(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification:
H01M 10/0525 (2010.01) *H01M 10/48* (2006.01)
H01M 10/50 (2006.01) *B60L 11/18* (2006.01)

(21) International Application Number:
PCT/HR201 1/000045

(22) International Filing Date:
2 December 201 1 (02.12.201 1)

(25) Filing Language: Croatian

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **RIMAC AUTOMOBILI D.O.O.** [HR/HR]; Industrijska cesta 13, HR-1043 1 Sveta Nedjelja (HR).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **RIMAC, Mate** [HR/HR]; Industrijska cesta 13, HR-1043 1 Sveta Nedjelja (HR).

(74) Agent: SUĆIĆ TATJANA & DRAGUN TIHOMIR; Viva Lang Ltd., Ogrizoviceva 9, HR-10000 Zagreb (HR).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

(54) Title: SYSTEM AND PROCESS FOR MANTAINING OF WORKING TEMEPERATURE OF BATTERY CELLS FOR STARTER ACCUMULATORS IN VEHICLES
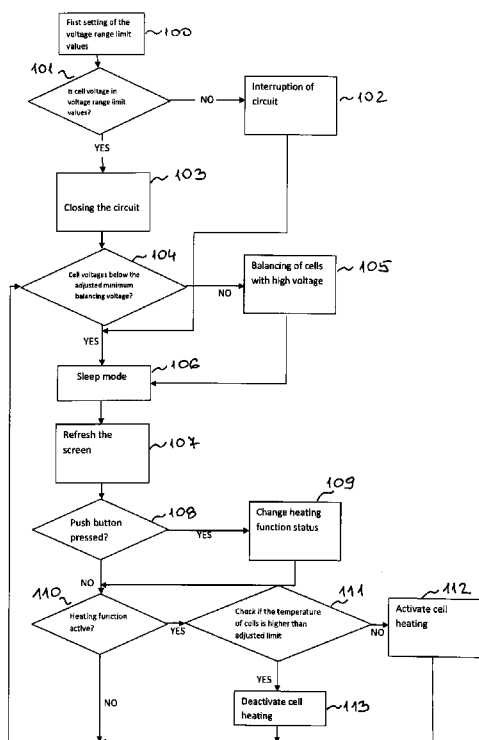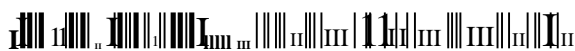

Fig. 1

(57) Abstract: The subject of the present Invention is the battery management system and procedure designed to maintain cell temperature in automobile starter batteries, containing more battery cells (8) of the new generation of lithium-ion; lithium-iron-phosphate battery cells mutually connected in series and parallel. The said system incorporates the unit (14) for cell temperature management and measurement, and voltage measurement of each individual battery cell (8) and for cell heating management (8). The unit (14) generates in real time the temperature signals of the cells. The unit (14) incorporates a temperature sensor mounted directly on one of the cells (8); the screen (12) that displays cell temperature data (43), total voltage or individual cell voltage (44) and the heating status (45) of the cells (8). The said system contains data on the predefined upper temperature value t2 and the lower temperature value ti, the push-button (34) to activate or deactivate the heating function of the battery cells (8); where the working temperature of the battery cells (8) is maintained by a heater (28, 33) in the form of foil pasted over the cells, or, in case of flat cells (8), by a heater in the form of flat foil placed in between the cells (8) or by a shared heater of any form inside the casing (1).

SYSTEM AND PROCESS FOR MANTAINING OF WORKING TEMEPERATURE OF BATTERY CELLS FOR STARTER ACCUMULATORS IN VEHICLES

Technical field

The subject of this Invention is the battery management system (BMS) and process designed to maintain cell working temperature in vehicle starter batteries, especially the cells of the new generation of lithium-ion; lithium-iron-phosphate 12/24V starter battery cells.

Technical problem

The lead batteries being used in automobiles weigh between 12 and 25 kg depending on the model. By replacing the lead batteries with a new generation of lithium batteries the weight would be greatly reduced and an improved product picture obtained in terms of environmental protection.

Due to its large mass and toxic ingredients, lead batteries are not considered a long-term solution for starting automobiles, trucks, other vehicles and products from similar areas of application. The subject of this Invention is the application of the new generation of 12 V batteries with systems that maintain optimum conditions for battery operation, featuring many advantages over the conventional lead battery, able to largely eliminate the shortcomings of the conventional battery in respect of bulky mass and toxic ingredients.

Lithium-iron-phosphate is a compound thinly applied to the anode and cathode layers of lithium-iron-phosphate battery cells. Such cells have proved to be the best choice for the new generation of 12V battery owing to a high degree of safety compared with other technologies (e.g., lithium-polymer or lithium-ion , long life (over 2000 charge/discharge cycles up to 80% capacity) and a relatively acceptable price per unit of stored energy.

However, tests have shown that at temperatures from 5 to 0 °C and lower a major fall in power potential (capability to give big currents without a big voltage drop) occurs. The technical problem being solved with the Invention is to maintain optimum conditions for the battery's operation, to keep the working temperature of battery cells if ambient temperature is too low for their functioning. This problem is solved in two possible ways: by having each cell of the battery pack in a direct contact with

the heater or by providing a common heater for the whole battery pack, where heating is activated if required.

Prior art

Porsche, the only car manufacturer to launch the 12V Li-ion starter battery, offers its own Li-ion battery as a very easy alternative to the conventional lead battery, with a note that it operates only above zero (0 °C). This battery now serves as racing equipment, for roadtrack races, anyway not for everyday use. With the Li-ion battery the manufacturer also supplies the conventional lead battery for everyday use.

There is likewise no 12V Li-ion battery with active thermal management that maintains the working temperature of cells if ambient temperature is too low for their functioning. This shortcoming confines the operation of the 12V Li-ion batteries exclusively to a range above zero temperatures and thus does not provide safety and reliability for replacing the conventional battery.

Description of the Invention

In order to avoid the low temperature problems encountered by similar systems, we have introduced the heating of battery cells to ensure unhindered work throughout the year and in all conditions.

Cell heating can be achieved in two ways, depending on the kind of application:

1. Each cell is in a direct contact with the heater (foil) which gets activated if required
2. The heater is shared by the whole battery pack

The temperature sensor is mounted directly on one of the cells and measures its temperature.

As the battery cell largely consists of metal (aluminium and copper), temperature is evenly distributed over the whole cell.

Our tests have shown that a sharp fall in energy potential (capability to generate big currents without a big voltage drop) occurs at temperatures from 0 do 5 °C and below. The program is so adjusted that the heaters are turned on when temperature falls below 0 °C and turned off when the cell temperature reaches 5 °C. The ON/OFF parameters and algorithms of heating can be adjusted as desired,

depending on ideal conditions of the used cell. In order to keep temperature high as long as possible, it is advisable to isolate the cells. It is also possible to fill the whole box (all cavities) with isolation foam. Since in heating the cells energy is used from the cells themselves, isolation is vital to ensure that energy is not be spent on heating, thus preventing the user to use the battery - e.g., automobile ignition.

There is a possibility of installing an algorithm which disables the heating function if the battery is not used for several days (the BMS is monitoring voltage development and records that for X days no voltage increase has taken place).

It is also possible to manually deactivate or activate heating by depressing the push-button on the box of the battery pack.

Brief description of drawings

The Invention will be described below in detail with reference made to the following drawings:

Fig. 1 - BMS software - operating diagram,

Fig. 2 - appearance of a completed battery pack with a casing,

Fig. 3 - battery pack - cross-section showing the main components inside the casing,

Fig. 4 - view of the battery pack cover and the parts arranged on the upper side,

Fig. 5 - front view of the battery pack,

Fig. 6 - front view with a transparent casing to show the components inside,

Fig. 7 - 3D-view of the main components of the battery pack without the casing,

Fig. 8 - side view of the battery pack with a transparent casing,

Fig. 9 - battery pack cross-section with all the components inside,

Fig. 10 - characteristic of lithium-iron-phosphate batteries (ratio between voltage and charge status),

Fig. 11 - screen, and

Fig. 12 - example of a battery pack with flat cells.

Figures 2 through 9 show the battery pack elements. The casing (1) and the cover (2) contain all the essential components of the battery pack. Visible on the outside are the casing handles (6), the terminals (3, 4), the terminal threads (5, 13, 17, 18, 20, 21), the push-button (34) and the LCD screen (12).

The casing shown in Figures 2, 4 and 5 corresponds in height and width to standard casings for lead batteries, which allows a broad application of the battery pack without a need for car modifications. The terminals (3, 4) can be connected from either side of the battery pack to required places, so that the battery could be used in automobiles with differently positioned battery clamps.

The butt (7) at the bottom of the casing serves to receive the battery pack in the car to hold faster in place.

Within the casing (1) are the battery cells (8). Depending on the cell type, capacity and area of application, there can be more or less of the cells. The more cells are series-connected, the higher voltage is obtained, the more of them are parallel-connected, the higher capacity is obtained. Figures 3, 6, 7, 8 and 9 show an example where the cylindrical cells in a configuration 4 series-, 3 parallel-connected are used. Physically they are held in place by the holders (35) inside the casing, the metal plates (22, 19, 31, 33), which also serve for electrical connection, and extra holders. When four battery cells (8) of this type are series-connected, the voltage obtained is similar to that of the conventional 12V lead batteries. For a 24V battery (e.g., in a truck), it would be necessary to series-connect eight instead of four cells (8). The shown examples use metal plates (9) for mutual connection in series or in parallel. Fig. 12 shows an example with flat cells (47) inside the casing (46). For the flat cells different methods of terminal connection are used.

The number of cells in parallel can be added as needed. If more current is required, more cells are added into parallel connection. In terms of monitoring and management, more cells in parallel are treated as one separate cell.

The battery cells (8) are mutually connected in parallel by metal plates (22, 19, 31, 33) and screws (32) or in series or parallel by other means. For example, the metal plate (22) connects at once three positive terminals (30) and three negative terminals (23) and thus simultaneously connects cells in series and parallel. The metal plates in the shown examples have relief holes (23, 24, 25). Through the metal plates (16, 19, 22) current flows from the battery cells (8) to the consumers and vice versa in case of charging. To each of the cells (8) a positive (29) and a negative (23) terminals are connected leading to the BMS. In that way the BMS monitors the voltage of each cell.

The LCD screen (12) spends very little electricity and thus does not generate a significant cost that can shorten the battery's life. It displays data such as cell temperature (43), total voltage or the voltage of individual cells (44), heating status (45) (ON/OFF), etc.

The battery management system designed to keep the working temperature of the starter battery pack containing more battery cells (8) of the new generation of lithium-ion; lithium-iron-phosphate cells mutually connected in series and parallel. The said system incorporates the unit (14) for cell temperature management and measurement, and voltage measurement of each individual battery cell (8) and for cell heating management (8). The unit (14) generates in real time the temperature signals of the cells. The unit (14) incorporates a temperature sensor mounted directly on one of the cells (8), the screen (12) that displays cell temperature data (43), total voltage or individual cell voltage (44), and the heating status (45) of the cells (8). The said system contains data on the predefined upper temperature value t_2 and the lower temperature value t_i and the push-button (34) for manual activation or deactivation of cell heating; where the working temperature of the battery cells (8) is kept up by a heater (28, 33) in the form of foil pasted over the cells, or in case of flat cells (8) by a heater in the form of flat foil placed in between the cells (8) or by a shared heater of any form inside the casing (1). All cavities between the adjacent battery cells (8) and the casing (1) and the battery cells (8) are filled with isolation foam, which prevents temperature loss from the battery pack. For heating the cells (8) the electric power of the cells (8) themselves is used. The upper temperature value t_2 amounts to 5 °C, and the lower temperature value t_i 0 °C. However, in dependence on the characteristics of individual cells, other upper temperature t_2 and lower temperature t_1 values can be set.

The working temperature maintenance procedure for the above described system involves the following steps:

- input of data on upper temperature t_2 and lower temperature t_i values;

- input of data on permissible voltage drop value;

- input of time interval data to detect the non-use of the battery pack;

- checking in step (108) whether the push-button (34) for cell heating activation or deactivation is pressed or not;

- if the push-button (34) is active, the heating status (45) of the battery cells (8) is changed and in step (110) it is checked whether or not the heating function is on;

- if the heating function is on, what follows is temperature t' measurement of the battery cell (8) and generation of measured temperature t' signals;

- checking in step (111) if the measured temperature t' is lower than the lower temperature value t_1, where, if the measured temperature t' is lower than the set temperature t_1, in step (112) cell heating is activated; and

- heating the cells (8) and generating the signals in real time on temperature t' of the battery cells (8) until the cell temperature is equal to or higher than the higher temperature value t_2, after which in step (113) cell heating is discontinued.

As far as known so far about the characteristics of the Li-ion battery cells, for their reliable work the lower temperature value t_i should not go below 0 °C, although it is already at temperatures below 15 °C that they manifest poorer performance. However, in dependence on the characteristics of the cells (8), appropriate temperature values t_2 and t_1 are set. Furthermore, depending on outdoor conditions or depending on the use of the starter battery pack, the user manually deactivates the cell heating function with the push-button (34), thus preventing the discharging of the battery pack. After the cell heating is off, the voltage of all cells is checked.

In case of the non-use of the battery pack, aimed to save energy, the heating function is automatically switched off, where the non-use of the battery pack is detected by:

- periodical voltage measurement of the cells (8) according to a predefined time interval;

- calculating the voltage difference between two periodical measurements and by memorizing the voltage difference value,

- where, if the voltage difference value is smaller than the permissible voltage drop value, the non-use of the battery pack is detected.

If no voltage change has occurred outside the predefined permissible voltage difference value (for example, 1 V difference) over a time longer than, say, 48 hours, it means that the battery has not been used for a longer period of time.

With the push-button (34) on the cover (2) the user can manually activate or deactivate heating. If the user does not want to have the heating option activated, that option can be switched off by pressing the push-button (34), which makes sense if the car has been standing idle for a long time without being driven at low temperatures - in that case it may happen that as a result of cell heating the battery gets empty after a certain time, because electric power from the cells themselves is being used for cell heating. The unit (14) in step (108) checks if the push-button (34) is pressed or not. If pressed, the heating function status (109) will change. The unit (14) checks if the heating function is active (110). If it is, the unit (14) checks if the temperature of the battery cells (8) is higher than the adjusted limit

(111). The limit (111) consists of data on the upper temperature value t_2 and the lower temperature value ti. If the measured temperature t' of the cells (8) is lower than the temperature t_1 cell heating in step (112) will be activated. If the measured temperature t' of the cells (8) is higher than the temperature t_2, cell heating in step (113) will be deactivated and the procedure returns to the beginning of the loop and the first step is restarted - checking the cell voltage (101).

CLAIMS

1. The battery management system for maintaining the working temperature of the starter battery pack containing more battery cells (8) of the new generation of lithium-ion; lithium-iron-phosphate battery cells mutually connected in series and parallel, where the said system incorporates the unit (14) for cell temperature management and measurement, and voltage measurement of each individual battery cell (8) and for cell (8)heating management, which unit (14) in real time generates the temperature and voltage signals of the battery cells (8), **characterized in that** the unit (14) incorporates a temperature sensor mounted directly on one of the cells (8); the screen (12) displaying the cell temperature data (43), the total and/or individual cell voltage (44); furthermore, the said system contains data on the predefined upper temperature value t_2 and the lower temperature value t_1 and the push-button (34) for manual activation or deactivation of cell heating; where the working temperature of the battery cells (8) is kept up by a heater (28, 33) in the form of foil pasted over the cells, or, in case of flat cells (8) by a heater in the form of flat foil placed in between the cells (8) or by a shared heater of any form inside the casing (1).

2. The system (14) according to claim 1, **characterized in that** all cavities between the adjacent battery cells (8) and the casing (1) and the battery cells (8) are filled with isolation foam or other isolation material, which prevents temperature loss from the battery pack..

3. The system (14) according to claim 1, **characterized in that** the electric power of the cells themselves (8) is used for cell heating.

4. The system according to claim 1, **characterized in that** the upper temperature value t_2 and the lower temperature value t_1 are adjusted according to the characteristics of the cells.

5. The process for maintaining the working temperature of the system defined in the foregoing claims, **characterized in that** it involves the following steps:

   - input of data on the upper temperature value t_2 and the lower temperature value t_1;

   - input of data on permissible voltage drop value;

   - input of time interval data to detect the non-use of the battery pack;

- checking in step (108) whether the push-button (34) for the activation or deactivation of cell heating is active or not;

- if the push-button (34) is active, the heating status (45) of the battery cells (8) will change and in step (110) checking is done to determine if the heating function is on;

- if the heating function is on, temperature t' measurement of the battery cell (8) and signal generation on measured temperature t';

- checking in step (111) if the measured temperature t' is lower than the lower temperature value ti, where, if the measured temperature t' is lower than the set temperature ti, in step (112) cell heating is activated; and

- heating the cells (8) and generating in real time the signals on temperature t' of each of the battery cells (8) until the cell temperature is equal to or higher than the upper temperature value t_2, after which in step (113) cell heating is discontinued.

6. The procedure according to claim 5, **characterized in that** depending on external conditions or depending on the use of the starter battery pack, the user manually deactivates the cell heating function with the push-button (34), thus preventing the discharging of the battery pack in the event of non-use for a longer period of time.

7. The procedure according to claim 5, **characterized in that** after the cell heating is off, the voltage of all cells (8) is checked.

8. The procedure according to claim 6, **characterized in that** in the event of the non-use of the battery pack, aimed to save energy, the heating function is automatically switched off.

9. The procedure according to claim 8, **characterized in that** the non-use of the battery pack is detected by:

- periodical voltage measurement of the cells (8) according to a predefined time interval;

- calculating the voltage difference between two periodical measurements and by memorizing the voltage difference value,

where, if the voltage difference value is less than the permissible voltage drop value, the non-use of the battery pack is detected.
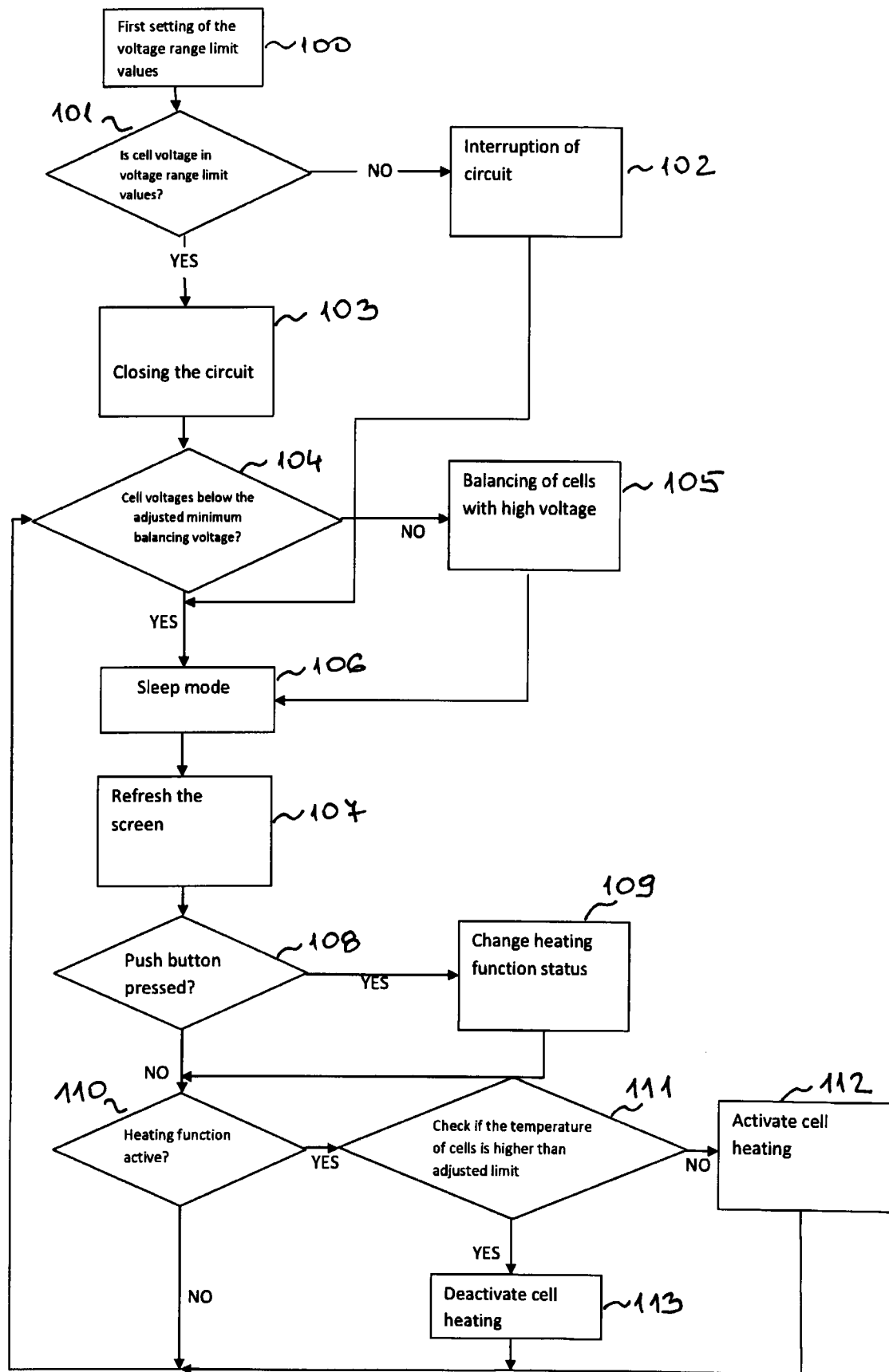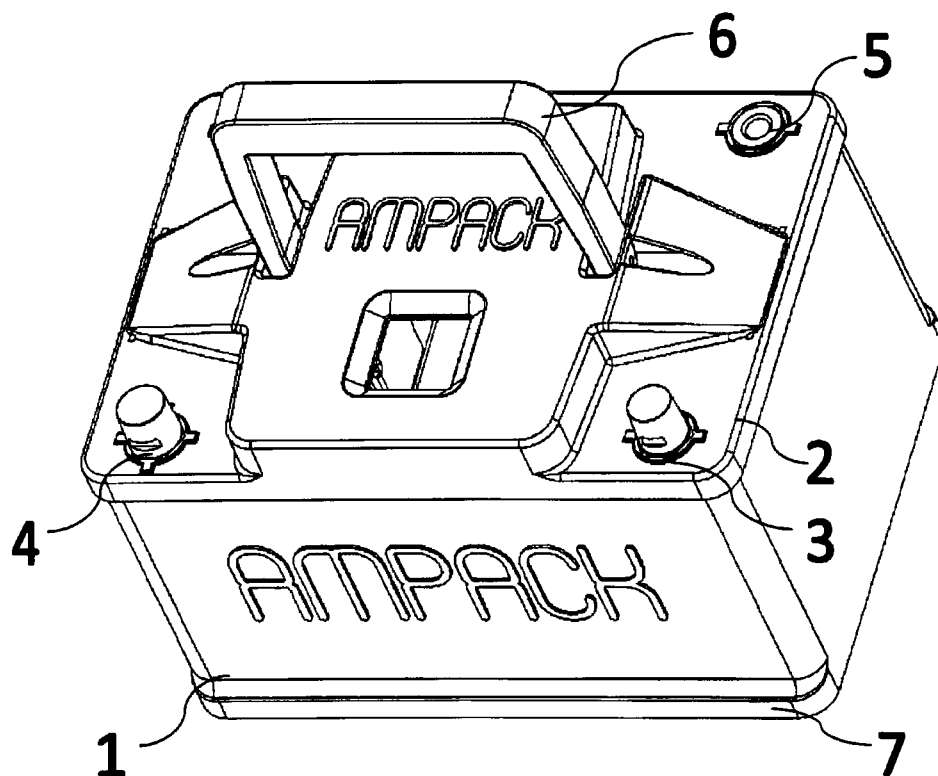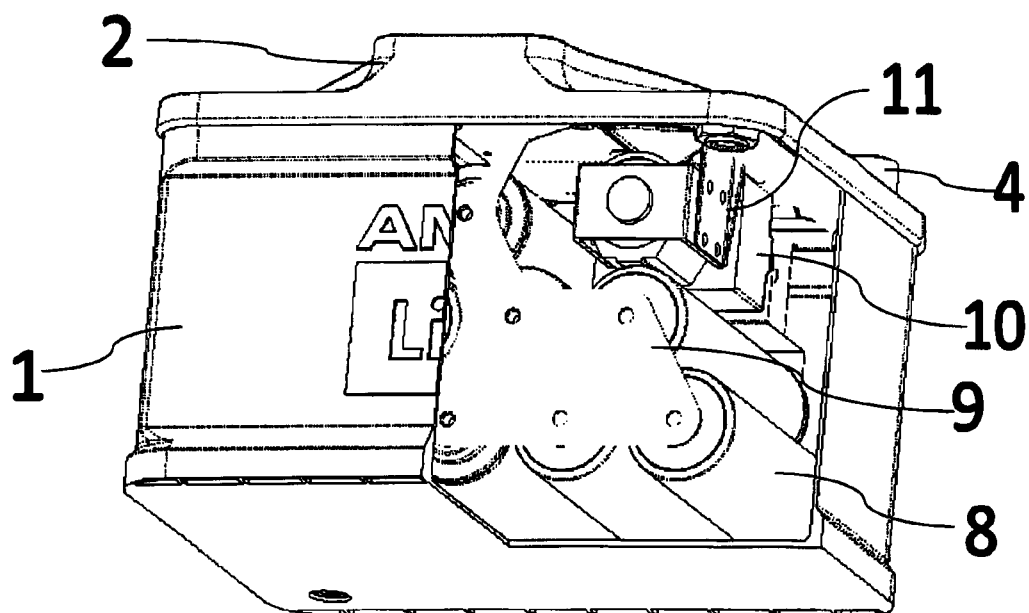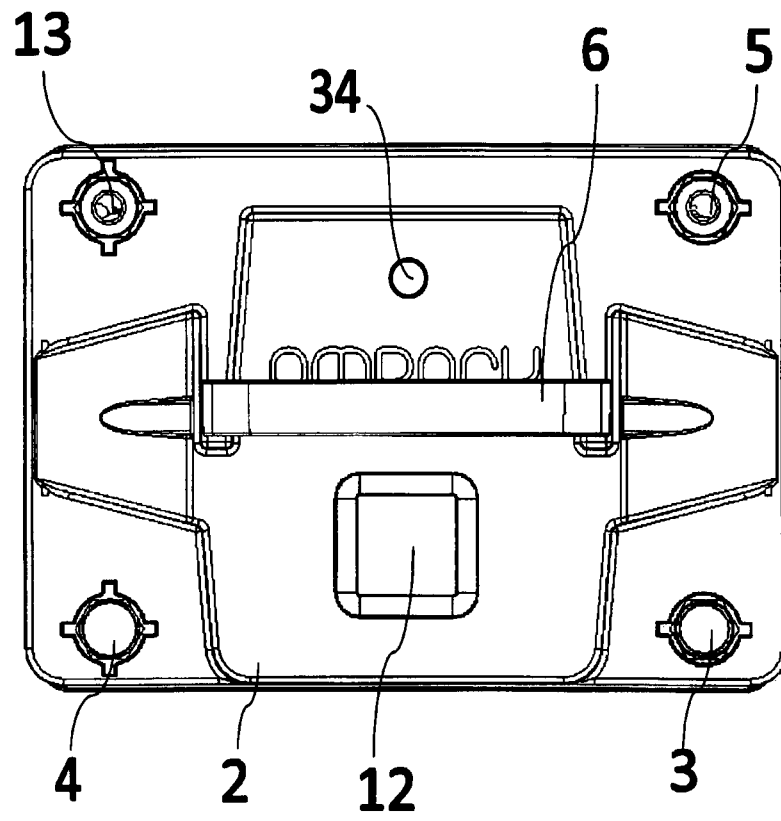
1/9

Fig. 1

Fig. 2

Fig. 3

Fig. 4
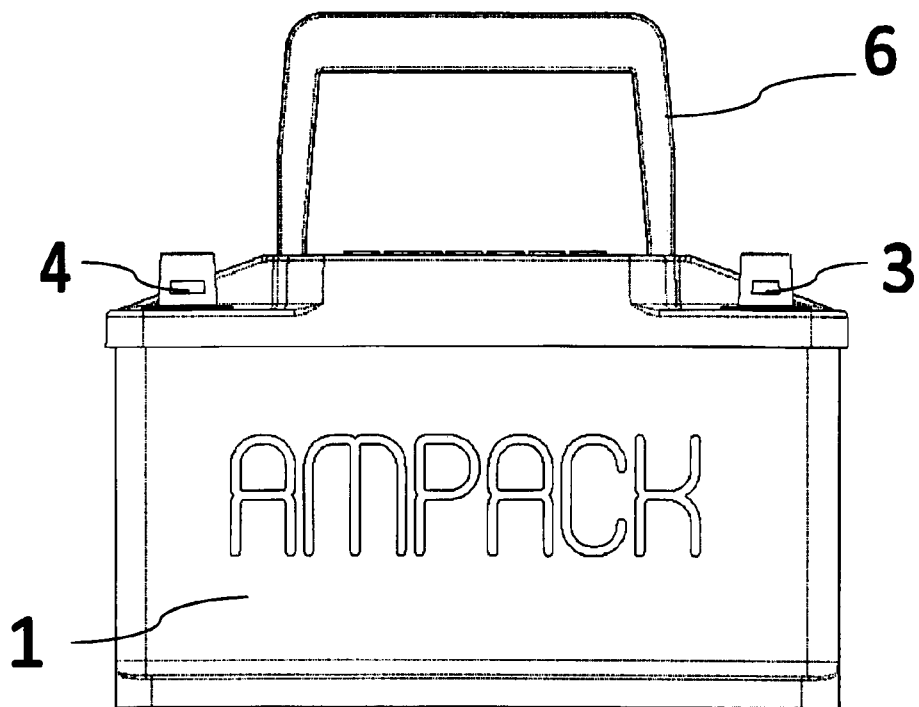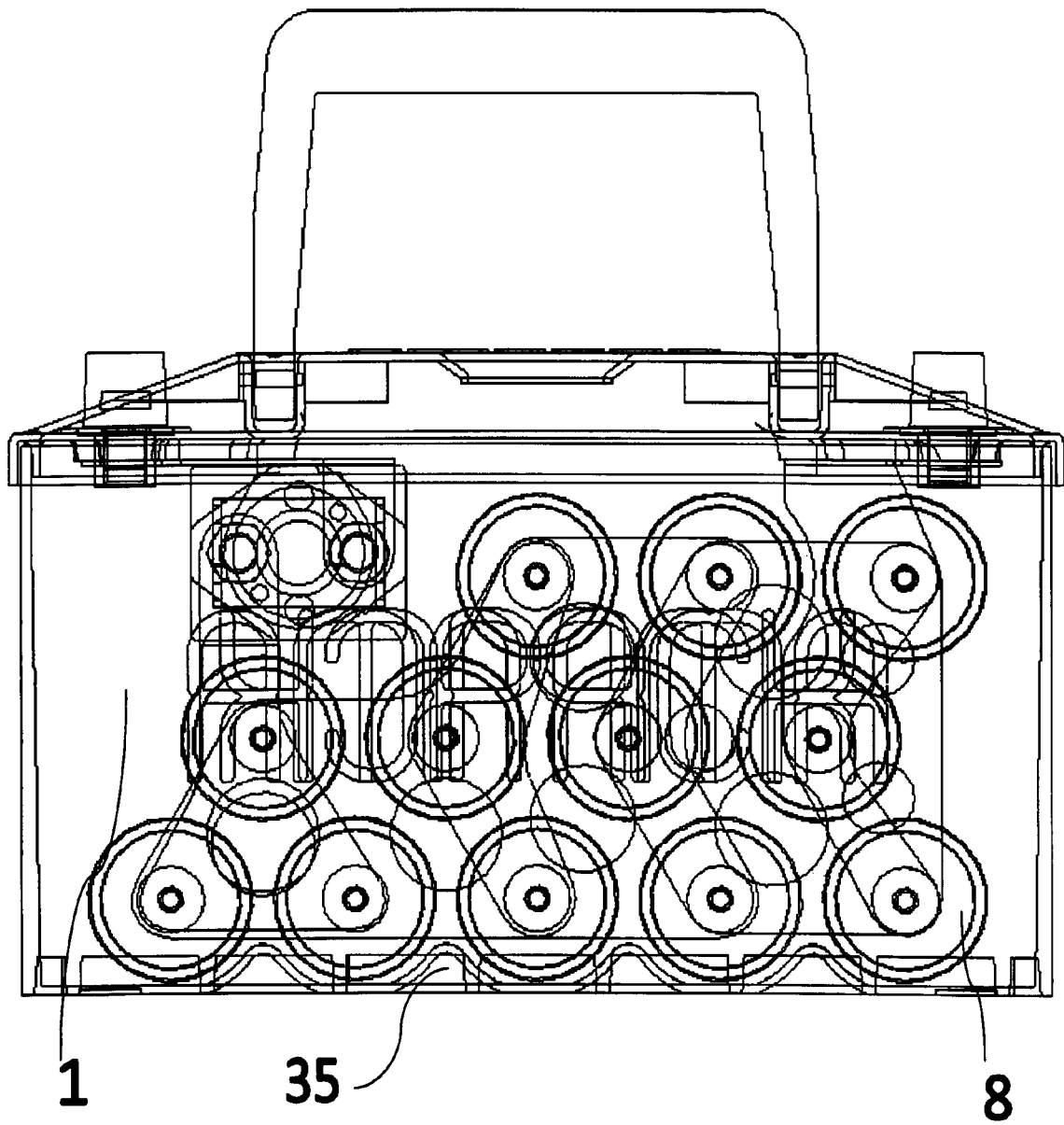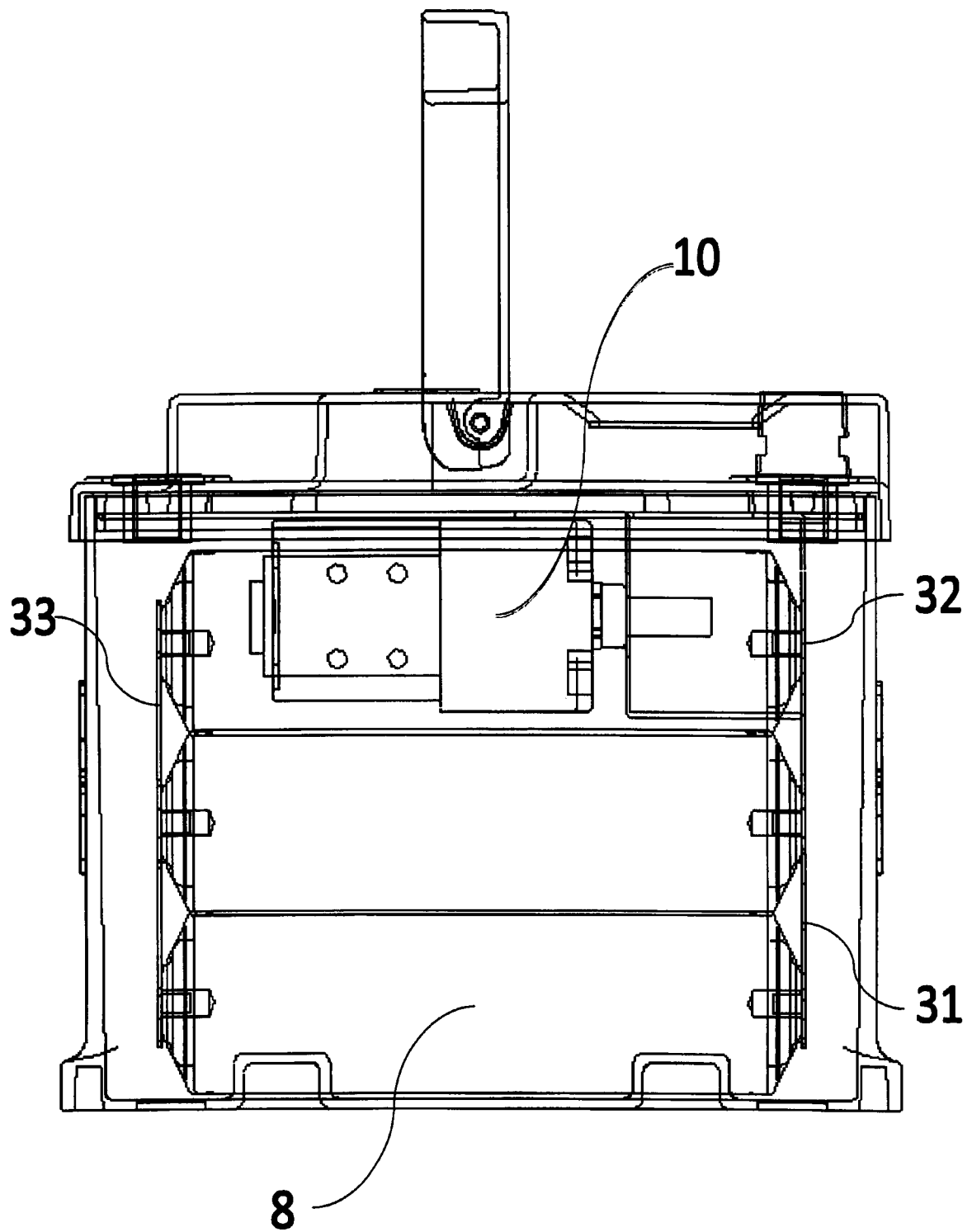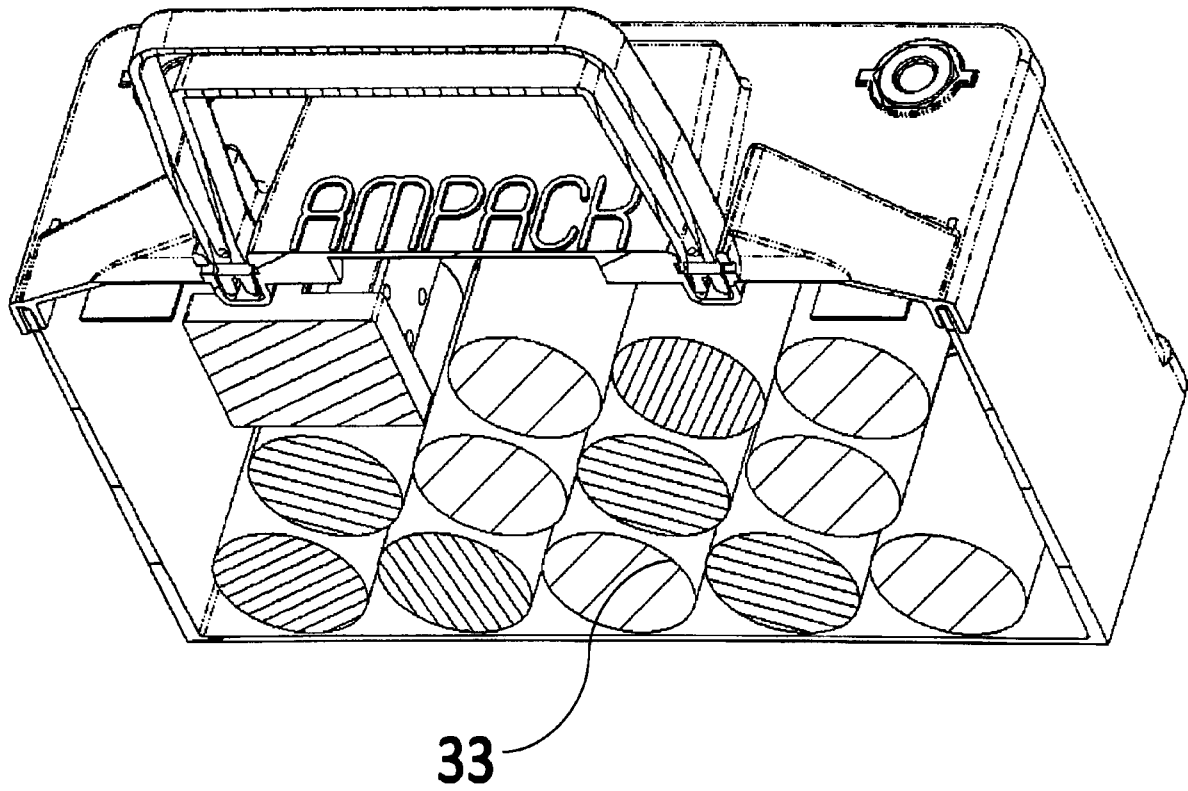
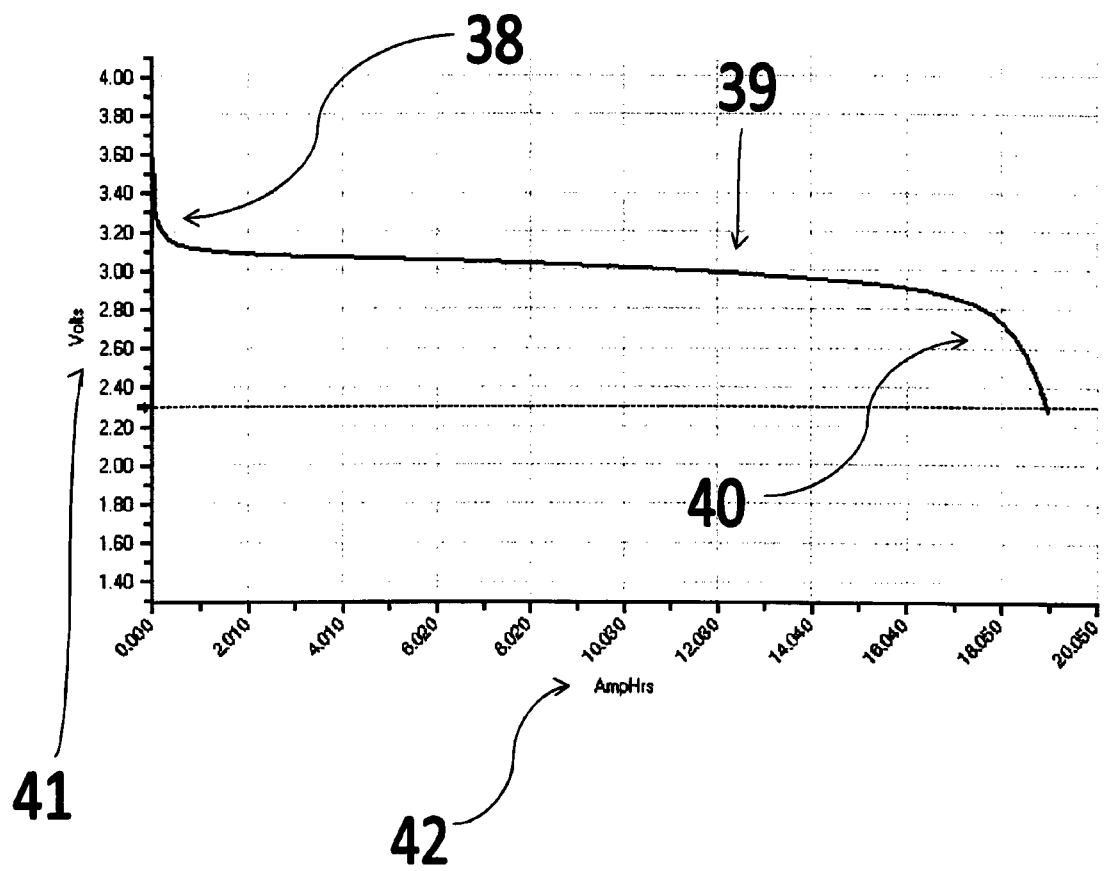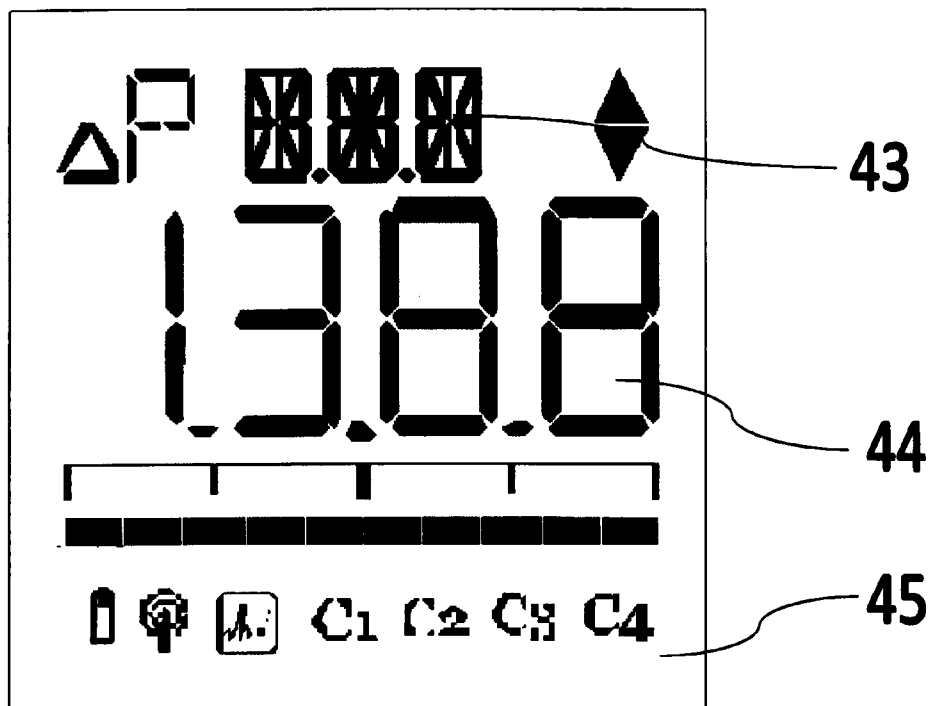Fig. 5

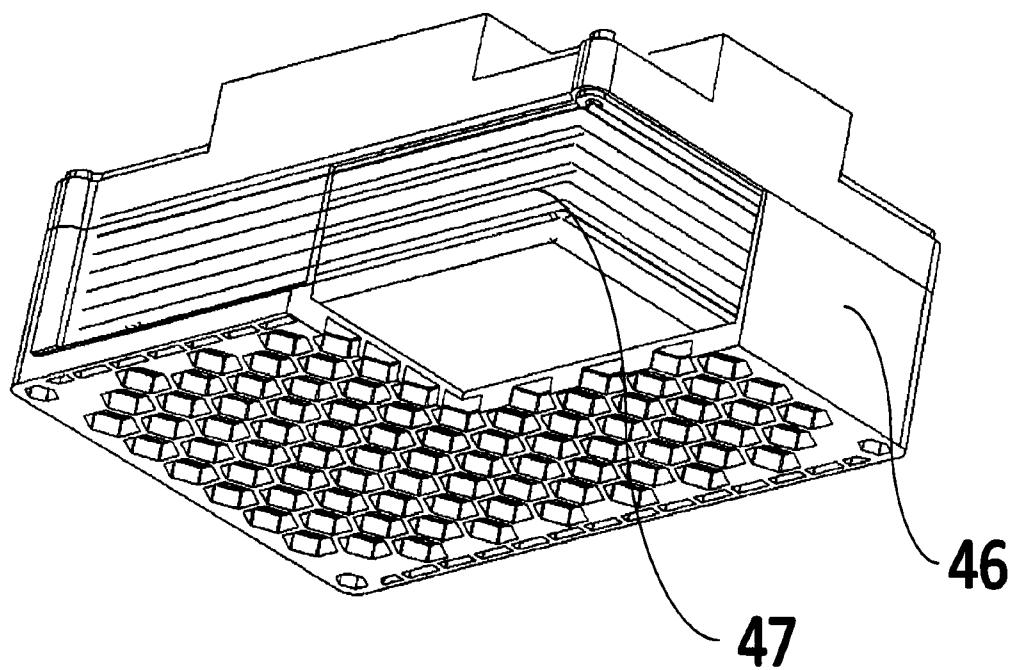Fig. 6
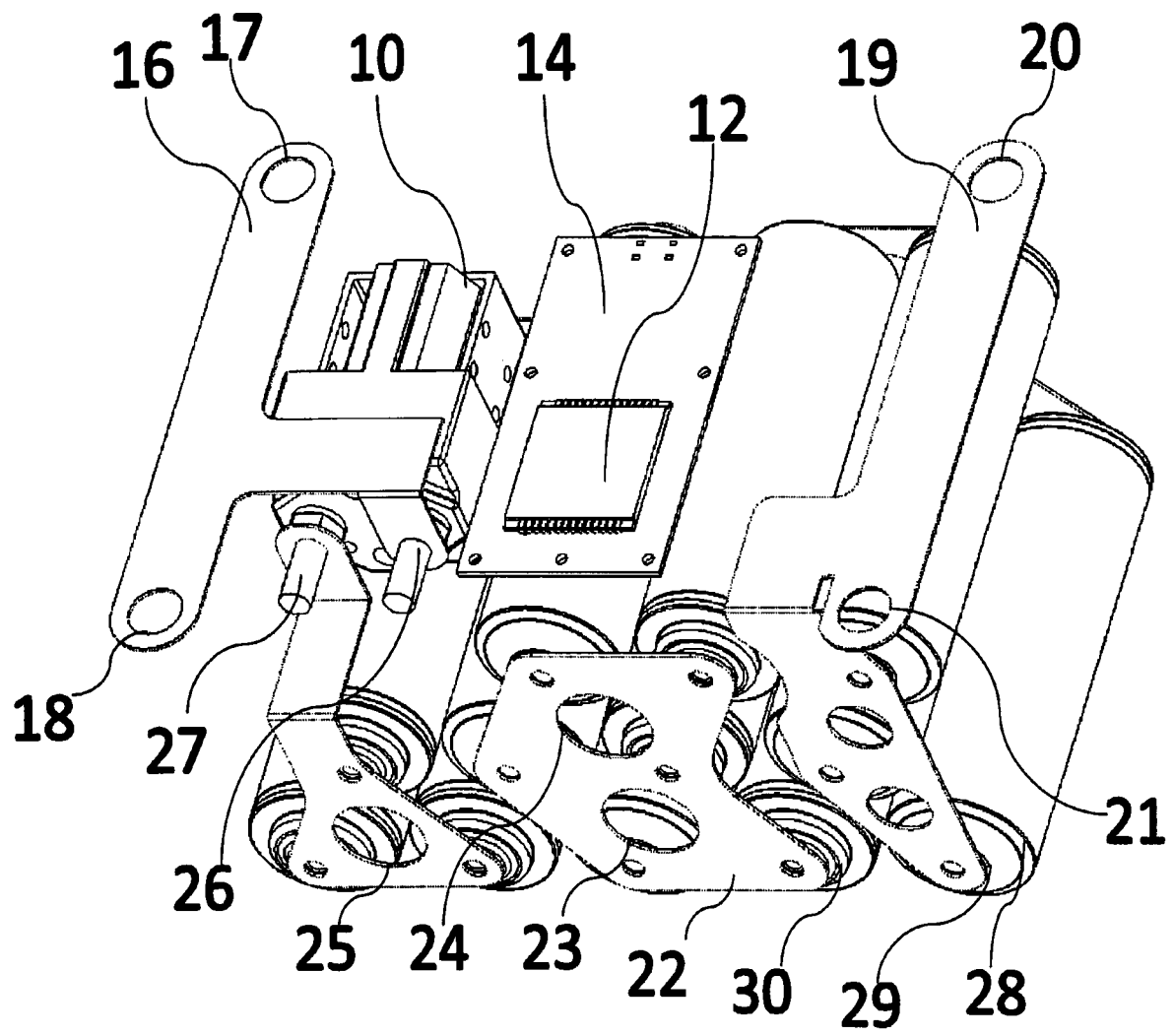
Fig. 7

Fig. 8

Fig. 9

Fig. 10

Fig. 11

Fig. 12

INTERNATIONAL SEARCH REPORT

International application No

PCT/HR2011/000045

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M10/0525 H01M10/50 H01M10/48 B60L11/18
ADD.

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)
H01M B60L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 1 333 521 A2 (SANYO ELECTRIC CO [JP]) 6 August 2003 (2003-08-06)	1-4
A	column 4, paragraph 15 column 7, paragraph 23 column 9, paragraph 31 column 10, paragraph 35 column 11, paragraph 37 column 12, paragraph 39 - paragraph 45 ----- -/--	5-9

[X] Further documents are listed in the continuation of Box C.

[X] 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 application or patent 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

26 September 2012

Date of mailing of the international search report

04/10/2012

Name and mailing address of the ISA/
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Gamez, Agnes

Form PCT/ISA/210 (second sheet) (April 2005)

	International application No
	PCT/HR2011/000045

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2005/218136 AI (KOTANI YASUO [JP] ET AL) 6 October 2005 (2005-10-06) figures 3, 10 page 1, paragraph 8 page 2, paragraph 15 page 2, paragraph 32 - page 3, paragraph 35 page 3, paragraph 41 page 5, paragraph 50 page 5, paragraph 54 - paragraph 55 -----	1-9
Y	US 2008/213652 AI (SCHEUCHER KARL FREDERICK [US]) 4 September 2008 (2008-09-04)	1-4
A	figures 3,8 page 1, paragraph 5 page 3, paragraph 44 - paragraph 45 page 4, paragraph 53 - paragraph 54 page 5, paragraph 57 page 6, paragraph 73 page 7, paragraph 80 -----	5-9
A	US 6 392 388 BI (YOUNG COLIN JEFFREY [US]) 21 May 2002 (2002-05-21) figure 2 column 2, line 22 - column 4, line 49 -----	1-9
A	WO 99/31752 AI (HYDRO QUEBEC [CA] ; MORIN ANDRE [CA] ; ROUILLARD JEAN [CA] ; COTE JEAN PI) 24 June 1999 (1999-06-24) page 2, line 23 - line 29 page 3, line 5 - line 13 page 3, line 25 - page 4, line 11 page 5, line 24 - line 28 page 6, line 25 - page 7, line 3 page 9, line 3 - line 20 -----	1-9

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/HR2011/000045

Patent document cited in search report			Publication date	Patent family member(s)			Publication date
EP	1333521	A2	06-08-2003	CN	1435909	A	13-08-2003
				DE	60305221	T2	01-03-2007
				EP	1333521	A2	06-08-2003
				JP	4020650	B2	12-12-2007
				JP	2003223938	A	08-08-2003
				KR	20030065380	A	06-08-2003
				US	2003162084	AI	28-08-2003
US	2005218136	AI	06-10-2005	JP	4390609	B2	24-12-2009
				JP	2005295668	A	20-10-2005
				US	2005218136	AI	06-10-2005
US	2008213652	AI	04--09-2008	US	2008213652	AI	04-09-2008
				US	2012092018	AI	19-04-2012
US	6392388	BI	21--05-2002	CA	2384545	AI	03-11-2002
				EP	1255341	A2	06-11-2002
				US	6392388	BI	21-05-2002
WO	9931752	AI	24--06-1999	AU	1655799	A	05-07-1999
				CA	2225585	AI	12-06-1999
				EP	1038331	AI	27-09-2000
				JP	4965763	B2	04-07-2012
				JP	2002509342	A	26-03-2002
				WO	9931752	AI	24-06-1999