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(72) Inventeurs/Inventors:
DASGUPTA, SANKAR, CA;
JACOBS, JAMES K., CA;
BHOLA, RAKESH, CA

(73) Propriétaire/Owner:
ELECTROVAYA INC., CA

(74) Agent: RICHES, MCKENZIE & HERBERT LLP

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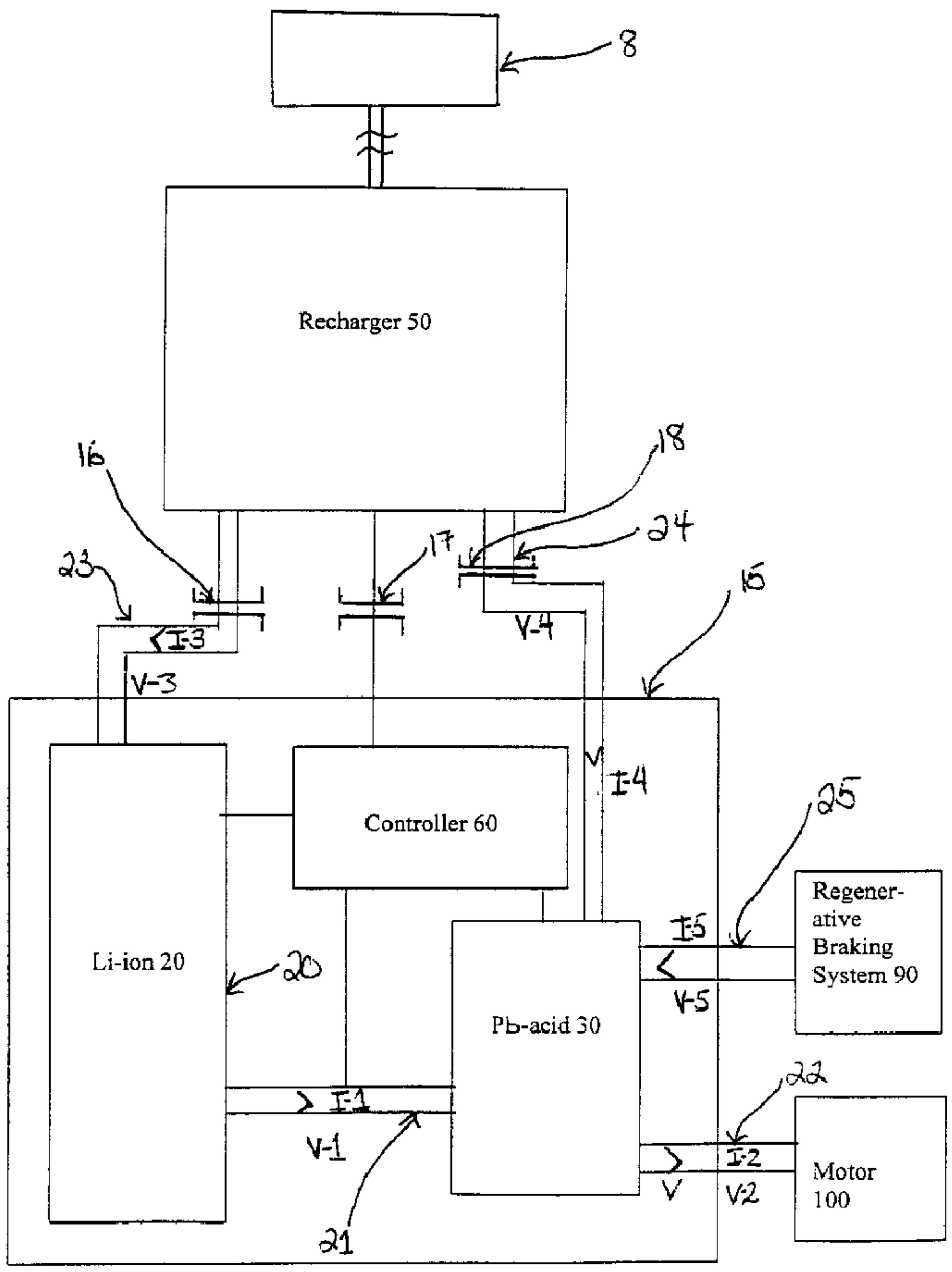
(54) Title: ENERGY STORAGE DEVICE FOR LOADS HAVING VARIABLE POWER RATES



(57) Abrégé/Abstract:
An electrical energy storage device for storing electrical energy and supplying the electrical energy to a driving motor at different power levels is disclosed. The electrical storage device has an energy battery connected to a power battery. The energy battery has

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(57) Abrégé(suite)/Abstract(continued):
a higher energy density than the power battery. However, the power battery can provide electrical power to the electrical motor at different power rates, thereby ensuring that the motor has sufficient power and current when needed. The power battery is continuously recharged by the energy storage battery. In this way, the power battery temporarily stores electrical energy received from the energy battery and provides the electrical energy at the different power rates as required by the motor. The energy storage device can be releasably connected to an external power source in order to recharge both batteries. Both batteries can be recharged independently to optimize the recharging and lifetime characteristics of the batteries.

ABSTRACT

An electrical energy storage device for storing electrical energy and supplying the electrical energy to a driving motor at different power levels is disclosed. The electrical storage device has an energy battery connected to a power battery. The energy battery has a higher energy density than the power battery. However, the power battery can provide electrical power to the electrical motor at different power rates, thereby ensuring that the motor has sufficient power and current when needed. The power battery is continuously recharged by the energy storage battery. In this way, the power battery temporarily stores electrical energy received from the energy battery and provides the electrical energy at the different power rates as required by the motor. The energy storage device can be releasably connected to an external power source in order to recharge both batteries. Both batteries can be recharged independently to optimize the recharging and lifetime characteristics of the batteries.

ENERGY STORAGE DEVICE FOR LOADS HAVING VARIABLE POWER RATES

Field of the Invention

The present invention relates to an apparatus, device and method for storing electrical energy and providing the electrical energy to an electrical load at different power rates. More particularly, the present invention relates to an apparatus, device and method utilizing a hybrid battery to provide variable power rates to an electrical load, such as an electric motor or engine utilized in driving a vehicle.

Background of the Invention

In the past, various manners of storing and providing electrical energy to drive an electrical load, such as an electrical driving motor, have been proposed. For example, different types of batteries, including lead-acid, nickel cadmium (Ni-Cd) and nickel metal hydride (Ni-MH), have been used in the past to drive electric vehicles. However, each type of battery has unique advantages and disadvantages.

For example, lead-acid batteries have the advantage that they can provide a high burst of power when required. Moreover, lead-acid batteries can provide large currents sufficient to accelerate and drive electrical loads, such as electrical motors and engines in vehicles. However, lead-acid batteries suffer from the disadvantage of having low energy density, sometimes expressed or measured as

Watt-hour per liter (W-h/l), meaning that the energy provided per unit volume is low. Likewise, lead-acid batteries have relatively low specific energy, expressed as watt-hour per kilogram (W-h/kg), meaning that a relatively large mass is needed to store a substantial quantity of energy.

By contrast, lithium-based batteries, such as lithium batteries having anodes or negative electrodes of lithium metal or alloy, and non-aqueous rechargeable lithium ion batteries, as disclosed for instance in U.S. Patent 6,159,635, issued to Dasgupta et al., have higher energy density and specific energy characteristics than lead or nickel based electrochemical cells. It should be noted, that some types of non-aqueous rechargeable lithium ion batteries are referred to as polymer lithium batteries, due to being packaged and sealed in polymer layers and having lithium ion conducting polymer electrolytes. On the other hand, lithium based batteries may not be able to provide large bursts of power, in particular, high current densities, on account of the intrinsic high impedance of such lithium based cells. Furthermore, to prevent degradation, lithium based cells require thermal management techniques to maintain the battery at an acceptable temperature, such as -20°C to a maximum of 70°C. Power bursts in lithium ion cells generally generate larger amounts of heat energy, which, if not managed properly, can degrade the battery.

In an electrical vehicle, it is desirable to have an energy storage device which has a high energy density, so that a minimum volume is occupied by the energy storage device, as well as a high specific energy, so that minimum weight is transported along with the vehicle. However, it is also desirable to have an energy storage device which can provide large bursts of power. In particular, a burst of power is generally required to overcome stationary friction and the inertia of a stationary electrically driven vehicle, as well as for acceleration. It is noted that attempts have been made to redesign rechargeable lithium batteries to be able to provide higher currents, but this led to lower specific energies and lower energy densities of such battery devices.

In the past, several different types of energy storage devices have been proposed in an effort to provide a high energy storage device that provide large bursts of power. For example, U.S. Patent 5,780,980 and U.S. Patent 5,808,448, both to Naito, disclose an electric car drive system having a direct current power supply comprising a fuel cell connected to a lead-acid battery. The fuel cell produces a constant output while operational and supplies electrical power to the car when the power rate for the electrical load is low. When the power rate for the electrical load increases, power is supplied by the lead-acid battery, as well as by the fuel cell. Naito also discloses that the fuel cell recharges the lead-acid battery when the charge for the lead-acid battery is below a specified value. However, Naito suffers from the disadvantage that the fluid reactants to operate the fuel cell must be carried in containers on the vehicle. This greatly reduces the specific energy capability of the device. Also, Naito discloses an elaborate electrical circuit to permit supply of energy from the fuel cell and the lead-acid battery.

For much smaller loads, such as in the micro-electronic field, as used in electrochromic eye wear, lithium/thionylchloride and lead-acid hybrid batteries have been proposed. For instance, U.S. Patents 5,900,720 and 5,455,637 to Kallman discloses using a hybrid battery comprising a primary, that is non-rechargeable, lithium/thionyl chloride battery cell and a secondary sealed lead-acid battery to power micro-electronic circuits. The primary and secondary batteries power a load, which in the case of Kallman are low power micro-electronic circuits for electrochromic eye wear. The primary battery also powers a controller which, in turn, can periodically charge the secondary battery. However, Kallman does not disclose that the primary lithium/thionylchloride battery is recharged. Also, the Kallman device is designed to be small with relatively low total energy output, and as such, could nct be utilized for larger loads.

Accordingly, there is a need in the art for an efficient energy storage device having a high energy density and high specific energy for use with large loads having variable power demands. Moreover, while energy density is an important consideration, it is also necessary to consider how the batteries will be housed within the vehicle. In other words, the effective volume of the device including the batteries, meaning the total volume required to house the batteries rather than the volume of the individual cells need to be considered. Yet another consideration should be the charging of the system after the output has dropped below a predetermined level.

Summary of the Invention

Accordingly, it is an object of this invention to at least partially overcome the disadvantages of the prior art. In addition, it is an object of the invention to provide an efficient energy storage device for use in relatively large load situations, such as for an electrical vehicle, and preferably having a high specific energy and energy density, while still being capable of providing large bursts of power in a thermally manageable manner.

Accordingly, in one aspect, the present invention provides a power source for supplying electrical power to a driving motor, said driving motor drawing electrical power at different rates, the power source comprising: a first rechargeable energy battery having a first energy density for storing electrical energy; a second rechargeable power battery having a second energy density, which is less than the first energy density, for storing electrical energy and providing electrical power to the electrical motor at the different rates; battery controller for controlling the continuous recharging of the power battery with electrical energy from the energy battery; and wherein electrical energy stored in the energy battery is supplied to the electrical motor through the power battery and at the different rates.

In another aspect, the present invention provides an energy storage device for storing electrical energy to be delivered to an electrical load, said energy storage device comprising: a first rechargeable battery having a first energy density and electrically connectable to an external power source; a second rechargeable battery having a second energy density, less than the first energy density, said second battery being electrically connected to the first battery and electrically connectable to the load; wherein, during operation, the second battery is connected to the load and supplies electrical energy to the load while the first battery continually recharges the second battery; and wherein the first battery is periodically connected to the external source for recharging as required.

One advantage of the present invention is that the energy battery can be a conventional lead-acid battery which is commonly used in vehicles. In this way, the lead-acid battery can provide sufficient bursts of power, and at sufficient current, to drive an electrical load having variable power demands, such as an electrical motor in a vehicle. However, the energy battery is preferably a lithium based cell or battery which will have a high energy density and high specific density. Accordingly, by having the energy battery continuously charging the power battery, the power battery will be maintained close to its top charge level, which should improve the life span of the power battery. Furthermore, by having the power battery near its top charge level, the energy generating capability of the power battery can be maintained and energy can be provided to the load at variable rates, thereby more readily satisfying the power demands of the load. However, as the major portion of the energy providing system of the present invention resides in the energy battery having high energy density and specific energy, relatively little extra volume and weight is added to the vehicle.

In one of the further embodiments, the lithium battery is a polymer lithium battery which comprises a non-aqueous, rechargeable lithium ion battery encased or wrapped and sealed in plastic covers, having solid polymer and organic liquid, lithium ion conducting electrolytes. Such polymer lithium ion batteries can be produced in specific shapes or forms, and molded into an appropriate shape which can occupy a space otherwise left vacant within the vehicle. In this manner, the effective volume of the energy storage device can be reduced, by ensuring that little space is wasted around the energy battery.

A further advantage of the present invention is that both batteries in the energy storage device can be recharged. As stated above, the power battery is continuously being recharged by the energy battery. However, when required, the energy battery can also be recharged by being connected to the external source. In this way, the energy storage device can be easily regenerated for continued use and does not require the addition of fluid reactants or replacement of the batteries. Furthermore, in a preferred embodiment, the power battery can be recharged from the external source when the energy battery is being recharged to improve recharging efficiency.

A still further advantage of the present invention is that, because a lead-acid battery is utilized, existing energy recovery techniques can be used. In particular, the energy generated during breaking can be harnessed for replenishing the energy level of the lead-acid battery when the vehicle is brought to a stop. This procedure is often referred to as regenerative breaking.

Further aspects of the invention will become apparent upon reading the following detailed description and drawings which illustrate the invention and preferred embodiments of the invention.

Brief Description of the Drawings

In the drawings, which illustrate embodiments of the invention:

Figure 1 shows an electrical system comprising an electrical storage device according to one embodiment of the present invention;

Figure 2A shows a graph plotting the discharge of the lead-acid power battery against time; and

Figure 2B shows a graph plotting the discharge of the non-aqueous rechargeable lithium energy battery pack against time.

Detailed Description of the Preferred Embodiments of the Invention

As described herein above, in one preferred embodiment of the invention, an energy storage device comprising an energy battery connected to a power battery is provided. The energy battery has a high energy density and a high specific energy so that it can easily and efficiently store a large amount of energy. The energy battery is also rechargeable from external sources. The energy battery is capable of providing a relatively steady voltage, but may have a relatively low current level. In other words, the energy battery performs the principal function of efficiently storing a large amount of energy, without having a great deal of mass or occupying a great deal of space, but may not be able to provide high or variable current levels or variable power output.

By contrast, the power battery is designed to have variable power output and to be capable of providing short high current pulses. For example, the power battery will be capable of providing high bursts of power at short high current pulses as required by the electrical load, such as the power requirements of an electrical motor or engine utilized in driving a vehicle. However, the power battery may not have a high energy density or high specific energy. In particular, the power battery is rechargeable and can be recharged by the energy battery and optionally by an external power source.

In operation, the power battery meets the variable current and power demands of an electrical load while being continuously recharged by the energy battery. In this way, the electrical storage device provides a hybrid battery having high energy density and high specific energy because of the energy battery, while still providing variable power rates, as well as high bursts of current as required by electrical loads because of the power battery.

The electrical storage device also comprises a controller for coordinating, charging and working of the energy battery, as well as the power battery. In order to recharge the power battery, the energy battery will have a potential which is higher than the potential or output voltage of the power battery. The controller also coordinates the charging and working of the energy battery and the power battery in order to preserve longevity of both, such as by preventing overcharging of the power battery and overheating of the energy battery. The controller also incorporates an instrument panel indicative of the voltage and current flow from the energy battery to the power battery, as well as from the power battery to the electrical load. The controller also indicates, such as through a warning or alarm device, the approach of the lowest permissible potential level of the energy battery so that recharging of the energy battery can occur. The energy battery, and optionally the power battery, can be recharged from an external source. The controller may also coordinate the recharging of the energy battery, and also the power battery, from the external source.

Figure 1 illustrates an electrical system, shown generally by reference numeral 10, utilizing an energy storage device 15 according to one embodiment of the present invention. As illustrated in Figure 1, the system 10 comprises the energy storage device 15 connected to a load, shown as motor 100 in Figure 1.

As also illustrated in Figure 1, the energy storage device 15 comprises two rechargeable batteries 20, 30. The first battery is an energy battery 20 and the second battery is a power battery 30.

As also illustrated in Figure 1, the energy battery 20 is connected to the power battery 30 through a first connection 21. The power battery 30 is in turn connected to an electrical load, which in this embodiment is an electrical motor 100, through a second connection 22. During operation, the power battery 30 supplies electrical energy through the second connection 22 to drive motor 100, and, the energy battery 20 supplies electrical energy through the first connection 21 to continuously recharge the power battery 30.

The power battery 30 provides power to the motor 100 through the second connection 22 at a second voltage V-2 and a second current I-2. It is understood that the second voltage V-2 and the second current I-2 will vary to permit the power battery 30 to supply bursts of current and electrical power at different rates depending on the requirements of the motor 100. Accordingly, the power battery 30 is selected and designed to satisfy the power rate, as well as current I-2 and voltage V-2 requirements of the electrical load.

In the embodiment where the electrical load is a motor 100, the motor 100 may be, for example, a 96 volt motor operating at between 75 and 500 amps. In this case, it is convenient and preferable that the power battery 30 has at least a 5 kilovolt hour capacity or higher. The lead-acid battery 30 is preferred so that high bursts of power at short high current pulses can be provided to the motor 100.

High power batteries, such as nickel metal or nickel alloy hybrid bearing batteries or nickel cadmium batteries, may also be used instead of lead-acid batteries.

By contrast, the energy battery 20 is designed to store a large amount of electrical energy. As such, the energy battery 20 preferably has an energy density which is relatively high, preferably higher than the energy density of the power battery 30. In this way, the energy battery 20 can efficiently store large amounts of electrical energy. Furthermore, because the power battery 30 has been selected to satisfy the variable power requirements of the motor 100, the energy battery 20 can be selected without concern to the power requirements of the motor 100. Rather, the principle concern of the energy battery 20 is that the energy battery 20 is capable of efficiently storing and providing sustained high energy at desirable levels, and at appropriate voltages, to continuously recharge the power battery 30 so that the power generating capability of the power battery 30 can be maintained.

In the preferred embodiment, the energy battery 20 is a lithium battery, but any other rechargeable battery capable of this function can be used. More preferably, a non-aqueous rechargeable lithium ion battery is utilized as the energy battery 20.

In another preferred embodiment, the non-aqueous rechargeable lithium ion battery can be a polymer lithium ion battery which is moldable into various shapes. In this way, the effective volume of the energy storage device 15 can be decreased by molding the polymer lithium battery to occupy any allotted space. Furthermore, the polymer lithium ion battery may be molded to occupy otherwise unused space, such as the space between other components or body parts in a vehicle. In yet another preferred embodiment, the polymer lithium ion battery may be molded to act as the casing or housing of the device 15 as a whole, thereby further decreasing the effective volume of the energy storage device 15.

The first current I-1 and the first voltage V-1 of the first connection 21 are selected so as to provide optimum life for the energy battery 20 and the power battery 30. For instance, the current I-1 is preferably selected so as to minimize the heat generated by the energy battery 20. The current I-1 is also preferably selected to provide sustained high energy at desirable levels to continuously recharge the power battery 30 and thereby maintain the power generating capability of the power battery 30, as well as satisfy the long term demands of the energy battery 20 and the power battery 30. Accordingly, for longevity, it is preferred that the first voltage V-1 and the first current I-1 be selected such that the power being transferred from the energy battery 20 to the power battery 30 is sufficient to satisfy the energy demands placed on the power battery 30 by the motor 100, but also be relatively low so that temperature effects of the energy battery 20 will be decreased.

Furthermore, in the case where the power battery 30 is a lead-acid battery 30, longevity can be obtained by keeping the lead-acid battery 30 near its top charge level. This can be accomplished by having continuous flow of the first current I-1 to the power battery 30 so that the power battery 30 is being continuously recharged by the energy battery 20. By having the first current I-1 relatively low, the energy transfer rate will also be correspondingly lower, but this can be accounted for by continuously recharging the power battery 30 with electrical energy from the energy battery 20.

In addition, in order to recharge the power battery 30, the first voltage V-1 should be higher than the voltage of the energy battery 20. In the case where the power battery 30 is a lead-acid battery, the first voltage V-1 from the non-aqueous lithium ion battery will be fairly high, and can be designed to be higher than the output voltage of the lead-acid battery, to thereby provide recharging of the lead-acid battery.

In order to control the flow of current and electrical energy between the batteries 20, 30, the electrical energy storage device 15 also comprises a controller 60. The controller 60 is connected to the batteries 20, 30, as well as the first connection 21, to regulate the flow of power from the energy battery 20 to the power battery 30.

As also illustrated in Figure 1, a regenerative braking system 90 is connected through connection 25 to the power battery 30. While the vehicle is braking, the regenerative braking system 90 converts the kinetic energy from the moving vehicle into electrical energy, as is known in the art. The regenerative braking system 90 delivers this recaptured electrical energy through the fifth connection 25 at the fifth current I-5 and the fifth voltage V-5.

Figure 1 also illustrates a recharger 50 used to recharge the storage device 15 from external power sources 8. The recharger 50 is connectable to the energy storage device 15 through connectors 16, 17, 18.

In a preferred embodiment, the energy storage device 15 is used to power an electrical motor 100 in a vehicle (not shown). The device 15 would be contained within the vehicle. The energy battery 20 would recharge the power battery 30 continuously, even when the vehicle is moving.

As these external power sources are generally fixed, regeneration of the device 15 will generally occur when the vehicle is stationary. In this case, the recharger 50 could be located at a fixed location and would provide electrical power for regeneration of the energy storage device 15 from external power sources 8, such as hydro mains.

Connectors 16 and 18 supply energy from the recharger 50 separately to the energy battery 20 and the power battery 30. As illustrated in Figure 1, the recharger 50 will deliver power to the non-aqueous lithium ion battery 20 through the third connection 23, formed by connector 16. The third connection 23 will provide power at a third voltage V-3 and third current I-3 selected to satisfy the recharging characteristics of the energy battery 20. Similarly, the recharger 50 will deliver power to the power battery 30 through the fourth connection 24, formed by the connector 18. The fourth connection 24 will provide power at a fourth voltage V-4 and fourth current I-4 selected to satisfy the recharging characteristics of the power battery 30. In this way, both the energy battery 20 and the power battery 30 can be recharged simultaneously by the recharger 50.

The controller 60 may be connected to the recharger 50 through connection 17 to permit the controller 60 to control the voltages V-3 and V-4 and the currents I-3 and I-4. The controller 60 controls the voltages V-3 and V-4 and the currents I-3 and I-4 to ensure that the batteries 20, 30 are recharged efficiently and without damage.

The energy battery 20 will likely require more time to recharge because it has a larger energy storing and operating capacity, providing the result that the controller 60 will cease recharging the power battery 30 first. It is also understood that it is not necessary to have the recharger 50 recharge the power battery 30 at least because the power battery 30 can be recharged by the energy battery 20. In other words, in one embodiment, only the energy battery 20 is recharged by the external power source 8 through the recharger 50, and the energy battery 20 then recharges the power battery 30. In this embodiment, the connector 18 and the fourth connection 24, as well as the associated control circuitry for the voltage V-4 and current I-4 of the fourth connection 24, are not required, thereby decreasing the overall cost. However, having the connector 18 and the fourth connection 24 directly from the recharger 50 to the power battery 30 is generally preferred as it permits both batteries 20, 30 to be recharged simultaneously, and therefore decreases the overall charging time of the device 15.

Figure 2A shows a graph plotting the discharge over time of the power battery 30. As shown in Figure 2, the capacity of the power battery 30, which in this preferred embodiment is a lead-acid battery 30, will decrease in steps corresponding to sudden bursts of power 210 being required by the motor 100. The sudden bursts of power 210 will be required, for instance, to overcome inertia, stationary friction when the vehicle is stationary, and also for acceleration. However, once these initial bursts 210 have occurred, the capacity will begin to increase, even through the power battery 30 is supplying power to the motor 100, because the lithium battery 20 is continuously recharging the lead-acid battery 30. In other words, after an initial burst 210 has occurred, and the motor 100 is operating at a steady state moving the vehicle at a fairly constant speed, the non-aqueous lithium battery 20 should be recharging the power battery 30 at a level greater than the power battery 30 supplies energy to the motor 100. In this way, the capacity of the power battery 30 may increase even as it supplies energy to the motor 100 at steady state.

At the point labelled with the letter "R" in Figure 2A, the device 15, including the lead-acid battery 30, will be recharged from a fixed external source 8 by means of the recharger 50. During recharging, shown in Figure 2A by reference numeral 250, the lead-acid battery 30 will be recharged through the recharger 50 from a fixed external source 8 so that its capacity will increase.

In between recharging from a fixed external source 8, the power battery 30 can be continuously recharged by the non-aqueous lithium ion energy battery 20. This continuous recharging increases the capacity of the lead-acid battery 30 to temporary plateaus, illustrated by reference numeral 220 in Figure 2A. These plateaus 220 represent the lead-acid battery 30 powering the motor 100 at low power levels while being continuously recharged by the lithium ion battery 20. In other words, these plateaus 220 represent a steady state level where energy is essentially flowing from the energy battery 20 through the power battery 30 and into the motor 100. While not shown, these plateaus 220 could also be sloped upwards towards the full or 100% capacity level of the lead-acid battery 30. This would illustrate that the energy battery 20 is supplying more than the required power levels to power the motor 100 and is also recharging the power battery 30 at a rate greater than the power rate of the motor 100 at that particular moment in time.

Figure 2B illustrates the capacity of the lithium ion energy battery 20 over time. As illustrated in Figure 2B, the capacity of the energy battery 20 will decrease over time fairly steadily. While the capacity of the energy battery 20 may have dips 212, corresponding to the sudden power bursts 210 of the power battery 30, these would not be as severe as the dips in the capacity of the power battery 30, at least because the energy battery 20 is not designed to transfer energy at a high rate. Likewise, as illustrated in Figure 2B, the energy battery 20 will have less steep decreases in power corresponding to the plateaus 220 in the power battery 30. This represents the power battery 30 supplying electrical energy at lower power levels to the motor 100.

It is clear that, over time, the capacity of the lead-acid battery 30 will decrease, as shown in Figure 2B. At the point labelled by the letter "R", the device 15, including the energy battery 20, will be recharged. Recharging of the energy battery 20 is shown in Figure 2B by reference numeral 251. As shown in Figure 2B, during recharging the capacity of the energy battery 20 will increase gradually to near or at full capacity.

The device 15 will generally be recharged when the capacity of the energy battery 20 falls below a threshold. While the capacity of the power battery 30 may be shown on the instrument and/or trigger an alarm, the capacity of the energy battery 30 will be the principal factor in determining when the device 15 must be recharged. The device 15 may comprise an alarm and/or instrument panel (not shown) to indicate when the capacity of the energy battery 20 is approaching or is at this threshold.

Accordingly, using the energy storage device 15 as described above, energy can be provided from a high energy density energy battery 20 to a lower energy density power battery 30 and then onto an electrical load, which is the motor 100. In this way, the lower energy density power battery 30 essentially temporarily stores energy from the energy battery 20 to provide the energy at the rates required by the load 100. The high energy battery 30 can efficiently store the electrical energy for the vehicle.

It is understood that while the present invention has been described in terms of the preferred embodiment where the energy battery 20 is a non-aqueous lithium ion battery, the energy battery 20 is not restricted to this type of battery. Rather, any type of battery having an energy density greater than the energy density of the power battery, such as for example a sodium-sulfur battery, or chemical equivalent, could be used. In one of the preferred embodiments, the energy battery 20 comprises a polymer lithium ion battery which can be molded to various shapes, thereby decreasing the effective volume of the energy storage device 15.

Likewise, while the present invention has been described in terms of a power battery 30 comprising a lead-acid battery 30, the present invention is not limited to this. Rather, any type of power battery 30 which can be recharged by an energy battery 20, such as a lithium battery, and provide the electrical energy at different rates as required by the load 100 can be utilized.

It is understood that the terms "cells" and "batteries" have been used interchangeably herein, even though a battery has a general meaning to be more than one cell. This reflects that both the energy battery 20 and the power battery 30 may be batteries or cells.

It will be understood that, although various features of the invention have been described with respect to one or another of the embodiments of the invention, the various features and embodiments of the invention may be combined or used in conjunction with other features and embodiments of the invention as described and illustrated herein.

Although this disclosure has described and illustrated certain preferred embodiments of the invention, it is to be understood that the invention is not restricted to these particular embodiments. Rather, the invention includes all embodiments which are functional, electrical or mechanical equivalents of the specific embodiments and features that have been described and illustrated herein.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A rechargeable battery power supply system comprising:

a rechargeable energy battery having an energy battery energy density and an energy battery voltage;

a rechargeable power battery having a power battery energy density and a power battery voltage, the power battery energy density being less than the energy battery energy density, and the energy battery voltage being greater than the power battery voltage;

a load structured to be driven by electrical energy;

first power supply circuitry structured and located to electrically connect the rechargeable power battery to the load so that the rechargeable power battery can supply electrical energy to the load through the first power supply circuitry; and

second power supply circuitry structured and located to electrically connect the rechargeable power battery to the rechargeable energy battery so that the rechargeable energy battery can supply electrical energy to the rechargeable power battery through the second power supply circuitry.

2. The system of claim 1 wherein the second power supply circuitry comprises a controller structured to control the flow of electrical energy between the rechargeable power battery and the rechargeable energy battery.

3. The system of claim 1 wherein the rechargeable energy battery is non-aqueous.

4. The systems of claim 3 wherein the rechargeable energy battery is a lithium ion battery.

5. The system of claim 1 wherein the rechargeable power battery is a lead-acid battery.

6. A vehicle where the power used to drive the vehicle into motion comes at least partially from batteries, the vehicle comprising:

a vehicle body;

an electric motor, in the vehicle body, structured to be driven by electrical energy and further structured to drive the vehicle into motion when the motor is driven by received electrical energy;

a rechargeable energy battery having an energy battery energy density and an energy battery voltage;

a rechargeable power battery having a power battery energy density and a power battery voltage, the power battery energy density being less than the energy battery energy density, and the energy battery voltage being greater than the power battery voltage;

first power supply circuitry structured and located to electrically connect the rechargeable power battery to the electric motor so that the rechargeable power battery can supply electrical energy to the electric motor through the first power supply circuitry; and

second power supply circuitry structured and located to electrically connect the rechargeable power battery to the rechargeable energy battery so that the rechargeable energy battery can supply electrical energy to the rechargeable power battery through the second power supply circuitry.

7. The vehicle of claim 6 wherein the second power supply circuitry comprises a controller structured to control the flow of electrical energy between the rechargeable power battery and the rechargeable energy battery.

8. The vehicle of claim 6 wherein the rechargeable energy battery is non-aqueous.

9. The vehicle of claim 8 wherein the rechargeable energy battery is a lithium ion battery.

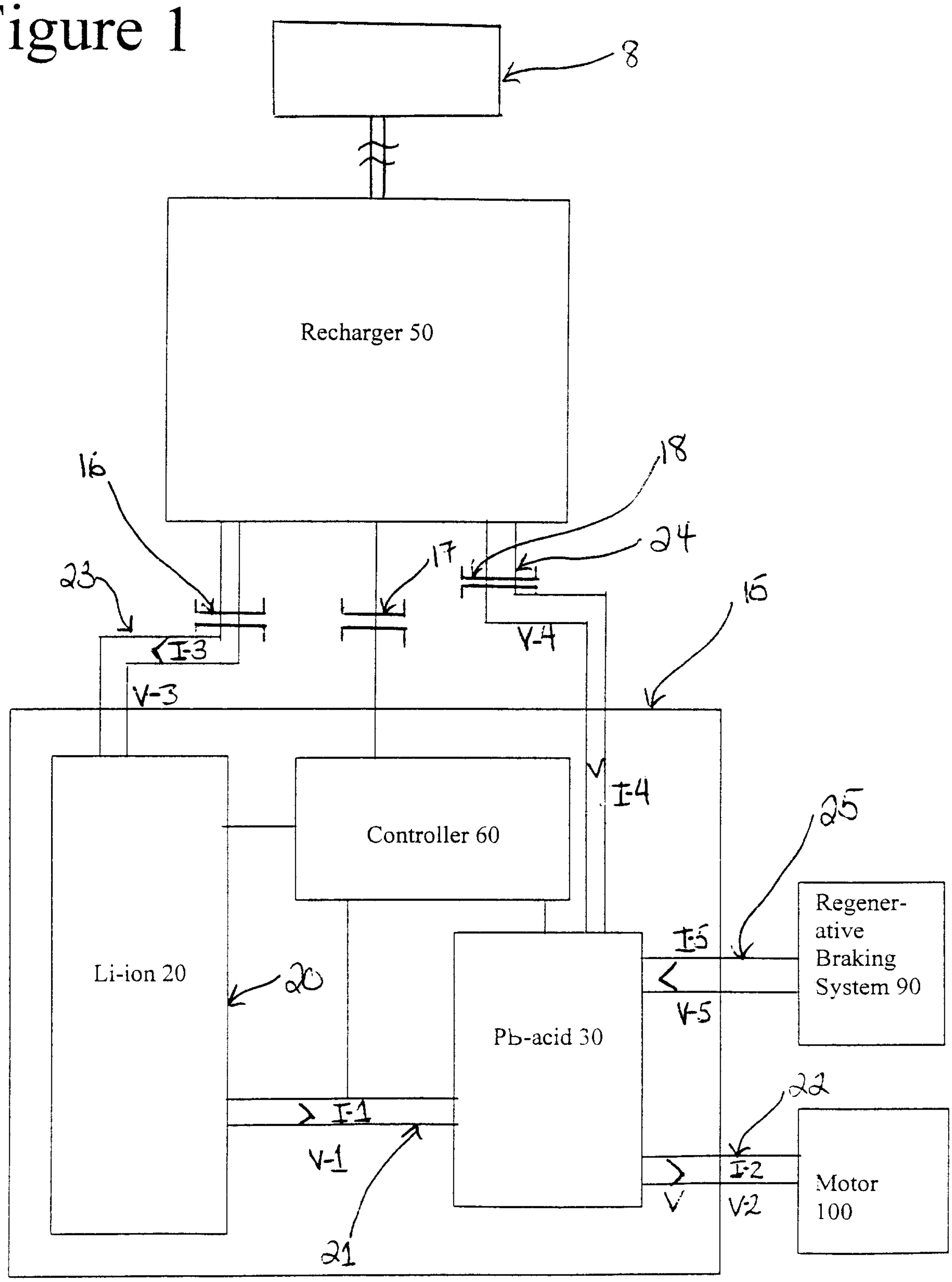
10. The vehicle of claim 6 wherein the rechargeable power battery is a lead-acid battery.

11. The vehicle of claim 6 further comprising:

a regenerative braking system structured and located to supply electrical energy captured when the vehicle brakes; and

third power supply circuitry structured and located to electrically connect the regenerative braking system to the rechargeable power battery so that the regenerative braking system supplies electrical energy to the rechargeable power battery through the third power supply circuitry when the vehicle brakes.

Figure 1


8
Recharger 50
16
18
17
24
23
I-3
V-3
V-4
15
I-4
Controller 60
25
Regener-
ative
Braking
System 90
I-5
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Pb-acid 30
I-1
V-1
22
I-2
V-2
Motor
100
21

Figure 2A

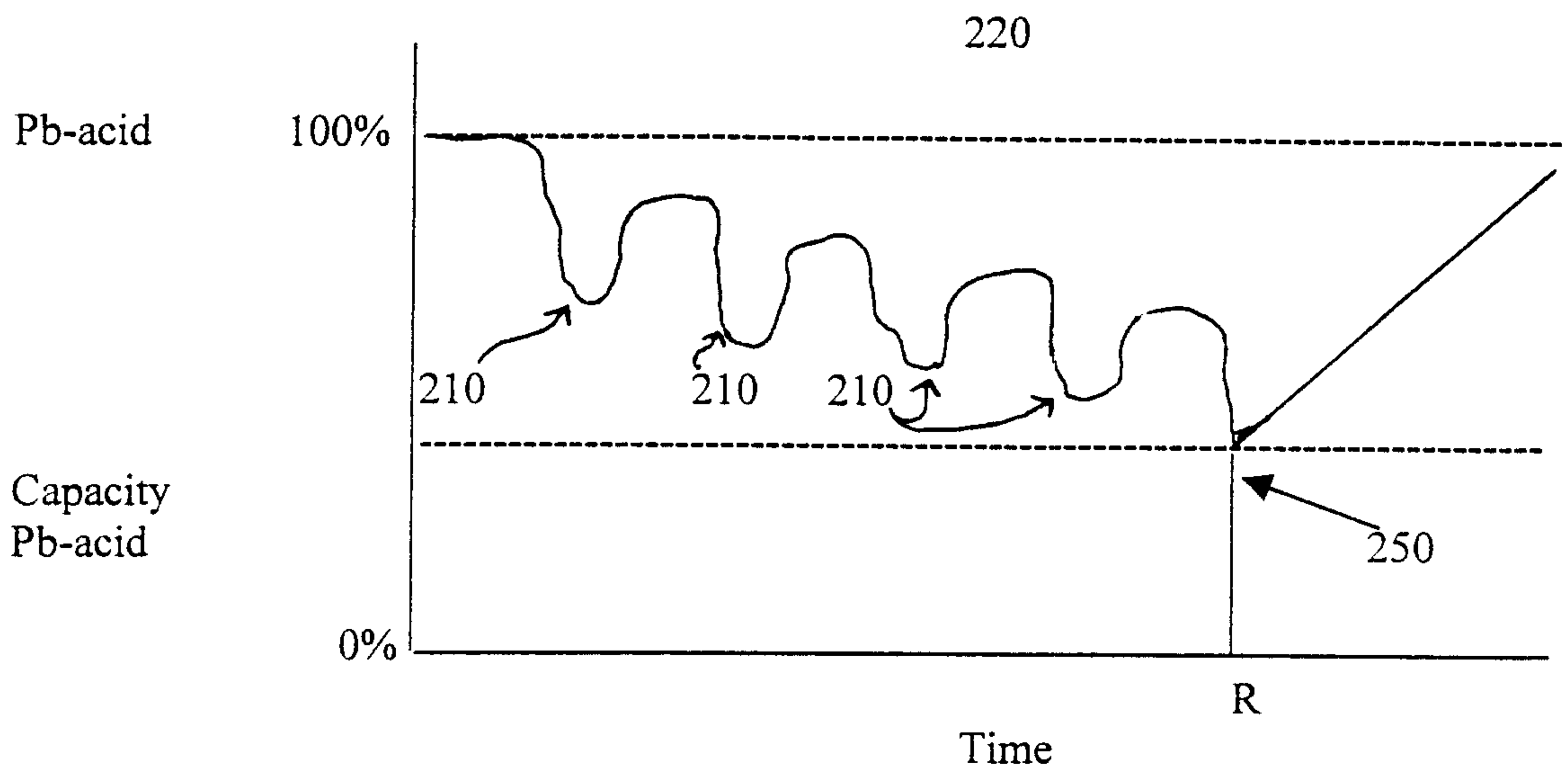
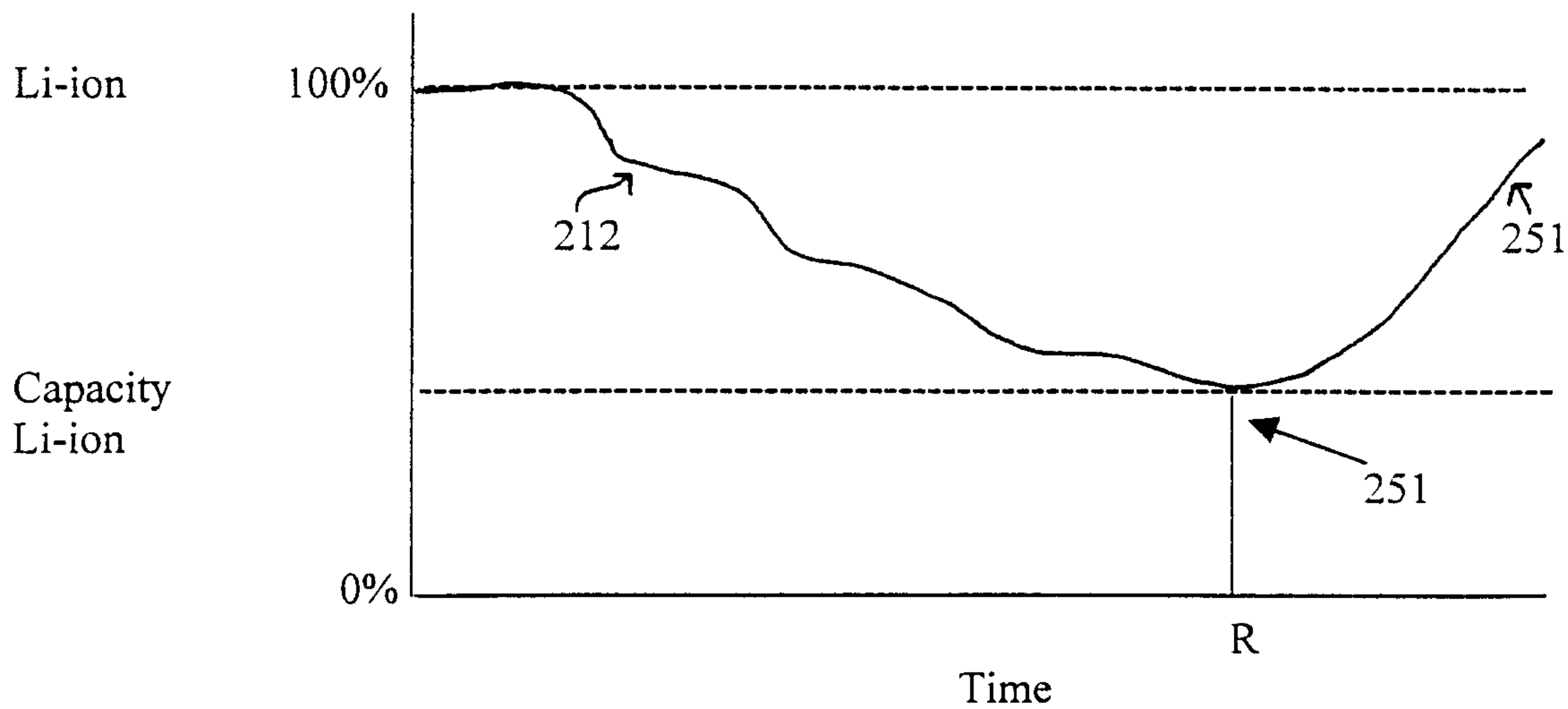
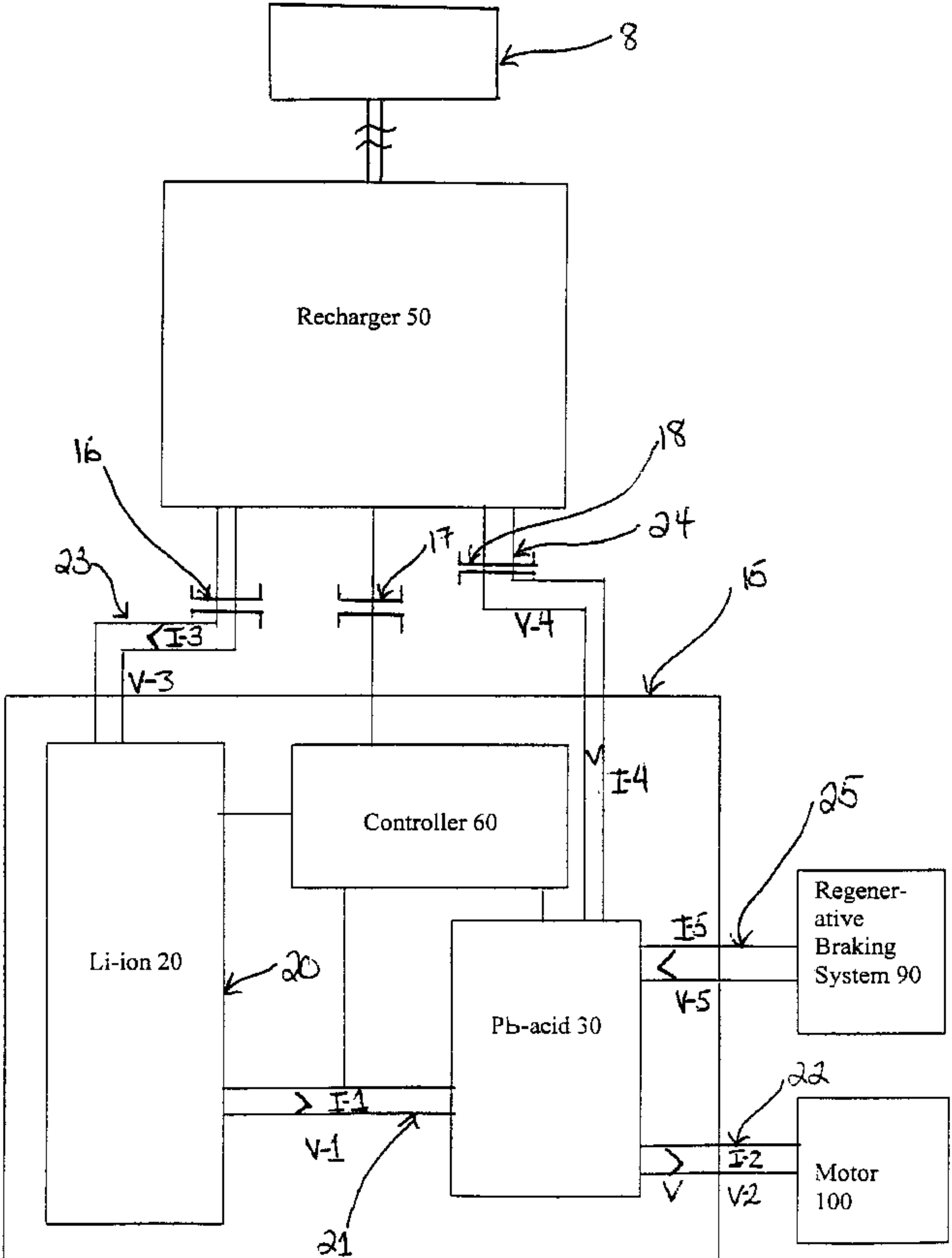


Figure 2B





8
Recharger 50
16
18
17
24
23
15
I-3
V-3
V-4
I-4
Controller 60
25
Regener-
ative
Braking
System 90
I-5
V-5
Li-ion 20
20
Pb-acid 30
I-1
V-1
22
I-2
V
V-2
Motor
100
21