# Installation, Commissioning & Operating Instructions

## Renewable Energy Storage Applications

**RE Tubular OPzS Flooded 2V, 6V or 12V Lead Acid Cells & Blocks**

CE Markings By:....................................................Date:........................./......................../.........................

InstallationBy: .......................................................Date:........................./......................../.........................

Commissioning By:.................................................Date:........................./......................../.........................

Number of Cells/Blocks: ..........................................Type: ....................................................................................

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INNOVATIVE POWER SOLUTIONS

# Safety Instructions

Read instructions carefully and place them close to the battery.

Use protective glasses, gloves and clothing when working on batteries. Always make safe working practices a priority.

No Smoking!

Do not expose batteries to flames, or sparks, as it may cause an explosion.

Clothing contaminated by acid should be washed in water.

Risk of explosion and fire.
CAUTION: Battery terminals and connector are always under voltage.
Do not place tools or other metal objects on the battery. Avoid short circuits!

Electrolyte is highly corrosive.

Batteries and cells are heavy.
Ensure secure installation! Use only suitable handling equipment and lifting gear.

Dangerous Voltage!

Batteries with this symbol can be recycled.

Do not mix with other industrial or household waste. Contact your servicing Discover® dealer for proper battery return and recycling!

# Definitions

- **Ampacity** - *The allowable current-carrying capacity of a conductor measured in amps. Ampacity is the current, in Amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.*
- **Battery Capacity -** *The power a battery can deliver from full charge at standard temperature, and at a specified (usually C10) discharge rate.*
- **Circuit Breaker**–*A**circuit breaker**is an automatically operatedelectrical switchdesigned to protect anelectrical circuitfrom damage caused by overload or shortcircuit. Its basic function is to detect a fault condition and interrupt current flow. Unlike a fuse which operates once and then must be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation.*
- **DOD** – *Depth of Discharge or how deeply the battery has been dis-charged. Like the fuel gauge of your car, DOD is the measure of how much fuel you have used.*
- **I10** – *The constant current (I) discharge rate that can be maintain for 10 hours (10).*
- **MDDOD** – *Maximum Daily Depth of Discharge allowable*
- **MDOD** – *Maximum allowable Depth of Discharge*
- **OCV -** *Open Circuit Voltage:The voltage across the cell/block or battery terminals with no load applied.The maximum possible voltage across a PV array, module, or cell with no load.*
- **SOC** – *State of Charge or how much energy is still available to be discharged. Like the fuel gauge of your car, SOC is the measure of how much gas you have left.*
- **V -** *The unit of measure for voltage. Voltage is the electrical pressure which forces the current to flow in a conductor such as a wire.*
- **VPC** – *Volts per Cel. The voltage of each individual cell, each cell in a block or each cell in a battery. The system voltage of your battery is the sum of the individual volts per cell.*
- **100AH $C_{10}$**- *Battery has a capacity (C)of 100 amp hours(AH) when rated at the 10 hour ($C_{10}$) rate.*
- **.3 x I10** – *30% of the I10 constant current discharge rate.*

# 1.0 Delivery and Storage

## 1.1 Receiving Inspection

- Inspect for missing components.
- Check against the shipping/packing documents.
- Inspect each package or pallet for integrity and electrolyte leakage.
- Record receipt date and inspection data results, and notify your servicing dealer of any damage. Take photographs if necessary.

## 1.2 Storage

- Store the battery in a dry, clean, ventilated, cool and frost-free location.
- Do not expose the cells to direct sunlight as damage to the container and cover may occur.
- Do not stack pallets on top of each other. DO NOT store unpacked cells/blocks on sharp-edged supports. Storage on a pallet and wrapped in plastic material (shrink wrap) is permitted except in rooms where the temperature fluctuates significantly, or when high relative humidity can cause condensation under the plastic. With time this condensation can cause a whitish hydration on the terminals and current leakage leading to high self-discharge.
- Protect the batteries from any risk of electric shock from short-circuiting poles/terminals with conductive objects or from the building up of conductive dust.
- Maintain the same storage conditions for all batteries within the same batch. Batteries are normally supplied charged. Depending upon storage conditions, storage time may be limited. In order to prevent batteries from becoming over discharged during storage do not store them for more than 3 months at 20°C/68°F, 2 months at 25°C/80°F, or 1 month at 40°C/104°F before performing a re-fresh charge. Failure to observe these conditions may result in significantly reduced capacity and service life.
- Record dates and conditions for all charges during storage.

## 1.3 Unpacking and Handling

- Never lift cells by the terminal posts. Lifting cells heavier than 25 kg/55 lb should be made with lifting belts available for order from Discover® or your servicing dealer.
- Never drag or roll the battery!
- The batteries are fully charged before shipment. Do not short circuit.
- Check for evidence of leakage. All cells or blocks with visible defects should be rejected.

# 2.0 Installation and Commissioning Charge

## 2.1 Installation and Battery Room Design

- All electrical protective measures, devices, and the accommodation and ventilation of the battery installation area must be in accordance with all local rules and governmental regulations.
- The battery should be installed in a clean and dry area and protected against dropped items and dirt.
- Avoid placing the battery in a hot place or in direct sunlight.
- The location or arrangement of cells should result in no greater temperature difference than 3°C/5°F between cells or blocks within a connected string at any given time.
- Avoid conditions that result in spot heating or cooling, as temperature variations will cause electrical imbalances in the battery. For better cooling and temperature management ensure the installation allows for adequate air flow around each cell or block. Keep 10mm/0.5in distance between cells or blocks.
- The layout of the battery room or installation area must allow for easy access to the batteries. The recommended minimum distance between battery rows is 1.5 times the depth of the row.
- Racks or cabinets shall be located 100mm/4in from the wall.
- Be sure to provide adequate space and lighting for inspection, maintenance, testing, and cell/block replacement. Space should also be provided to allow the operation of lifting equipment and for taking measurements (cell voltage and temperature) during service.

## 2.2 Racks and Mechanical Stability

- Approved and insulated battery racks are recommended for proper installation. Calculations should be performed to ensure that floor loading capabilities are not exceeded. Seismic forces should also be considered. The installation should provide for adequate structural support and exposure to the minimum possible vibration.

## 2.3 Cells in Parallel Strings

- Discover®tubular flooded cells/blocks may be connected in parallel to increase capacity, current capability and/or discharge durations.
- In the case of each parallel connected string, only use batteries of the same voltage, capacity, design and age.
- The resistance and ampacity of the cables or connector bars in each string must be the same, e.g. same cross-section, same length and same conductor type (copper, aluminium)
- In addition, each string should be equipped with disconnect capabilities (circuit breakers) for maintenance and safety purposes.
- **Paralleling of up to 10 strings is possible:**If the following steps are fulfilled it is possible to have more strings in parallel without reducing battery life or cells/blocks getting out of balance if the following requirements are fulfilled.

1. The samevoltage drop must be realized from each string to the end connection (loadand ground). This can be achieved by proper choice of cable lengths, cable diameters and arrangement for crosswise connection configurations
2. The connector cables for positive and negative terminals of each battery string must have the same length
3. The minimum cable size for the end connectors of a string is 25mm²/100 Ah of $C_{10}$ nominal string capacity
4. The end-connector cables (of the shortest possible length) must be placed on a copper bar (bus) with at least 100mm²/100 Ah of $C_{10}$ nominal string capacity.
5. It is a must that each string has a manually operated switching device that also automatically opens or breaks the circuit in the event of an over current (circuit breaker).
6. Each string must have the same number of cells/blocks.
7. Each string must be exposed to the same heat or temperature potential**.**
8. **Always connect the individual series strings first**and then check that the different strings are at the same potential before connecting them together on the bus.

**Note:**The combined **performance data**of all of the cells/blockswill be realized at the end pole/terminal of each string.

**Note:**Battery life or reliability will not be negatively affected if this form of paralleling is done correctly.

**Note:**Parallel connectionof strings with different capacities as well as different ages is possible (the age and capacity of the batteries within each string must be the same).

**Note:**The current during both discharge and charge will be split according to the capacity or age of the batteries respectively.

**Note:**The type of lead-acid batteries may differ between strings as long as the required charging regime and voltage (VPC) per string is guaranteed.

## 2.4 Cells in Series Strings

- Discover® tubular flooded cells/blocks may be connected in series to increase system voltage.
- In the case of each series connected string, only use batteries of the same voltage, capacity, design and age.
- The resistance of the cables or connector bars in each string must be the same, e.g. same cross-section, same length and same conductor type (copper, aluminium.
- Each string should be equipped with disconnect capabilities (breakers) for maintenance and safety purposes.

## 2.5 Pre-installation Control

- Check cells or blocks for evidence of leakage.
- All cells or blocks with visible defects such as cracked jars or containers, loose terminal posts, or other unrecoverable problems shall be rejected.

- Before installation, in cases where the battery container is dirty, wash with soapy water only.
- Carry out OCV (Open Circuit Voltage) measurements on each individual cell or block and check their compliance against the following variation and absolute voltage criteria:

1. The OCV must not deviate from average more than ±0.025V for 2V cells, ± 0.04V for 6V blocks and ± 0.06V for 12V blocks.
2. The OCV must not be lower than 2.03V for 2V cells, 6.1V for 6V blocks and 12.2V for 12V blocks.
3. The OCV of a fully charged cell/blockat 20°C/68°Fis 2.08V for 2V cells, 6.24V for 6V blocks and 12.48V for 12V blocks.
4. Per 10% Depth of Discharge (DOD) the voltage is reduced by .0125VPC (12.5mVPC). (e.g. OCV of 2.03V equals a 40% discharged cell (2.08V – (4 x .0125V) = 2.03V)).

## 2.6 Electrical Connections

- Ensure that the cells are installed and connected in the correct polarity.
- Check that all contact surfaces are clean. If required, clean poles/terminals with a brass brush/pad.
- You may slightly lubricate terminal inserts and connections with silicone grease. Petroleum-based lubricants are not recommended.
- Tighten the terminal screws using a torque loading of 22 Nm or 16 Ft-lbs. Electrical connections between cells/blocks or cells/blocks on separate levels or racks should be made making sure to minimize mechanical strain on the battery poles/terminals.
- For systems where the total battery voltage is measured at the controller, use oversized cables between the controller and the battery to minimize the voltage drop.
- Check the battery's total voltage. It should match the number of cells/blocks connected in series. If the measurement is not as expected, recheck the connections for proper polarity.
- The installer of the battery is responsible for conformity to local electrical standards.
- For future identification, apply individual cell/block numbers in sequence starting from one end of the series string. Also apply identification letters or numbers for the parallel strings.
- Only connect the battery to the DC power supply after ensuring that the polarity is correct, the charger is switched off,and the load is disconnected.

## 2.7 Instrumentation

- For large installations consider using permanent instrumentation for measurements and alarms. These include voltmeters, ammeters, Ah counters, high and low voltage indicators, ground fault detector(s) and temperature sensor(s) for the battery and the ambient air.
- For smaller installations, use portable test equipment. The battery temperature sensors shall be fixed on the cell/block side wall or negative pole/terminal.
- The use of monitoring and recording systems is mandatory in “Hybrid” systems.

## 2.8 Commissioning Charge

The initial charge is very important for the future battery operation and the battery’s service life. It is performed as a “full charge” as listed in paragraph 3.2.1. Keep records in the battery’s logbook.

# 3.0 Operations

In “Stand-alone” systems, the renewable source (e.g. PV array) is the only charging source available for the battery. In some systems, an external source - like a diesel generator - can be used but this is not within the basic design principle of a stand-alone system.(e.g. the source is engaged only intermittently and manually by the user in order to serve excessive loads or to maintain the batteries.)

Two types of charger controllers can be used:

- **On-Off PV controllers:**
  The controller interrupts the charging current from the PV array (off state) when the battery voltage reaches the high regulation point (e.g 2.45VPC) and re-connects it (on state) when the voltage drops to the low regulation point (e.g. 2.35VPC).

- **Constant Voltage type** (PWM method is also included here):
  Once the battery voltage reaches the regulation point, the controller limits the charging current to keep the voltage constant at this level as long as there is enough power available from the renewable source.

Two sub types may be defined here:

- One voltage step controllers: There is only one voltage regulation point.
- Two voltage steps controllers: There are two voltage regulation points.

Initially the controller maintains an elevated voltage to recharge the battery fast (absorption stage) then, after a certain time or other criteria, it steps back to a lower voltage to prevent unnecessary overcharging (floating stage).

In “Hybrid” systems, the renewable source size is most often smaller than the application load. There is always an independent source available - diesel or grid – to recharge the battery in every cycle. The same independent source can also be engaged, either automatically at regular intervals or manually when required to maintain the battery with equalizing charges.

- **Only Constant Voltage controllers** (usually with two voltage steps) shall be used.

## 3.1 Discharging

No restriction on the discharge current up to the maximum allowable is required as long as the connections are properly sized and the battery temperature stays within the allowable limits. The Maximum Daily Depth of Discharge per cycle (MDDOD) is:

- 20%-25% of the batteries $C_{10}$ nominal capacity rating for Stand-alone
- 50%-60% of the batteries $C_{10}$ nominal capacity rating for Hybrid systems
- Standard RE warranty is reduced on system designs that exceed the MDDOD.
- The Maximum allowable Depth of Discharge (MDOD) is 80% of the batteries temperature compensated $C_{10}$ nominal capacityat any given discharge rate.

## 3.1.2 Over-Discharge Protection

MDOD limits should not be managed solely based on Ah-counters (counting the ampere- hours into and out of the battery). Monitoring the battery voltage against the low-voltage disconnect setting (LVD) should always be included.

- For Hybrid Applications: The MDDOD limit control can be realized either by Ah-counters, control units and/or by battery voltage monitoring.
- For Stand-Alone Systems (see the note below for PV Array to Load ratios)

The graphs at the end of this document present the battery voltage to DOD reference as a guide for the initial LVD settings (first-try after setup settings). The system designer or installer shall adjust and confirm the LVD settings based on the actual conditions of the system.

- For systems where the voltage is measured at the controller and not on the battery, the voltage drop on the connections to the battery shall be considered.
- For mission critical systems with the load directly connected on the battery, an alarm or other method of user feedback must be included to provide information about the battery status when DOD exceeds the design limits.

## 3.1.3 Array to Load Ratios for Stand-alone Systems

In Stand-alone systems, the renewable source shall be sufficiently oversized against the application load in order to avoid excessive cycling beyond design limits which may limit the battery's life expectancy. The ampere hour output of the PV array (or other renewable source) over the load ampere hours for the minimum design month (month with minimum PV output) should be at least 1.3x times to recharge the battery while the daily load is supplied. (acc.to IEEE1013)

## 3.1.4 Low-voltage Re-Connect (LVR) for Stand-alone Systems

The battery voltage at which the load is reconnected after a low voltage disconnect, should be above 2.3 volts per cell, 6,9 volts per 6 volt block and 13.8 volts per 12 volt block.

## 3.2 Charging

## 3.2.1. Balance or Complete Charge

A balance or complete charge is a prolonged charge at an elevated voltage, performed with the supervisor nearby. It lasts until certain charge criteria are fulfilled but not outside certain minimum and maximum time limits. It is mainly used as:

- Commissioning charge after installation (Sec. 2.2.8)
- Corrective equalizing charge (Sec. 3.3.2)
- Preparation charge before a capacity test (Sec. 6)
- Refresh charge during long storage period (Sec. 1.1.2)
- The battery temperature must be monitored during charge. It should never exceed 45°C/113°F. If the upper temperature limitsare reached, the charge shall be interrupted or the charge voltage should be reduced to float voltage for a period of time sufficient enough to allow the battery to cool down. Operation can continue once the temperature stabilizes below 45°C/113°F.

### 3.2.2 Charging using a charger with I-U characteristic

Limit commissioning charge current to 1 x I10 Amps. (10% of the batteries $C_{10}$ nominal capacity

**Voltage - Full Charge PER CELL voltage:**
- Stability in the last 4 hours: voltage shall not rise by more than 0.02 V
- Deviation at the end of the charge: cell voltages shall not deviate more than 0.15 V from average.

**Electrolyte Density at Full Charge:**
- Stability within the last 4 hours: densities shall not rise more than 0.01 g/ml
- Deviation at the end of the charge: densities shall not deviate more than ±0.015 g/ml from average.

**Current - Full Charge current behavior:**
- Stability in the last 4 hours: current shall not change by more than ±25%.

| Battery Temperature | Voltage Settings | Min. / Max. Hours |
|---|---|---|
| 0to15°C / 32 to60°F | 2.45VPC – 2.50VPC | 24 – 48 |
| 15to30°C / 60 to86°F | 2.40VPC – 2.45VPC | 24 – 48 |
| 30to40°C / 86 to104°F | 2.50VPC – 2.55VPC | 24 - 48 |

### 3.2.3 Charging using a charger With I-U-I or I Characteristics

Use an I-U-I or I charger that can charge the battery with constant current at elevated voltages greater than 2.50VPC to 2.80VPC.
- Bulk charge current limit: 2 x I10 Amps (20% of the batteries $C_{10}$ nominal capacity
- Voltage settings for U (absorption) phase: 2.33-2.40VPC
- Gassing charge current limit: 0.3 x I10 (3% of the batteries $C_{10}$ nominal capacity
- Min.- Max. Charge time at gassing phase: 5 h – 8 h (*** See Below)

**Voltage**- Full Charge PER CELL voltage:
- Stability in the last 1 hour: voltage shall not rise by more than 0.02VPC.
- Deviation at the end of the charge: cell voltages shall not deviate more than 0.12V from the average.
- Absolute value: shall be above 2.6VPC

**Electrolyte** - Density at Full Charge:
- Stability within the last 4 hours: densities shall not rise more than 0.01 g/ml
- Deviation at the end of the charge: densities shall not deviate by more than ±0.015 g/ml from average.

(***) In special cases where the maximum charging time has elapsed but the full charge criteria has not been achieved, the Equalizing program shall be continued with the following charge & pause profile:
- Charge for 2 h with 0.3 to 0.5 x I10 (3%-5% of the batteries $C_{10}$ nominal capacity)
- Repeat charge & pause profile until the full charge criteria are fulfilled or a maximum of five charge & pause cycles have been performed.

## 3.2.4 Charging using the Solar Charge Controller

Connect the battery to the PV Array via the charge controller and leave it for 1-2 weeks while the application load is disconnected. Use the following voltage settings paying close attention to the ambient temperature near the battery.

| For On-Off Controllers | | | |
|---|---|---|---|
| **Temperature Range** | **-20°to 0°C<br>-4° to 32°F** | **0° to 35°C<br>32° to 95°F** | **>35°C to 95°F** |
| High Disconnect Voltage | 2.6V | 2.50V | 2.45V |
| Low Restart Voltage | 2.4V | 2.35V | 2.30V |

| For Constant Voltage Controllers | | | |
|---|---|---|---|
| **Temperature Range** | **-20° to 0°C<br>-4° to 32°F** | **0° to 35°C<br>32° to 95°F** | **>35°C to 95°F** |
| Regulation Voltage | 2.55V | 2.45V | 2.40V |

## 3.3 Equalizing Charge

## 3.3.1 Functional Equalizing

To avoid permanent capacity loss and acid stratification in cycling operation the goal is to achieve a complete recharge (100% SOC) after every discharge. Capacity loss and acid stratification will threaten the battery's state of health.

- In Stand-alone Systems this is not always possible as in Stand-alone applications where the RE source depends on the weather conditions causing the load to exceed the designed limitations. In this case proper "Array to Load ratios" (as given in paragraph 3.1) are critical for the life expectancy of the battery to be achieved
- For Hybrid Systems with diesel generators (mainly telecom hybrid systems), the charging source is always available but the boost charging time is restricted to favor a more efficient utilization of the diesel.

In both cases, a scheduled (functional) equalizing charge shall be performed at regular intervals (see "Normal operation charging") to protect the battery from acid stratification, sulphation and loss of capacity.

Functional Equalizing frequency is adjusted according to the charge deficit. The less complete the daily recharge is, the more frequently an equalizing charge will be required (see Normal operation charging)

- The charge duration is fixed.
- The values of the voltage settings are the same as those for a normal recharge.

### 3.3.2 Corrective Equalizing

Equalizing charges are also required after incidents of excessive stress for the battery (deep discharges with inadequate charges) or when the individual cell or block voltages show excessive deviation from the average (lagging cells and sulphation problems). Should the voltage in individual cells/blocks deviate from the average value more than the following limits, perform an equalizing charge.

| Battery Status | 2V Cells | 6V Blocks | 12 Volt Blocks |
|---|---|---|---|
| Floating | -0.1V - +0.2V | -0.17V - +0.35V | -0.25V - +0.50V |
| At the end of a normal charge when the current is stable | -0.2V - +0.35V | -0.35V - +0.60V | -0.50V - +0.90V |
| During discharge when the DOD is between 5% and 25% | +/-0.04V | +/-0.06V | +/-0.08V |
| During discharge when the DOD is between 25% and 60% | +/-0.06V | +/-0.09V | +/-0.12V |
| At rest at least 16 hours after a Functional Equalizing Charge | +/-0.025V | +/-0.04V | +/-0.06V |

Corrective Equalizing is performed as a Full Charge as outlined in paragraph 3.2.1. If the voltages are still out of the limits, contact Discover® Engineering or Discover® Customer Service or your servicing Discover® dealer. A service contract with an authorized Discover® factory warehouse or dealer is recommended.

### 3.3.3 Normal Operation Charging

The following voltage settings during charge are optimum values when the battery is not heavily undercharged or overcharged. A good indicator to check is the percent of overcharge per cycle (charging factor) within a long period of operation (a month to a year). Deviations from the charging factors given below require that the charge settings and the overall system operation be checked again:

- Overcharge% >110% for Stand-alone systems with MDDOD less than 5%
- Overcharge 110% to 125% for Stand-alone systems with MDDOD greater than 5%
- Overcharge 110% to 115% for Hybrid systems.

### 3.3.4 Settings for Stand-Alone Systems

Settings shall be adjusted according to battery temperature. Temperatures are averaged over one month:

| Controller Type | Setting | -20°Cto0°C<br>-4°F to 32°F | 0°Cto15°C<br>32°Fto95°F | 15°C to 35°C<br>60°F to 95°F | >35°C<br>>95°F |
|---|---|---|---|---|---|
| Constant Voltage One Step | Voltage Regulation | 2.55VPC | 2.5VPC | 2.45VPC | 2.4VPC |
| | Absorption time up to 4 hrs per day | 2.6VPC | 2.55VPC | 2.5VPC | 2.45VPC |
| Constant Voltage Two Step | Float | 2.5VPC | 2.45VPC | 2.4VPC | 2.35VPC |
| | High Voltage | 2.6VPC | 2.55VPC | 2.5VPC | 2.45VPC |
| On-Off | Low Voltage | 2.4VPC | 2.35VPC | 2.35VPC | 2.3VPC |

- For systems with oversized PV array and low MDDOD (<5%), use lower settings (Sec. 3.3).
- Functional equalizing charges (3.2.2.1) are required in periods with marginal “Array to Load ratio”, less than 1.3x times
- Typical functional equalizing would be performed 1 to 6 times per year.

### 3.3.5. Settings for Hybrid Systems

Daily charge after discharge:

- Only a constant voltage controller is permitted.
- The absorption voltage setting shall be adjusted according to the batteries averaged temperature over one month:

| Temperature | -20°Cto0°C<br>-4°F to 32°F | 0°Cto15°C<br>32°Fto95°F | 15°C to 35°C<br>60°F to 95°F | >35°C<br>>95°F |
|---|---|---|---|---|
| Absorption Voltage | 2.55VPC | 2.5VPC | 2.45VPC | 2.4VPC |

- The absorption time setting can be selected between 4 to 12 hours. The frequency of the functional equalizing charge shall be adjusted accordingly:

| **Absorption Time Setting for Daily Charge** | | 4-6 hours | 6-8 hours | 8-10 hours | 10-12 hours |
|---|---|---|---|---|---|
| Do One Equalizing Charge Every: | If the daily DOD is 20% to 40% | 10 days | 20 days | 30 days | 40 days |
| | If the Daily DOD is within 40% to 60% | 7 days | 14 days | 21 days | 28 days |

## 3.3.5. Settings for Hybrid Systems (Continued)

Functional Equalizing includes a gassing stage with constant current for a fixed time:

- Before the gassing stage charge the battery at the absorption voltage. Continue charging until the current drops below 0.3 x I10 amps (3% of the batteries $C_{10}$ nominal capacity)

| Temperature | -20°Cto0°C<br>-4°F to 32°F | 0°Cto15°C<br>32°Fto95°F | 15°C to 35°C<br>60°F to 95°F | >35°C<br>>95°F |
|---|---|---|---|---|
| Absorption Voltage | 2.55VPC | 2.5VPC | 2.45VPC | 2.4VPC |

- Then, charge with current 0.3 x I10 amps (3% of the batteries $C_{10}$ nominal capacity). The battery voltage will climb to exceed 2.6VPC within this charging stage.
- Double check Functional Equalizing regime and electrolyte density
- Functional Equalizing frequency and duration is sufficient when the electrolyte density at the end of the charge reaches its rated value for each cell (temperature compensated).

## 3.4 Operation at Very Low or No Load

When there is little or no load connected to the system for long periods (more than 1 month) while the battery remains connected, the **normal charging settings in paragraph 3.2 are too high** and result in unwanted overcharging. The same applies to Stand-alone systems with oversized PV array and very low MDDOD (<5%) **(e.g. remote telecom transmitters).** In these circumstances use the following settings. The temperatures are average over one month.

**For Stand-Alone Systems:**

| Controller Type | Setting | -20°Cto0°C<br>-4°F to 32°F | 0°Cto15°C<br>32°Fto95°F | 15°C to 35°C<br>60°F to 95°F | >35°C<br>>95°F |
|---|---|---|---|---|---|
| Constant Voltage One Step | Voltage Regulation | 2.4VPC | 2.35VPC | 2.30VPC | 2.30VPC |
| Constant Voltage Two Step | Absorption time up to 4 hours per day | 2.40VPC | 2.35VPC | 2.30VPC | 2.30VPC |
| | Float | 2.35VPC | 2.30VPC | 2.25VPC | 2.25VPC |
| On-Off | High Voltage | 2.40VPC | 2.35VPC | 2.30VPC | 2.30VPC |
| | Low Voltage | 2.20VPC | 2.20VPC | 2.20VPC | 2.20VPC |

**For hybrid systems:**

- When only the PV is engaged: use settings shown in “Constant Voltage One Step.”
- When only the diesel is engaged (continuously): use Constant Voltage Two Step settings.”

| Controller Type | Setting | -20°Cto0°C<br>-4°F to 32°F | 0°Cto15°C<br>32°Fto95°F | 15°C to 35°C<br>60°F to 95°F | >35°C<br>>95°F |
|---|---|---|---|---|---|
| Constant Voltage One Step | Voltage Regulation | 2.4VPC | 2.35VPC | 2.30VPC | 2.30VPC |
| Constant Voltage Two Step | Absorption time up to 4 hours per day | 2.40VPC | 2.35VPC | 2.30VPC | 2.30VPC |
| | Float | 2.35VPC | 2.30VPC | 2.25VPC | 2.25VPC |
| On-Off | High Voltage | 2.40VPC | 2.35VPC | 2.30VPC | 2.30VPC |
| | Low Voltage | 2.20VPC | 2.20VPC | 2.20VPC | 2.20VPC |

## 3.5 Temperature Limits

- The ideal operating temperature range is 25°C/77°F ± 5°C/5°F.
- The recommended operating temperature range is 15°C to 35°C (60°F to 95°F).
- Higher temperatures reduce operating life. A maximum ambient operating temperature of 50°C/122°F must not be exceeded.
- In hybrid applications the yearly average ambient temperature should be less than 30°C/86°F.
- Sub-zero temperatures may cause electrolyte freezing and irreversible damage when the battery's state of charge (SOC) is low.
- The minimum safe temperature Versus the cell/block state of charge (SOC) is given below:

| State of Charge (SOC) | >80% | 60%-80% | 40%-60% | 20%-40% |
|---|---|---|---|---|
| Freezing Point | -35°C / -31°F | -25°C / -13°F | -18°C / 0°F | -12.5°C / -10°F |

To counter low temperature operation the system designer shall consider thermal insulation, increasing battery capacity or increasing the minimum system voltage. In Stand-alone systems it is recommended to use controllers with adjustable LVD settings for the battery temperature (higher LVD for lower temperature). During operation the temperature difference between individual cells/block should be below 3°C / 5°F.

## 3.6 Current Limits

The maximum charging current during the bulk charging is 3 x $I_{10}$(30% of the batteries $C_{10}$ nominal capacity) while the battery voltage is below the gassing voltage of 2.40 VPC.

## 3.7 Ripple Currents

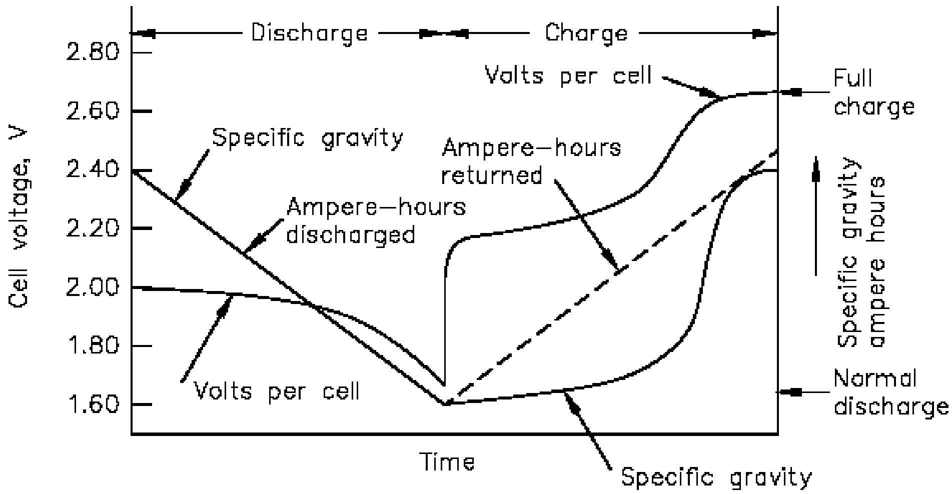
- During recharging (up to 2.40VPC) the effective value of the AC ripple current may temporarily reach a maximum 10A per 100Ah of $C_{10}$ nominal capacity.
- After recharging and at float charge in stand-by operation or buffer operation the effective value of the AC ripple current must not exceed 5A per 100 Ah of $C_{10}$ nominal capacity.

## 3.8 Electrolyte, Specific Gravity and Topping Up with Water

One of the key operating parameters of battery operation is the specific gravity of the electrolyte. Specific gravity is the ratio of the weight of a solution to the weight of an equal volume of water at a specific temperature. Specific gravity is used as an indicator of the state of charge of a cell. Specific gravity cannot determine a cell's capacity. During discharge the specific gravity decreases linearly with the ampere-hours discharged as indicated in the illustration below. *(Illustration obtained from Engineers Edge LLC)*

- Cell/block electrolyte is a diluted sulphuric acid solution.
- The rated specific density of the electrolyte in a fully charged Discover RE series cell/block at 20°C/68°F is of 1.24 kg/l with a maximum deviation of ±0.01kg/l.

3.8 Electrolyte, Specific Gravity and Topping Up with Water (Continued)




OCV Plots on the downward sloping line for the specific gravity during discharge can be estimated by using the following equations:

- Specific Gravity = The Open Circuit Voltage of a single cell – 0.845
- Cell Open Circuit Voltage = Specific Gravity +0.845
- Density changes with temperature. Specific Gravity readings of a fully charge cell decrease when the temperature of the electrolyte rises and vice versa. The temperature correction factor is -0.0007 kg/l per degree Cup from 20°C and +.0007 kg/l per degree C down from 20°.

| Specific Gravity READING at Full Charge | Temperature of Electrolyte |
|---|---|
| 1.235 - 1.240 | 25°C/77°F |
| 1.240 - 1.245 | 20°C/68°F |
| 1.245 - 1.250 | 15°C/59°F |

- Errors can occur if the electrolyte has stratified, meaning the concentration of acid is lighter on top than lower down in the cells. Make sure that the electrolyte has stabilised after charge and discharge before taking final specific gravity readings. Readings will increase only slightly once the gassing stage has been reached during charge.
- Density increases when the electrolyte level becomes low due to water decomposition.
- When at minimum levels the density of the electrolyte is approximately 1.26 kg/l as the water has been decomposed out of the electrolyte as the levels dropped.
- The water decomposition rate depends on several factors like daily DOD, charging factors, temperature and battery age.
- The user shall top up with purified water before the water level drops to minimum levels (a level at least 10mm/0.5in above the plate straps) or to minimum level markings on the cell/block container.

- Only purified water with a maximum electrical conductivity of 30 µS/cm must be used. mS=milli-Siemens,µS = micro Siemens. Therefore 30µS = 0.030mS

# 4.0 Battery Maintenance

## 4.1Visual Inspection and Cleaning Instructions

- Check for leakage evidence and any visible defects such as cracked jars, loose terminal posts and oxidized connectors.
- To avoid leakage currents and the associated risk of fire, keep the battery dry and clean. Clean with clear water. Do not use any solvents or detergents.
- Avoid electrostatic charges.

## 4.2 Topping up

- Top up with water at regular intervals to ensure levels never drop below "minimum levels. Follow the instructions in Sec.3.8.

## 4.3 Bi-annual Maintenance

For Hybrid systems perform the maintenance after each Functional Equalizing charge:

- Visual inspection. Clean if necessary.
- Measure/record the battery voltage.
- Measure/record the voltage of each cell/block.
- Measure/record the electrolyte density and temperature of each cell.
- Confirm/record that the MDDOD is not being exceeded.
- Confirm/record that the MDDOD does not exceed the allowed limit.
- Confirm/record that the charging factor is within acceptable limits.
- Confirm/record that charge settings correspond to the recommended ones.
- Check/record if corrective equalizing is applied according to 3.3

## 4.4 Yearly Maintenance

Further to the bi-annual maintenance, do the following:

- Check/record if connectors are firmly tightened.
- Inspect/record the racks for corrosion or loss of integrity.
- Check/record if ventilation is sufficient.
- Check/record voltage of all cells/blocks
- Check/record surface temperature of all cells/blocks
- Check/record battery room temperature
- Check/record ventilation

# 5.0 Faults

Should faults be detected in the battery or the charging device, contact your servicing dealer immediately. Keeping records of all measured data will simplify fault detection and corrective action. A service contract with your servicing Discover® dealer will help to detect faults in time.

# 6.0 Testing

Check that the battery is fully charged before testing. Before testing new batteries, ensure that a sufficient commissioning charge has been applied and the battery is fully charged.

# 7.0 Storage

If filled lead acid batteries are to be taken out of operation for extended periods of time, they must be placed fully charged in a dry, frost-free room. To avoid damage, perform periodical equalizing charging (see 3.2.1) or permanent float charging.

# 8.0 Transport

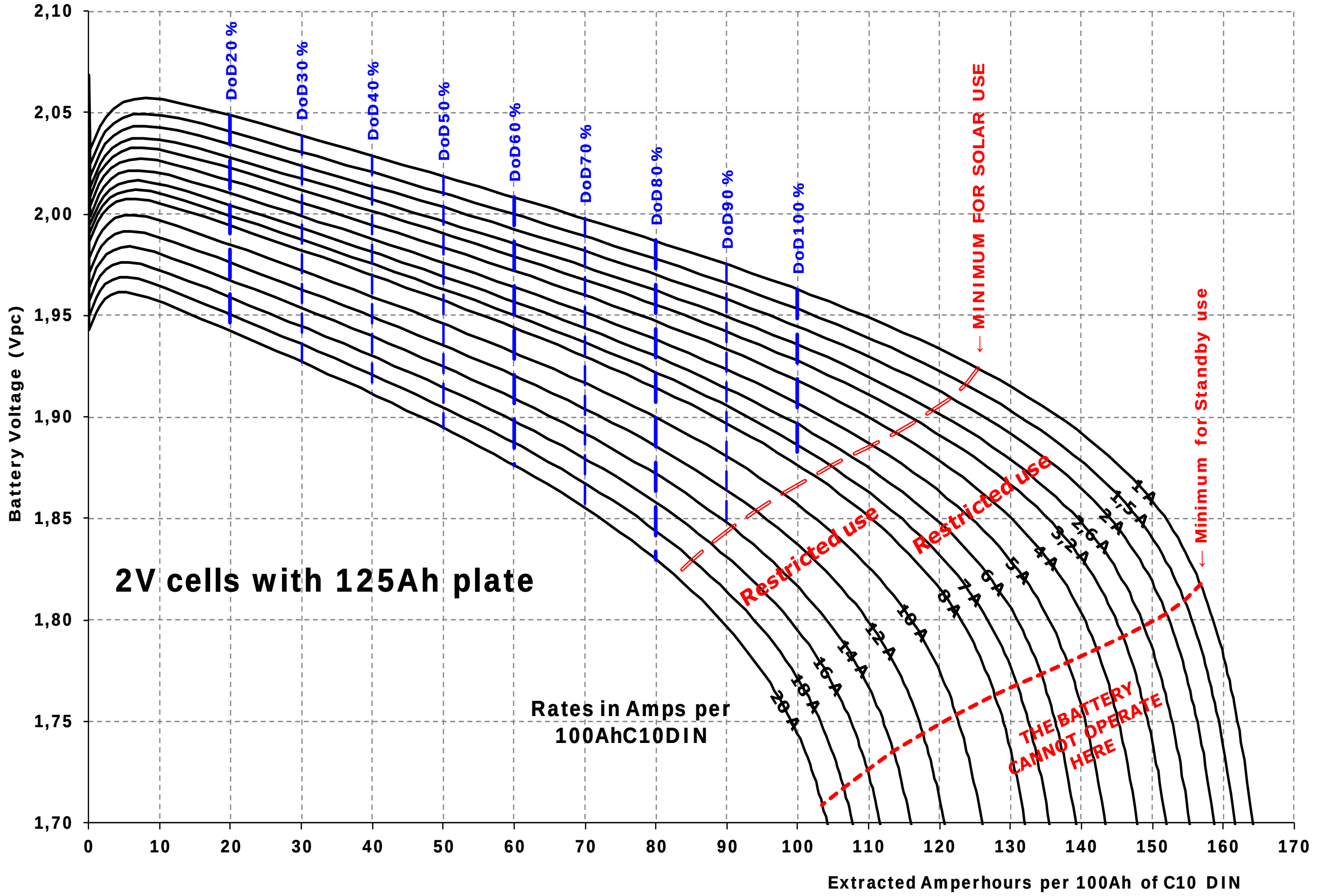
Be sure that all cells/blocks are protected against short-circuit. Be sure to document and transport all cells/blocks or batteries according to local department of transportation rules and regulations.

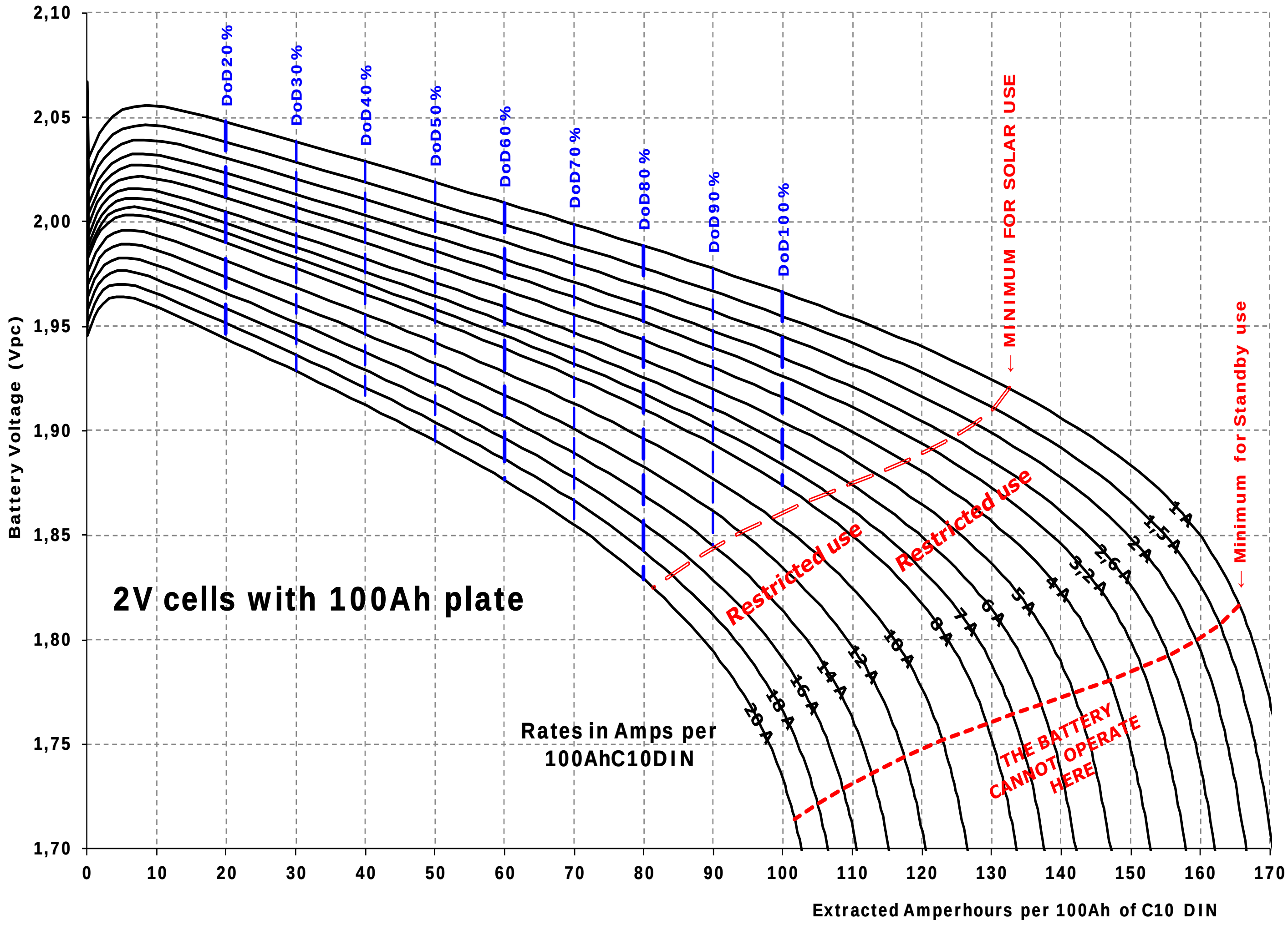
# 9.0 Recycling

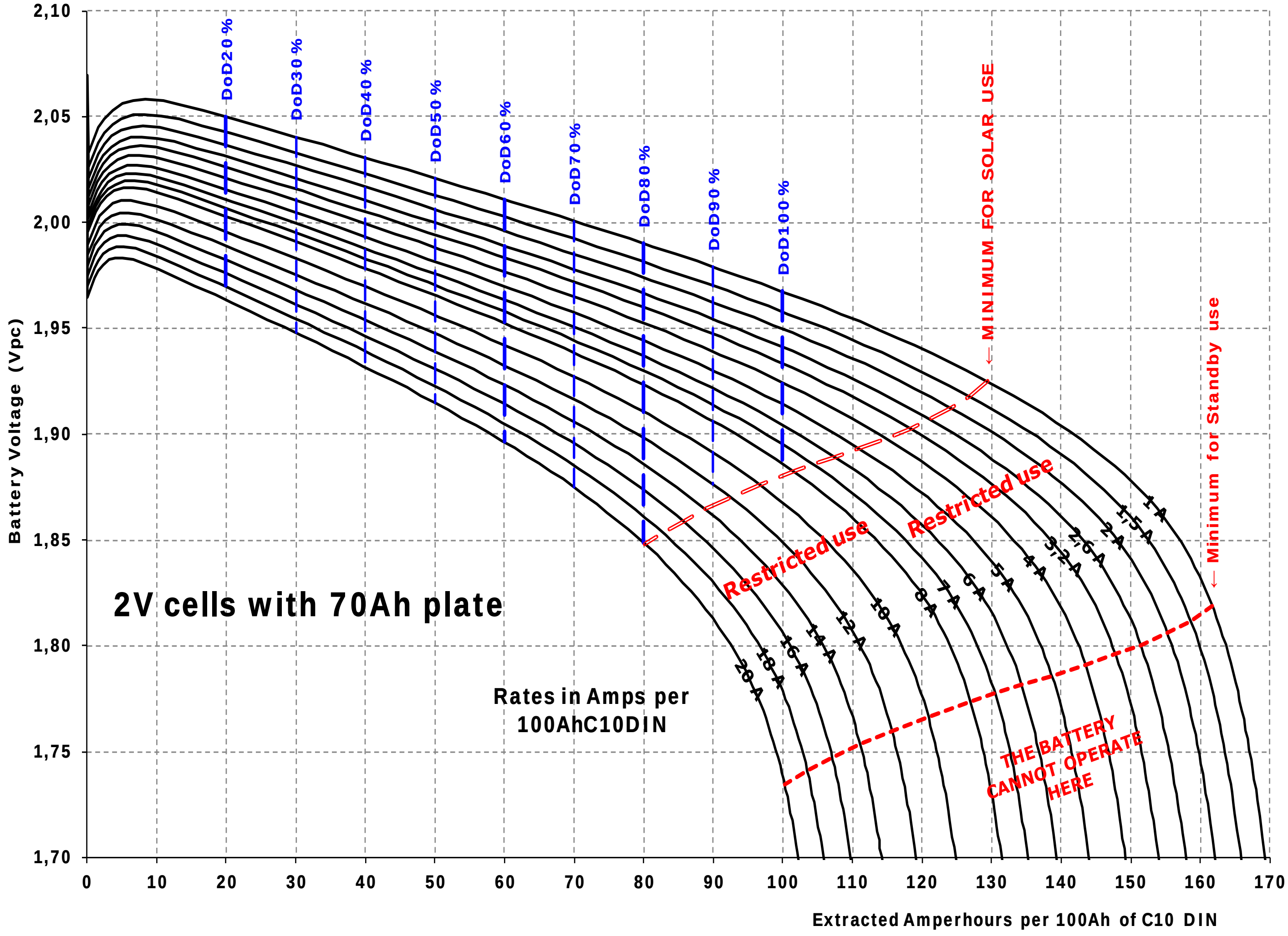
Discover's lead acid batteries are recyclable products. All Discover Factory Warehouses and servicing dealers are qualified to accept and handle all used lead acid batteries. Contact Discover®or your servicing dealer for details.

# 10 Graphs

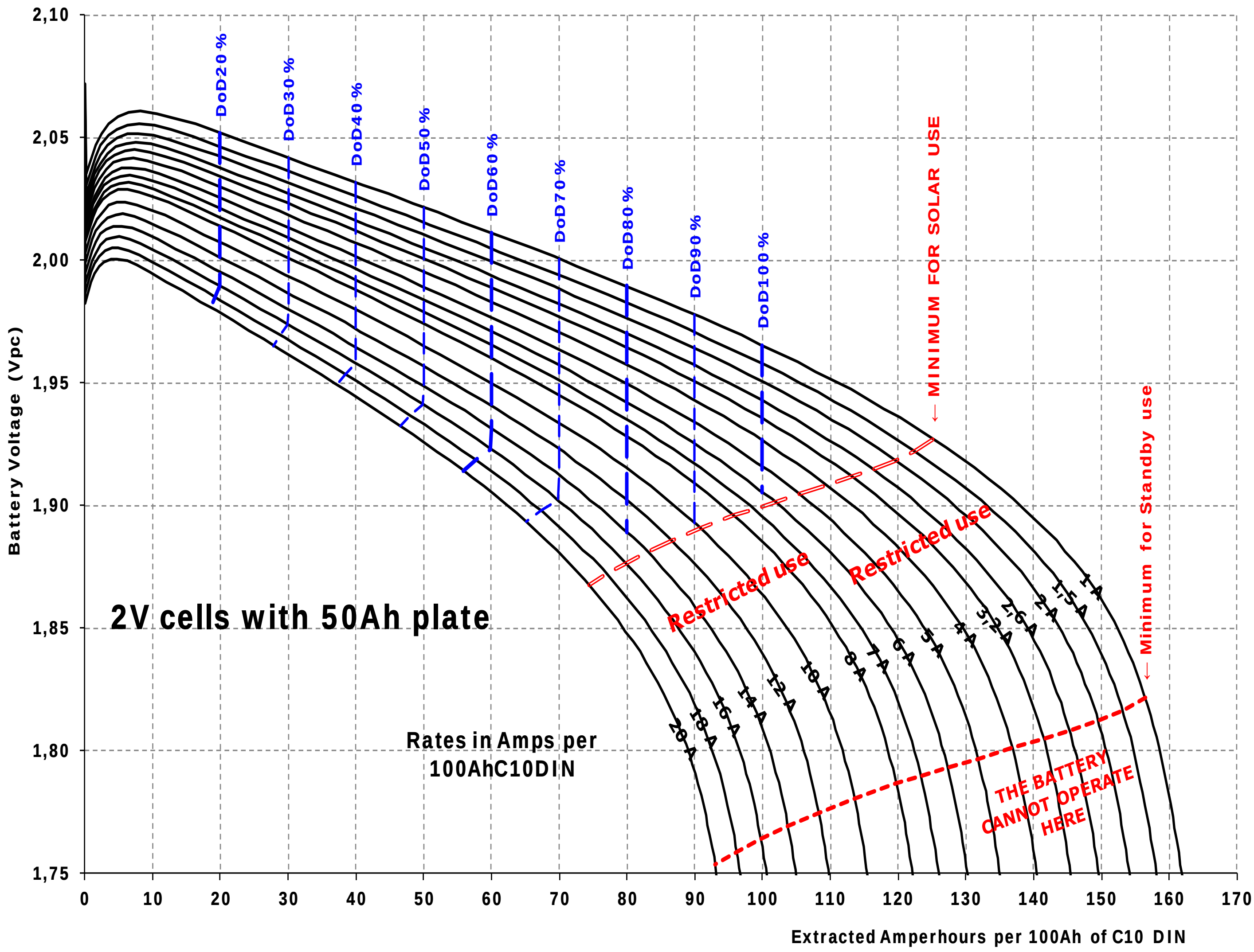
- Battery Voltage in relation to DOD as guidance for the initial LVD settings (first-try settings) 25°C/77°F reference temperature
- The minimum voltage shown for standby use represents the maximum available capacity.
- The minimum voltage shown for solar use represents the maximum available capacity. It is the lowest LVD setting and should only be used with Discover's approval. Systems design to be discharged regularly to this level will have reduced warranty coverage.
- The recommended LVD and the LVD required for standard warranty coverage, is the minimum voltage which represents a 50% DOD.
- The DOD 60% line, represents the minimum voltage setting to control the end of each discharge voltage in hybrid applications. It's always recommended to implement a supplementary control by Ah counter.




2V cells with 100Ah plate
Battery Voltage (Vpc)
Extracted Amperhours per 100Ah of C10 DIN
Rates in Amps per 100AhC10DIN
DoD20 %
DoD30 %
DoD40 %
DoD50 %
DoD60 %
DoD70 %
DoD80 %
DoD90 %
DoD100 %
← MINIMUM FOR SOLAR USE
← Minimum for Standby use
Restricted use
Restricted use
THE BATTERY CANNOT OPERATE HERE
1 A
1,5 A
2 A
2,6 A
3,2 A
4 A
5 A
6 A
7 A
8 A
10 A
12 A
14 A
16 A
18 A
20 A
2,10
2,05
2,00
1,95
1,90
1,85
1,80
1,75
1,70
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170



2V cells with 70Ah plate
Rates in Amps per 100AhC10DIN
Battery Voltage (Vpc)
Extracted Amperhours per 100Ah of C10 DIN
DoD20 %
DoD30 %
DoD40 %
DoD50 %
DoD60 %
DoD70 %
DoD80 %
DoD90 %
DoD100 %
← MINIMUM FOR SOLAR USE
← Minimum for Standby use
Restricted use
Restricted use
THE BATTERY CANNOT OPERATE HERE
1 A
1,5 A
2 A
2,6 A
3,2 A
4 A
5 A
6 A
7 A
8 A
10 A
12 A
14 A
16 A
18 A
20 A
2,10
2,05
2,00
1,95
1,90
1,85
1,80
1,75
1,70
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170


2V cells with 50Ah plate
Battery Voltage (Vpc)
Extracted Amperhours per 100Ah of C10 DIN
Rates in Amps per
100AhC10DIN
DoD20%
DoD30%
DoD40%
DoD50%
DoD60%
DoD70%
DoD80%
DoD90%
DoD100%
← MINIMUM FOR SOLAR USE
← Minimum for Standby use
Restricted use
Restricted use
THE BATTERY
CANNOT OPERATE
HERE
1 A
1,5 A
2 A
2,6 A
3,2 A
4 A
5 A
6 A
7 A
8 A
10 A
12 A
14 A
16 A
18 A
20 A
2,10
2,05
2,00
1,95
1,90
1,85
1,80
1,75
0
10
20
30
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100
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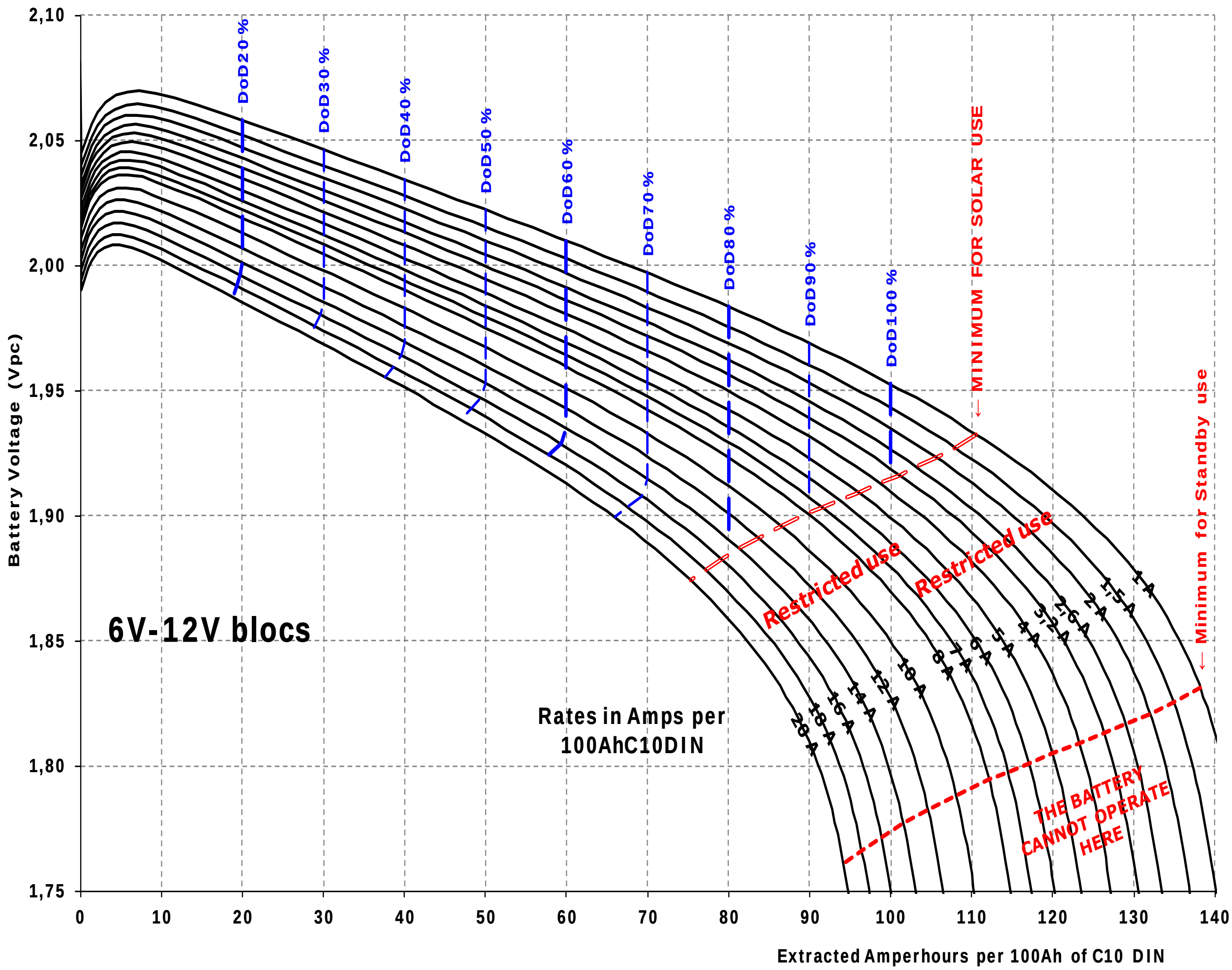
140
150
160
170



2,10
2,05
2,00
1,95
1,90
1,85
1,80
1,75
Battery Voltage (Vpc)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Extracted Amperhours per 100Ah of C10 DIN
DoD20%
DoD30%
DoD40%
DoD50%
DoD60%
DoD70%
DoD80%
DoD90%
DoD100%
← MINIMUM FOR SOLAR USE
← Minimum for Standby use
6V-12V blocs
Rates in Amps per
100AhC10DIN
Restricted use
Restricted use
THE BATTERY
CANNOT OPERATE
HERE
1 A
1,5 A
2 A
2,6 A
3,2 A
4 A
5 A
6 A
7 A
8 A
10 A
12 A
14 A
16 A
18 A
20 A

# Index