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EP 0323539 A1
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US 20020145430 A1
WO 2004/062010 A1
US 5831435 A

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(54) Abstract Title: **Apparatus and method for simulating a battery tester with a fixed resistance load**

(57) A method and apparatus for simulating a battery tester with a fixed resistance load, such as a widely used Japanese load tester that rates the strength of Japanese batteries that are categorized under the Japanese Industrial Standard (JIS), are provided. This invention simulates such a device without invoking large current loads, yields familiar results, utilizes an existing database and provides more conclusive testing. The method includes measuring an open circuit voltage (OCV), temperature and a dynamic parameter of the battery. A load voltage of the battery is estimated as a function of the measured battery dynamic parameter, the OCV, the load resistance value of the load tester and the battery temperature. A bounce-back voltage or recovery voltage is then predicted using the temperature and the open circuit voltage. The dynamic parameter is preferably the measured conductance or resistance of the battery in response to an applied current pulse. The strength of the battery can thus be rated.

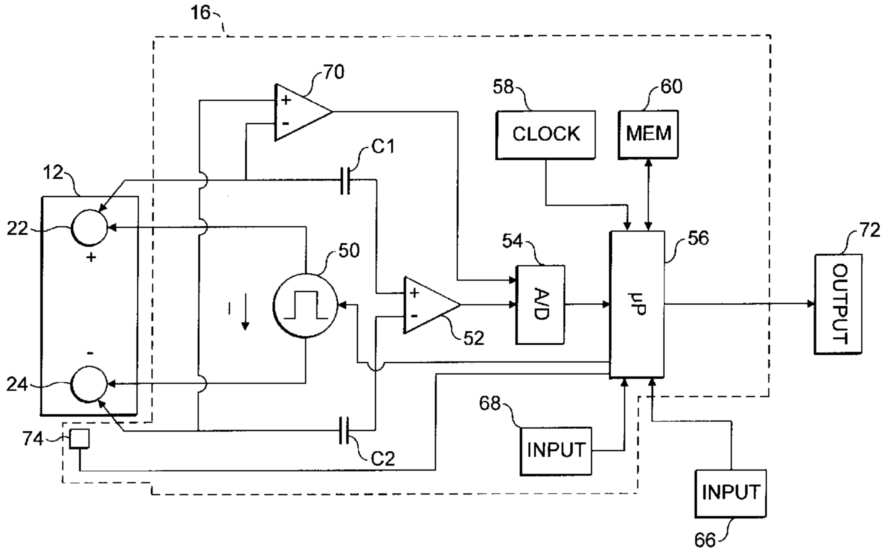

FIG. 1

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22 10 04

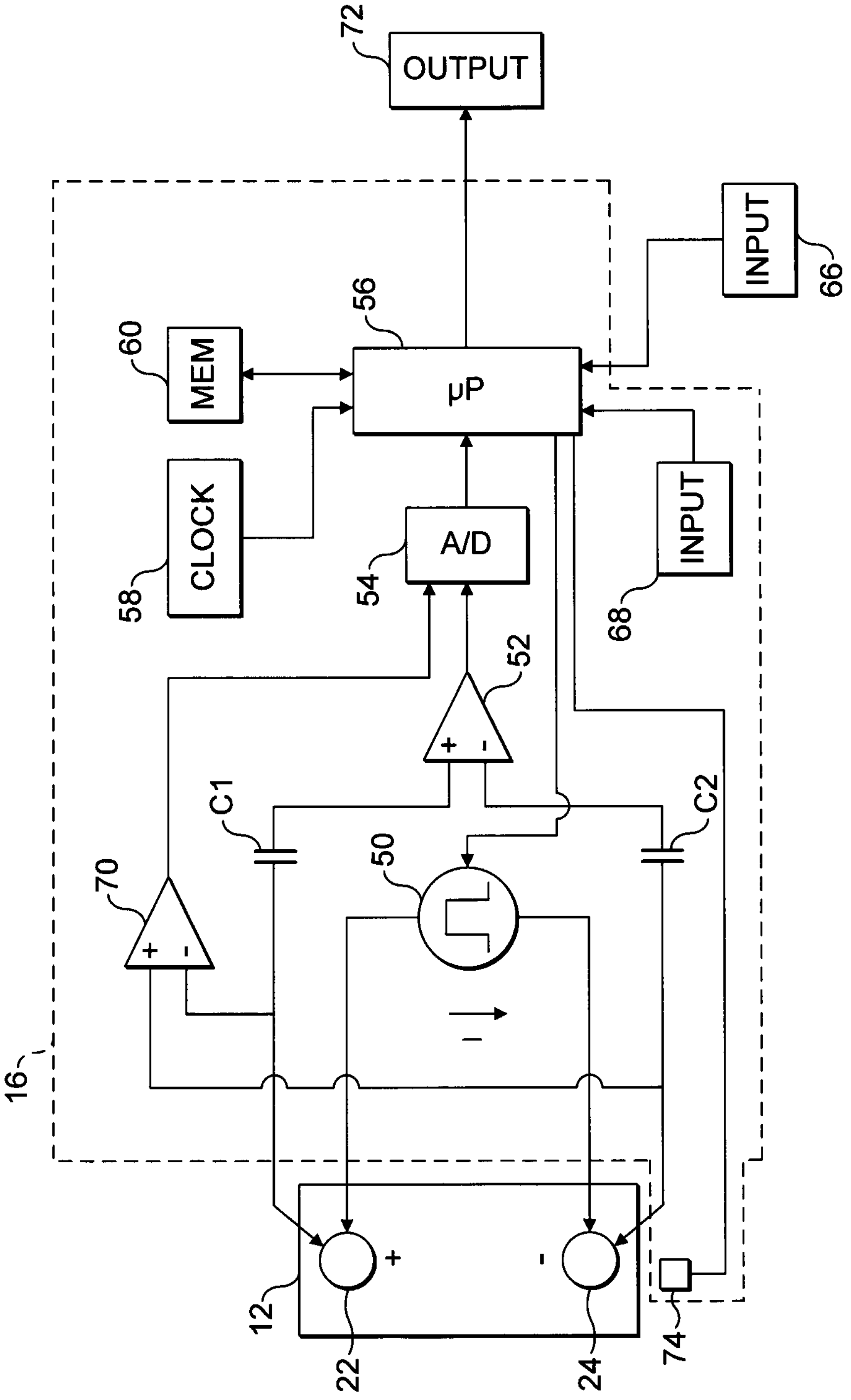
72
OUTPUT
16
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FIG. 1

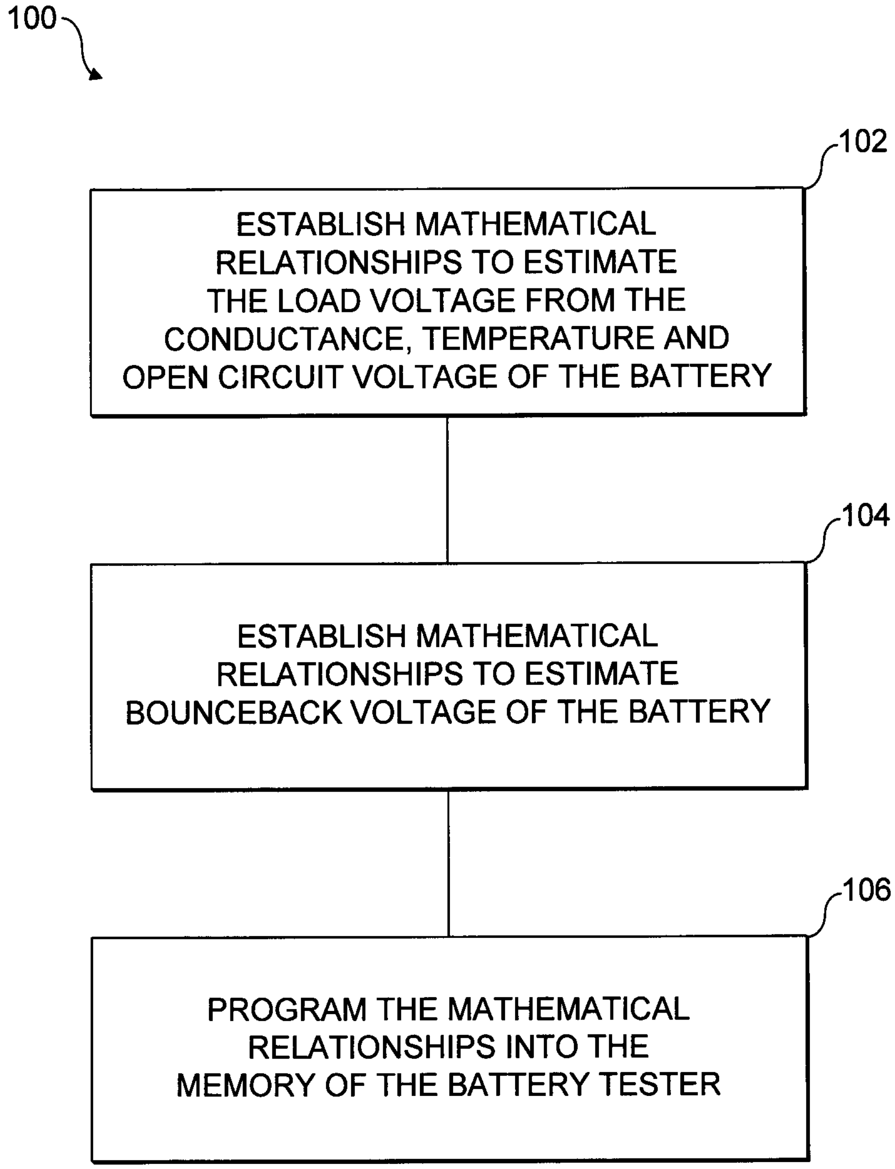
100
102
ESTABLISH MATHEMATICAL RELATIONSHIPS TO ESTIMATE THE LOAD VOLTAGE FROM THE CONDUCTANCE, TEMPERATURE AND OPEN CIRCUIT VOLTAGE OF THE BATTERY
104
ESTABLISH MATHEMATICAL RELATIONSHIPS TO ESTIMATE BOUNCEBACK VOLTAGE OF THE BATTERY
106
PROGRAM THE MATHEMATICAL RELATIONSHIPS INTO THE MEMORY OF THE BATTERY TESTER

FIG. 2

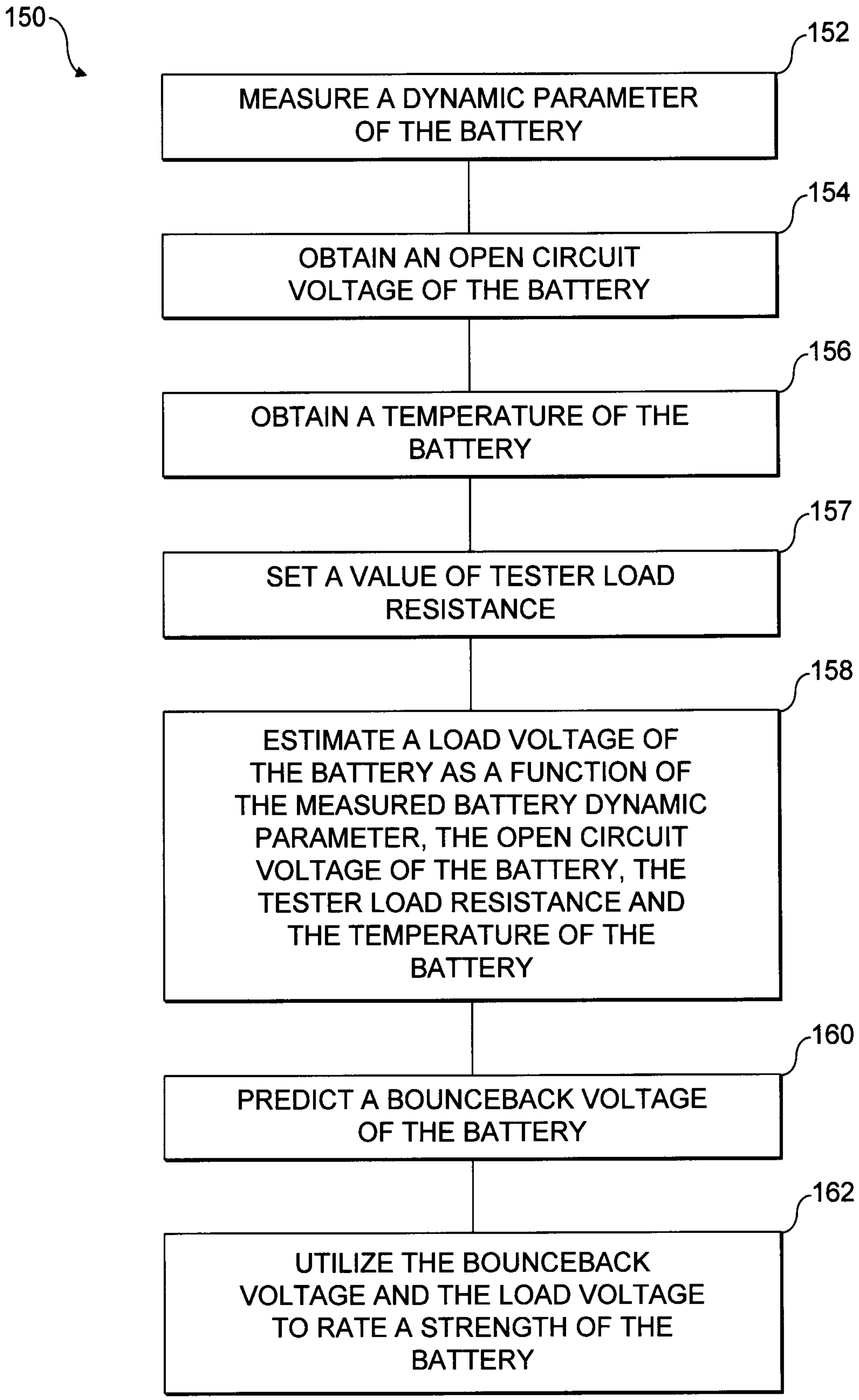
150
152
MEASURE A DYNAMIC PARAMETER OF THE BATTERY
154
OBTAIN AN OPEN CIRCUIT VOLTAGE OF THE BATTERY
156
OBTAIN A TEMPERATURE OF THE BATTERY
157
SET A VALUE OF TESTER LOAD RESISTANCE
158
ESTIMATE A LOAD VOLTAGE OF THE BATTERY AS A FUNCTION OF THE MEASURED BATTERY DYNAMIC PARAMETER, THE OPEN CIRCUIT VOLTAGE OF THE BATTERY, THE TESTER LOAD RESISTANCE AND THE TEMPERATURE OF THE BATTERY
160
PREDICT A BOUNCEBACK VOLTAGE OF THE BATTERY
162
UTILIZE THE BOUNCEBACK VOLTAGE AND THE LOAD VOLTAGE TO RATE A STRENGTH OF THE BATTERY

FIG. 3

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APPARATUS AND METHOD FOR SIMULATING A BATTERY TESTER WITH A FIXED RESISTANCE LOAD

BACKGROUND OF THE INVENTION

The present invention relates to testing storage batteries. More specifically the present invention relates to simulating a battery tester with a fixed resistance load such as a widely used Japanese load tester that rates the strength of Japanese batteries that are categorized under the Japanese Industrial Standard (JIS). The present invention simulates such a device without invoking large current loads, yields familiar results, utilizes an existing database and provides more conclusive testing.

In general, battery state of health decisions are based on battery rating standards. Japanese battery manufacturers design and manufacture batteries according to Japanese Industrial Standards (JIS). Lead-acid storage batteries used for purposes such as starting, lighting and ignition of automobiles are defined by standard JIS D 5301. This standard defines performance, testing, construction, and labeling criteria for JIS rated batteries.

One type of Japanese battery tester uses measurements of battery voltage under a resistive load and subsequent recovery voltage to assess the viability of JIS rated batteries for further service. This tester encompasses several ranges of battery sizes grouped by JIS numbers and multiple temperature ranges. Depending on the response, the battery is diagnosed, as "good," "replace soon," "replace," etc.

Because this tester has a fixed load resistor that discharges batteries at sizable rates (for example, 150 amperes for 5-6 seconds), the tester is rather bulky and may get hot with repeated tests. Also, waiting for the completion of the load and the recovery time takes a moderate amount of time and further depletes battery charge. Further, this tester has voltage sensing leads that are not directly connected to the battery, and therefore the cables must be ohmically perfect and the current must be exactly known to give the correct voltage reading at the battery terminals. Furthermore, if the tester is to be powered by the battery to be tested, then heavy loads can drain a weak or discharged battery causing the tester to lose sufficient power to keep its control circuits running thereby causing a reset.

Thus, it is desirable to obtain load test results, that the above-described Japanese load tester, and other such load testers, are capable of providing, using a more amenable testing technique.

SUMMARY OF THE INVENTION

A method and apparatus for simulating a battery tester with a fixed resistance load, such as a Japanese load tester that rates the strength of Japanese batteries that are categorized under the Japanese Industrial Standard (JIS), are provided. The method includes measuring a dynamic parameter of the battery and obtaining an open circuit voltage of the battery. A temperature of the battery is then obtained. A load voltage of the battery is estimated as a function of the measured battery dynamic parameter, the open circuit voltage of the battery, a load resistance value of the load tester and the temperature of the battery. A bounceback voltage of the battery is then predicted. The bounceback voltage, the load voltage and the battery temperature are utilized to rate the strength of the battery by categories of JIS group size numbers for JIS rated batteries. In addition, the apparatus and method of the present invention can be employed for non-JIS batteries by using reference CCA (cold cranking amps) ranges for each group size.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a simplified schematic diagram showing battery test circuitry in accordance with an embodiment of the present invention.

Figure 2 is a simplified block diagram showing the steps of a method of programming a battery tester in accordance with an embodiment of the present invention.

Figure 3 is a simplified block diagram showing the steps of a method of testing a battery in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention provides an apparatus and method for simulating a battery tester with a fixed resistance load, such as a Japanese load tester that rates the strength of Japanese batteries that are categorized under the Japanese Industrial Standard (JIS). A battery tester according to an embodiment of the present invention assesses a dynamic parameter, such as conductance, of a battery rated according to Japanese Industrial Standards (JIS) and, together with the resistance of the tester load to be simulated, an open circuit voltage and the temperature of the JIS rated battery, outputs calculated values that are used to rate the strength of the JIS rated battery by categories of JIS group size numbers. In addition, the tester can be used for non-JIS batteries by using reference CCA (cold cranking amps) ranges for each group size.

Figure 1 is a simplified block diagram of battery test circuitry 16 in accordance with an embodiment of the present invention. Apparatus 16 is shown coupled to battery 12, which includes a positive battery terminal 22 and a negative battery terminal 24. Battery 12 may be a JIS rated battery or a non-JIS rated battery such as a CCA rated battery.

Circuitry 16 operates in accordance with one embodiment of the present invention and determines the conductance (G) of battery 12, the open circuit voltage (OCV) between terminals 22 and 24 of battery 12 and the bounceback voltage (change in voltage after the battery is initially released from a load until some time later (for example, 3 seconds)) of battery 12. Circuitry 16 includes current source 50, differential amplifier 52, analog-to-digital converter 54 and microprocessor 56. Amplifier 52 is capacitively coupled to battery 12 through capacitors C_1 and C_2. Amplifier 52 has an output connected to an input of analog-to-digital converter 54. Microprocessor 56 is connected to system clock 58, memory 60 and analog-to-digital converter 54. Microprocessor 56 is also capable of receiving an input from input devices 66 and 68. Microprocessor 56 also connects to output device 72.

In operation, current source 50 is controlled by microprocessor 56 and provides a current I in the direction shown by the arrow in Figure 1. In one embodiment, this is a square wave or a pulse. Differential amplifier 52 is connected to terminals 22 and 24 of battery 12 through capacitors C_1 and C_2, respectively, and provides an output related to the voltage potential difference between terminals 22 and 24. In a preferred embodiment, amplifier 52 has a high input impedance. Circuitry 16 includes differential amplifier 70 having inverting and noninverting inputs connected to terminals 24 and 22, respectively. Amplifier 70 is connected to measure the OCV of battery 12 between terminals 22 and 24. The output of amplifier 70 is provided to analog-to-digital converter 54 such that the voltage across terminals 22 and 24 can be measured by microprocessor 56.

Circuitry 16 is connected to battery 12 through a four-point connection technique known as a Kelvin connection. This Kelvin connection allows current I to be injected into battery 12 through a first pair of terminals while the voltage V across the terminals 22 and 24 is measured by a second pair of connections. Because very little current flows through amplifier 52, the voltage drop across the inputs to amplifier 52 is substantially identical to the voltage drop across terminals 22 and 24 of battery 12. The output of differential amplifier 52 is converted to a digital format and is provided to microprocessor 56. Microprocessor 56 operates at a frequency determined by system clock 58 and in accordance with programming instructions stored in memory 60.

Microprocessor 56 determines the conductance of battery 12 by applying a current pulse I using current source 50. The microprocessor determines the change in battery voltage due to the current pulse I using amplifier 52 and analog-to-digital converter 54. The value of current I generated by current source 50 is known and is stored in memory 60. Microprocessor 56 calculates the conductance of battery 12 using the following equation:

$$Conductance = G = \frac{\Delta I}{\Delta V}$$

Equation 1

where ΔI is the change in current flowing through battery 12 due to current source 50 and ΔV is the change in battery voltage due to applied current ΔI. In a preferred embodiment of the present invention, the temperature of battery 12 is input by a tester user through input 66, for example. In other embodiments circuitry 16 also includes a temperature sensor 74, coupled to microprocessor 56, that can be thermally coupled to battery 12 to thereby measure a temperature of battery 12 and provide the measured battery temperature value(s) to microprocessor 56. In one embodiment, the battery temperature is measured using an infrared signal from the outside of the battery. Microprocessor 56 can also use other information input from input device 66 provided by, for example, an operator. This information may consist of the particular type of battery, location, time, the name of the operator, battery group size number, battery temperature, etc.

Under the control of microprocessor 56, battery tester 16 estimates a load voltage of battery 12 as a function of the battery conductance G (Equation 1), the OCV, the resistance of the simulated tester load and the battery temperature. Further, battery tester 16 predicts, as mentioned above, a bounceback voltage of the battery. The bounceback voltage, the load voltage and the battery temperature are utilized by microprocessor 56 of battery tester 16 to rate the strength of the battery by categories of JIS group size numbers. Details regarding the derivation of an example algorithm utilized by battery tester 16 to estimate the bounceback voltage and load voltage of battery 12 are provided below. The algorithm included below was derived by analyzing a popular Japanese battery load tester.

Analysis of Japanese Load Tester

The Japanese load tester requires the user, after connecting the cable clamps to a battery, to input the size of the battery and the temperature. The user then pushes a start button. The tester puts a load on a battery for 5-6 seconds and then records the load voltage (LV). It then looks at the bounceback or recovery voltage 2.5 seconds later and makes a decision about the battery.

As mentioned above, the user inputs battery size. Specifically, batteries are input in 10 group size ranges (0-9) that go in increasing cranking power range. Each range, however, is strictly associated with various JIS battery numbers printed on the tester(s). Table 1 below shows the different group size ranges.

Table 1

Group Size	JIS BATTERY NUMBER	Cold Cranking Amp (CCA) range
0	26A17, 26A19, 26B17, 28A19, 28B17, 28B19, 32C24	200-250 CCA
1	30A19, 32A19, 34A19, 34B17, 34B19, 36B20, 48B26	251-300 CCA
2	38B19, 40B19, 38B20, 40B20, 46B24, 50D20,	301-350 CCA

	55D26	
3	42B19, 42B20, 44B19, 50B24, 55D23, 65D31	351-400 CCA
4	55B24, 65D23, 65D26, 75D31	401-450 CCA
5	60B24, 70D23, 75D23, 75D26, 80D23, 80D26, 85D31, 95E41, 100E41, 105E41, 110E41	451-600 CCA
6	90D26, 95D31, 105D31, 115E41, 115F51	601-750 CCA
7	115D31, 120E41, 130E41, 130F51, 145F51, 145G51, 155G51	751-900 CCA
8	150F51, 170F51, 165G51, 190H52	901-1050 CCA
9	180G51, 195G51, 210H52, 225H52, 245H52	1051+ CCA

As mentioned above, in addition to group size, the user inputs temperature. The temperature is input by the user in four ranges (shown in Table 2):

Table 2

	Temperature range (degrees Celsius(°C))
1	0
2	10
3	25
4	"After Driving" (50)

The tester allows the battery to be tested down to 11.5 volts (V) after recovery where it is then reported as low voltage, provided that the battery provides enough voltage to support the tester during the load. If indeed the voltage goes very low, the load tester simply resets and reports nothing.

A basic relationship between the group size (0-9) and temperature (°C) for this type of tester follows the following relationship:

Good Voltage (Vg in Volts):

$$Vg = 8.8 + 0.1 * GroupSize + 0.02 * TempC$$

Equation 2

Where GroupSize = battery group size (Table 1 above)

TempC = battery temperature in degrees Celsius (Table 2 above)

Replace Voltage (Vr in Volts):

$$Vr = Vg - 0.3$$

Equation 3

However, because the battery may be discharged or have other problems, the measured recovery or bounceback voltage (BBV) is assessed and combined with the group size criteria and temperature gives the following (shown in Table 3 below):

Table 3

Comparison	Result
LV >= Vg AND BBV >= 11.5V	Good
LV < Vg AND LV >= Vr AND BBV >= 11.5V	Replace Soon
LV < Vr AND LV >= 7V AND BBV >= 11.5V	Replace
LV >= Vr AND LV < Vg AND BBV < 11.5V	Attention (Charge Soon)
LV >= 7V AND LV < Vr AND BBV < 11.5V	Warning (Charge and Retest)

LV < 7V (Normally the tester simply resets for lack of power. In such a case the battery is retested after charging.)	Fail/Replace (Charge and Retest)

Example Algorithm for Battery Tester of the Present Invention

As mentioned above, the battery tester of the present invention works by predicting the load voltage (LV) using measured values of the battery's OCV, conductance and temperature (measured or input by the user).

To predict the load voltage in Volts, the following relationship is used:

$$LV = Vact - I * R$$

Equation 4

Where Vact = activation voltage

I = load current

R = battery resistance

The activation voltage (Vact) can be estimated by:

$$Vact = K1 * OCV^2 + K2 * OCV + K3 * TempC - K4$$

Equation 5

where K1, K2, K3 and K4 are constants whose values are selected based upon the type of battery tester being simulated.

The battery conductance (G) is measured as described above using Equation 1. Using conductance measured at 100Hz, the battery resistance can be estimated by:

$$R = K5/G + K6$$

Equation 6

where K5 and K6 are constants. However, because the Japanese tester uses a fixed resistor for loading, the current will vary with the resistance of the battery. Therefore, the load current must first be estimated. This can be carried out using the following relationship:

$$I = Vact / (R + R1)$$

Equation 7

where R1 is the estimated resistance of the load tester in ohms.

It was generally found that the load varies between 110 - 160 amperes; if below 110 amperes the load tester will reset. Therefore, the load voltage can be predicted and used for assessing the battery strength.

In addition, it was found that the recovery or bounceback voltage (BBV) could be predicted with a second order equation using the open circuit voltage and the temperature:

$$BBV = K7 * OCV + K8 * OCV - K9 + K10 * (TempC - K11)$$

Equation 8

where K7, K8, K9, K10 and K11 are constants.

Therefore, using these calculations (Equations 1 and 4-8), the values attained by the Japanese load tester can be predicted without invoking a high load.

Figure 2 is a flowchart 100 showing steps of a method of programming battery tester 16 in accordance with an embodiment of the present invention. As shown in flow chart 100, at step 102, mathematical relationships to estimate the load voltage from the conductance, temperature and OCV of the battery are established (Equations 1 and 4-7 above). At step 104, a mathematical relationship to estimate bounceback voltage of the battery is established (Equation 8). At step 106, the mathematical relationships are programmed into memory 60 of battery tester 16. At this point, battery tester 16 is ready to estimate battery load voltage and bounceback voltage and to utilize the estimated bounceback voltage, the load voltage and the battery temperature to rate the strength of the battery by categories of JIS group size numbers.

Figure 3 is a flowchart 150 showing steps of a method of testing a battery in accordance with an embodiment of the present invention. At step 152, a dynamic parameter of the battery is measured. At step 154, an open circuit voltage of the battery is obtained. At step 156, a temperature of the battery is obtained. At step 157, a value of tester load resistance is set. This is a predetermined load resistance value that is appropriate for a load tester being simulated. At step 158, a load voltage of the battery is estimated as a function of the measured battery dynamic parameter, the open circuit voltage of the battery, the load resistance and the battery temperature. At step 160, a bounceback voltage of the battery is predicted. At step 162, the bounceback voltage, the load voltage and the battery temperature are utilized to rate the strength of the battery by categories of JIS group size numbers. Different techniques, some of which are set forth above, can be employed to carry out the steps shown in the flow chart of Figure 3 while maintaining substantially the same functionality without departing from the scope and spirit of the present invention.

Furthermore, because there is no load from the tester of this invention, the tester can improve upon the standard load tester by making judgements in areas that would reset the standard load tester. In particular, if the bounceback voltage is above 11.5V and the load voltage is very low (<7V), such a battery can be certain to be a cause for "Fail/Replace." If the bounceback voltage is below 11.5V, the OCV is greater than 11V and the load voltage estimate is less than Vr then a judgement can be deferred and the battery can be put in a "Charge and Retest" category. In addition, the tester can detect batteries with probable shorts by finding significant conductance when the OCV is less than 11V. These can be placed in a "Fail/Replace" category. If little conductance is present when the voltage is very low, the battery can be placed in a

"Charge and Retest" category. The improved and more specific comparisons and results are provided in Table 4 below.

Table 4

Comparison	Result
LV >= Vg AND BBV >= 11.5V	Good
LV < Vg AND LV >= Vr AND BBV >= 11.5V	Replace Soon
LV < Vr AND LV >= 7 AND BBV >= 11.5V	Replace
LV < 7V AND BBV >= 11.5V	Fail/Replace
LV >= Vr AND LV < Vg AND BBV < 11.5V AND OCV >= 11V	Attention (Charge Soon)
LV < Vr AND BBV < 11.5V AND OCV >= 11V	Warning (Charge and Retest)
IF OCV < 11V AND CCA >= f(GROUP SIZE) (PROBABLE SHORT)	Fail/Replace
IF OCV < 11V AND CCA < f(GROUP SIZE)	Warning (Charge and Retest)

Although the example embodiments of the present invention described above relate to estimating load voltage from battery conductance measurements, dynamic parameters other than battery conductance may be utilized without departing from the spirit and scope of the invention. Examples of other dynamic parameters include dynamic resistance, admittance, impedance, reactance, susceptance or their combinations. In preferred embodiments of the present invention, battery tester 16 is relatively small and portable.

The above embodiments of the present invention are primarily described in connection with simulating a Japanese load tester. However, the significance of this present invention is not necessarily that it mimics a Japanese tester, but that it mimics, in general, any tester with a fixed resistance load. In general, simulating a tester with a fixed resistance load is a two stage process: (1) determining what current will be drawn from the battery (Equation 7 above) and (2) determine what voltage the battery will achieve under that load (Equation 4 above). Many prior art algorithms assume that the load current is defined and then the voltage is predicted.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

CLAIMS

1. A method of testing a storage battery rated using the Japanese Industrial Standard (JIS), the method comprising:

(a) measuring a dynamic parameter of the battery;

(b) obtaining an open circuit voltage of the battery;

(c) obtaining a temperature of the battery;

(d) setting a predetermined load resistance value;

(e) estimating a load voltage of the battery as a function of the measured battery dynamic parameter, the open circuit voltage of the battery, the load resistance value and the temperature of the battery;

(f) predicting a bounceback voltage of the battery; and

(g) utilizing the bounceback voltage, the load voltage and the battery temperature to rate a strength of the battery by categories of JIS group size numbers.

2. A method of testing a storage battery comprising:

(a) measuring a dynamic parameter of the battery;

(b) obtaining an open circuit voltage of the battery;

(c) obtaining a temperature of the battery;

(d) setting a predetermined load resistance value;

(e) estimating a load voltage of the battery as a function of the measured battery dynamic parameter, the open circuit voltage of the battery, the load resistance value and the temperature of the battery;

(f) predicting a bounceback voltage of the battery; and

(g) utilizing the bounceback voltage, the load voltage and the battery temperature to rate a strength of the battery.

3. The method of claim 1 or claim 2 wherein setting the predetermined load resistance value in step (d) comprises setting the load resistance value to be appropriate for a load tester being simulated.

4. The method of any of claims 1 to 3 wherein obtaining the temperature of the battery in step (c) comprises receiving the temperature of the battery as an input provided by a user.

5. The method of any of claims 1 to 4 wherein obtaining the temperature of the battery in step (c) comprises receiving the temperature of the battery as an input from a temperature sensor.

6. The method of any of claims 1 to 5 wherein measuring the dynamic parameter measurement in step (a) comprises determining a response of the battery to an applied current pulse.

7. The method of any of claims 1 to 6 wherein the measured battery dynamic parameter value is battery conductance.

8. The method of any of claims 1 to 6 wherein the measured battery dynamic parameter value is battery resistance.

9. An electronic battery tester comprising:

a positive connector coupled to a positive terminal of the battery;

a negative connector coupled to a negative terminal of the battery;

a voltage sensor configured to measure an open circuit voltage of the battery;

an input configured to receive a temperature of the battery; and

battery test circuitry configured to:

(a) measure a dynamic pressure of the battery using the first and second connectors;

(b) estimate a load voltage of the battery as a function of the measured battery dynamic parameter, the open circuit voltage of the battery, a load resistance value and the temperature of the battery;

(c) predict a bounceback voltage of the battery; and

(d) utilize the bounceback voltage, the load voltage and the battery temperature to rate a strength of the battery by categories of JIS group size numbers.

10. An electronic battery tester comprising:

a positive connector coupled to a positive terminal of the battery;

a negative connector coupled to a negative terminal of the battery;

a voltage sensor configured to measure an open circuit voltage of the battery;

an input configured to receive a temperature of the battery; and

battery test circuitry configured to:

(a) measure a dynamic pressure of the battery using the first and second connectors;

(b) estimate a load voltage of the battery as a function of the measured battery dynamic parameter, the open circuit voltage of the battery, a load resistance value and the temperature of the battery;

(c) predict a bounceback voltage of the battery; and

(d) utilize the bounceback voltage, the load voltage and the battery temperature to rate a strength of the battery.

11. The electron battery tester of claim 9 or claim 10 wherein the input is configured to receive the temperature of the battery from a user.

12. The electronic battery tester of any of claims 9 to 11 wherein the input is configured to receive the temperature of the battery from a temperature sensor.

13. The electronic battery tester of any of claims 9 to 12 wherein the battery test circuitry is configured to measure the dynamic parameter in step (a) by determining a response of the battery to an applied current pulse.

14. The electronic battery tester of any of claims 9 to 13 wherein the measured battery dynamic parameter is battery conductance.

15. The electronic battery tester of any of claims 9 to 13 wherein the measured battery dynamic parameter is battery resistance.

16. The electronic battery tester of any of claims 9 to 15 wherein the positive connector is a first Kelvin connector and the negative connector is a second Kelvin connector.

17. A method of testing a storage battery comprising:
   (a) determining a value of load current that will be drawn from the battery;
   (b) determining the value of voltage that the battery will achieve under the load current; and
   (c) utilizing the values determined in steps (a) and (b) to rate a strength of the battery.

18. A method of testing a storage battery comprising:
   (a) obtaining an open circuit voltage of the battery;
   (b) obtaining a temperature of the battery; and
   (c) predicting a bounceback voltage of the battery as a function of the open circuit voltage and the temperature of the battery.

19. A method of testing a storage battery substantially as described herein with reference to any of Figures 1 to 3.

20. An electronic battery tester substantially as described herein with reference to any of Figures 1 to 3.

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Application No: GB0422992.8
Claims searched: 1,2,9,10 not 17,18
Examiner: Gareth Lewis
Date of search: 16 February 2005

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	US5831435 A (MIDTRONICS) See figures and columns 4 to 6
A,P	-	WO2004/062010 A1 (MIDTRONICS) See all figures and abstract
A	-	WO83/02005 A1 (BEAR) See abstract and figures.
A	-	EP0323539 A1 (RAMOT) See abstract and figures
A	-	US2002/0145430 A1 (YAZAKI) See abstract and figures

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X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

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Worldwide search of patent documents classified in the following areas of the IPC^{07}

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The following online and other databases have been used in the preparation of this search report

Online : EPODOC WPI