in this figure by a conventional battery symbol) is again referenced 1, and the diode 3, secondary battery 4 and watch circuitry 5 are all as in Figures 1, 2 and 3. The base of the transistor 2, however, is connected to the junction point of a resistance 8 with a thermistor 9, the two components 8 and 9 being connected as shown in series across the solar battery 1. The collector of the transistor is connected to the positive side of the solar battery 1 and its emitter to the negative side thereof. When the voltage of said solar battery exceeds the sum of the voltage of the secondary battery 4 and the voltage drop across the diode 3 in one direction, a charging current flows from said solar battery 1 into the said secondary battery 4. As the voltage of the solar battery increases the charging current increases, but increase in current is accompanied by decrease in solar battery voltage and accordingly, even although the open circuit output voltage of the solar battery may be large it becomes reduced when charging current flows.

However, if the charging current becomes very large, the voltage of the secondary battery 4 is increased, and the output voltage of the solar battery 1 is also somewhat increased. This increased output voltage is divided by the potential divider constituted by the resistance 8 and the thermistor 9 and the divided voltage is applied to the base electrode of the transistor. This causes the transistor 2 to become conductive when its base-emitter voltage exceeds a certain predetermined value, and current flows between the collector and emitter electrodes. The voltage dividing ratio of the potential divider (resistor 8 and the thermistor 9) is so chosen that the transistor 2 becomes conductive so as to prevent overcharging of the secondary battery 4 if the voltage from the solar battery 1 becomes high enough.

Figure 6 is again a characteristic connecting charging current I with the intensity of illumination L . The full line curve X shows the charging current which would flow if the overcharge prevention circuit of Figure 5 were not provided, while the broken line curve Y shows the result achieved by the circuit of Figure 5, the maximum charging current being limited to 1 m. The thermistor 9 serves to compensate for the temperature characteristics of the transistor 5, and is so chosen that if the base-emitter potential required to make transistor 2 become conductive changes with temperature, the voltage applied to the base changes in a compensatory manner.

Figure 7 shows another embodiment of the invention. In this embodiment the emitter-base circuit of transistor 2 is connected as shown across a series resistor 10 inserted between the diode 3 and the secondary battery 4, the collector of the said

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transistor being connected through a collector resistance 11 to the negative terminal of the solar battery 1. When the charging current becomes large, the voltage drop across resistance 10 increases and transistor 2 becomes conductive and limits the charging current. To quote practical figures by way of example the value of the resistance 10 could be 100 ohms, and the transistor 2 arranged to be conductive when the charging current reaches 5 or 6 mA thus preventing the charging current exceeding this value. The value of the resistor 11 may be in accordance with well known principles: it may, indeed, not be needed at all in some cases. In Figure 7 the electrical load provided by the watch is represented by the resistance 5.

WHAT WE CLAIM IS:—

1. A time-piece having a secondary or chargeable battery supplying operating voltage thereto, a solar battery for charging said secondary or chargeable battery and a transistor, the state of the conductivity of which is controlled directly or indirectly by the output voltage of the solar battery and which is connected to act as a limiting resistance limiting the charging current to a predetermined maximum.

2. A time-piece as claimed in claim 1, wherein the emitter-collector circuit of the transistor is connected across the solar battery and the emitter-base circuit thereof is connected in the current output circuit of said solar battery.

3. A time-piece as claimed in claim 2, wherein said emitter-base circuit is connected across a diode also included in said current output circuit.

4. A time-piece as claimed in any of the preceding claims 1 to 3, wherein a resistance is included in series with the base of the transistor.

5. A time-piece as claimed in any of the preceding claims 1 to 3, wherein a diode is included in series with the base of the transistor.

6. A time-piece as claimed in claim 1 wherein the collector emitter collector circuit of the transistor is connected effectively in parallel with the secondary or chargeable battery and the base-emitter voltage of said transistor is controlled in dependence upon voltage produced by the solar battery.

7. A time-piece as claimed in claim 6, wherein a diode is connected between the positive terminal of the solar battery and the positive terminal of the secondary or chargeable battery, the collector of the transistor is connected to the solar battery side of said diode and the base of the transistor is connected to a tap on a potential divider connected across said solar battery.

8. A time-piece as claimed in claim 7, wherein the potential divider consists of a resistance in series with a thermistor of such temperature characteristic as substantially to compensate for the temperature characteristic of the transistor by varying the value of charging current at which limitation is effected.

9. A time-piece as claimed in claim 6, wherein a diode in series with a resistance in the order stated are connected between the positive terminal of the solar battery and the positive terminal of the secondary or chargeable battery, and the base-emitter circuit of the transistor is subjected to voltage drop produced across said resistance by charging current flow therethrough.

10. Time-pieces having secondary or charge batteries and solar batteries for charging the same and wherein means, substantially as herein described and illustrated in Figures 1, 2, 3, 5 and 7, are provided for preventing overcharging by the solar batteries.

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3. A time-piece as claimed in claim 2, wherein said emitter-base circuit is connected across a diode also included in said current output circuit.

4. A time-piece as claimed in any of the preceding claims 1 to 3, wherein a resistance is included in series with the base of the transistor.

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