Narada®

LEAD-CARBON BATTERY

REXC Series

OPERATION MANUAL

Version：V1.2

Content

Safety and Warning

Please read this manual! It provides very important direction for fix and operation, which can make best capability for the equipment, and elongate the using life.

- For your safety, please do not try to dismantle or open the equipment. The equipment does not contain any spare parts for you. The maintain work can only be done by specially trained service persons.
- As a result of the batteries' latent endanger to health and environment, they should be only changed in our authorization service center. If you need to change the battery or maintain the equipment, please call the nearest service center.
- Batteries can be reclaimed, if it could not be carefully handled, it will do great harms to environment and heath. Please check local laws and regulations to get the validity handle ways or send the equipment to authorized service center.
- The replacement of battery can only be done by persons who know well about the danger and the prevention. When changing the battery, please use the same model and type of sealed lead acid battery.

⚠ Warning—do not smoke or use fire near batteries

⚠ Warning—do not use organic solvent to wash batteries

⚠ Warning—dot not put batteries into the fire, or it may bombed

⚠ Warning—do not open batteries, it contains electrolyte, which can hurt the skin and eyes.

⚠ Warning—There may happen shock or short circuit when replacing the batteries. Please operate with tools with insulated handles.

Please take care of the following marks in using

					
Warning	Electricity danger	Protecting your eyes	Watch Short-circuits	With adults custody	Do not put batteries into dustbin
					
Read the manual	Fire forbidden	Circle used			

Chapter One Introduction of REXC series

REXC series battery is designed for renewable energy sources such as wind power and solar system, and developed for home energy system with long life, high energy efficiency, superb security and reliability characteristic, which can be applied to energy storage system, telecom and generator, etc.

1. Product Characters

- Lead carbon battery add carbon material with high capacitance or highly conductive into the negative electrode, combine the advantages of lead acid battery and super capacitors, lead carbon battery provide not only high energy density, but also high power, rapid charge and discharge, longer cycle life.
- Combine the advantages of lead acid battery and super capacitors
- Ideal for PSOC cycle application
- Excellent recharge acceptance performance, super fast charge/large discharge performance
- Reduce sulfation of the negative plate, longer cycle life

1.1 Design floating life is above 20 years

Grid alloy with special patented formula

Special patented negative paste formula

4BS paste technology

Extra-thick plate design

1.2 Superb security and reliability

Reliable seal performance, no acid spillage, recombination efficiency reach above 99%

1.3 Initial capacity above 100%, the remaining capacity above 90% when storage for 3 months (25℃)

1.4 Remarkable high rate discharge performance.

Low internal resistance. Patented grid design. Large section copper structure

1.5 Innovation patented lead carbon technology

The innovation patented lead carbon technology can solve sulfation of the negative plate when used underfilling; compare with tradition VRLA battery, cycle life of the lead carbon battery can be extended 3-10 times

1.6 Ideal for PSOC cycle application

Cycle use at 80% SOC (part state of charge) can be longer PSOC cycle life, which especially designed for solar or wind energy storage system

1.7 Supply the unique flexible connectors made of rubber wrapped with copper wires

and another option is copper bar connector.

Assure the good connections of post and connectors and low connection resistance;

Combination of suppleness and rigidity for more flexible connections;

1.8 Flexible and convenient installation, slinky outside looking

Shockproof blocking assembling

Satisfy customer's individual requirements and provide up to 8-class shockproof Streamline and dime-light battery outside-looking design.

2. Main applications

- Home energy storage system
- Hybrid energy system such as solar and wind energy
- Distributed energy storage system
- Smart power grids and microgrids system
- Generator and battery hybrid energy system
- Solar power generation grid/off-grid energy storage system
- Emergency lighting system
- Other standby, cycling system

3. Configuration

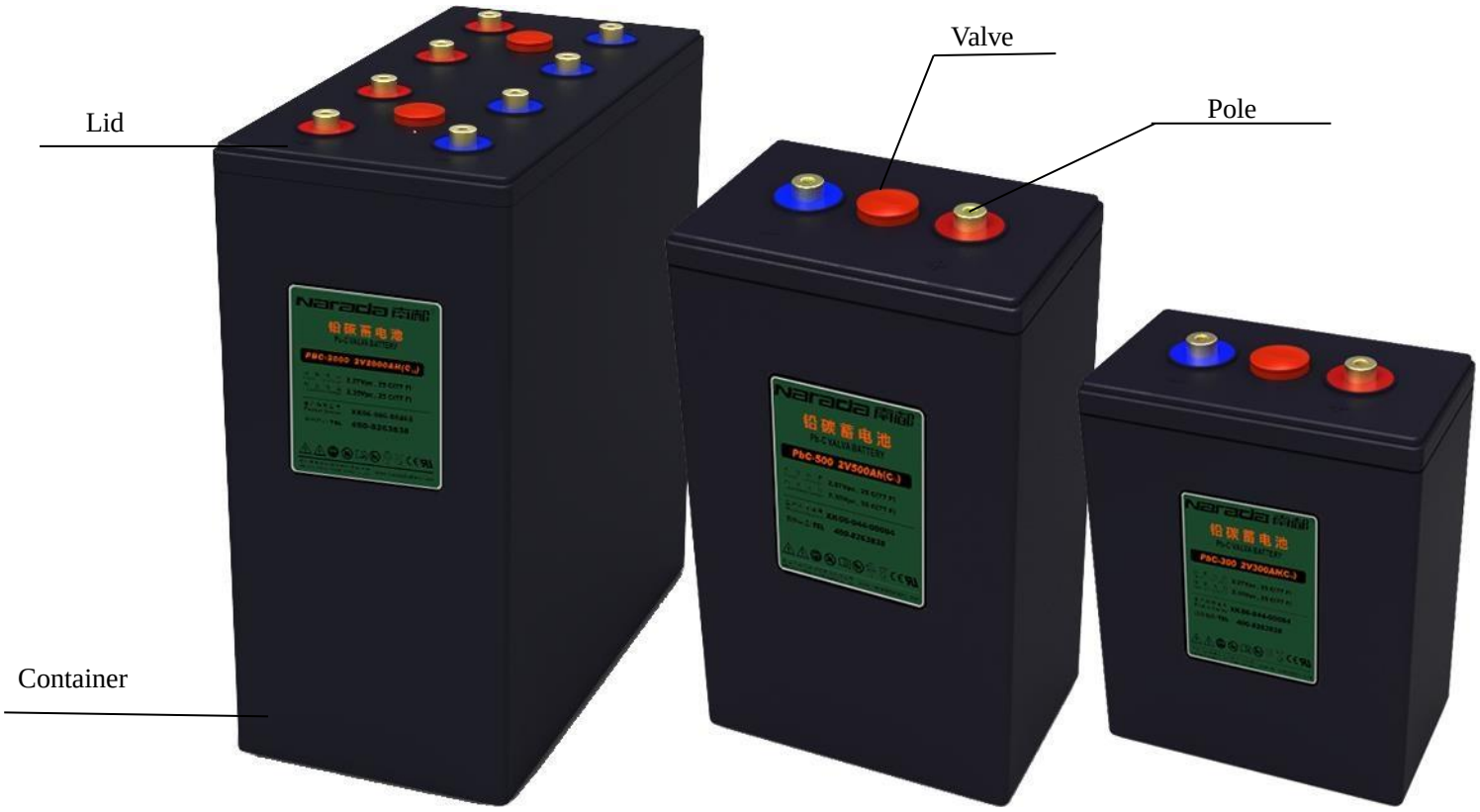


Fig. 1-1 Configuration

4. Types and Dimensions

Table 1-1 type specifications

Battery Type	Rated Voltage per cell (V)	Rated Capacity (Ah)		Dimensions (mm)				Weight (Kg)
		C_{10}	C_{120}	Length	Width	Height	Overall Height	
		End-voltage 1.80V	End-voltage 1.85V					
REXC-200	2	200	240	227	96	291	303	17
REXC-300	2	300	360	227	133	291	303	24
REXC-400	2	400	480	227	170	291	303	31
REXC-500	2	500	600	231	155	396	408	39
REXC-600	2	600	720	231	180	396	408	46
REXC-800	2	800	960	231	231	396	408	60
REXC-1000	2	1000	1200	231	282	396	408	75
REXC-1200	2	1200	1440	232	264	502	514	90
REXC-1500	2	1500	1800	232	322	502	514	110
REXC-2000	2	2000	2400	232	456	502	514	155

5.Lead Carbon Working Principle

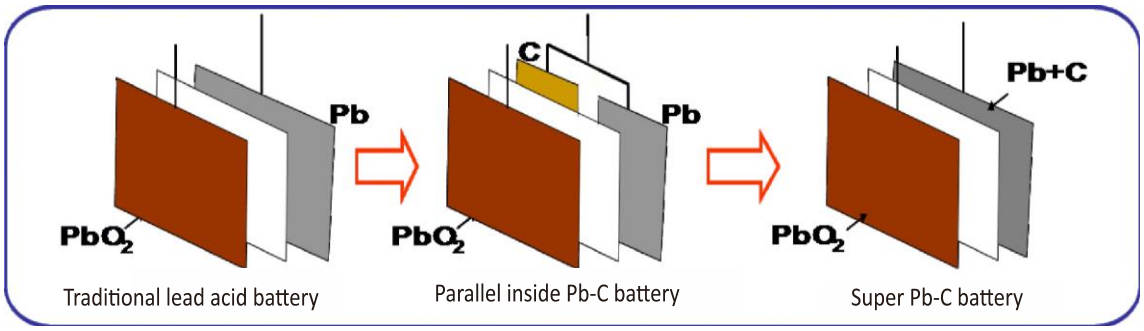


Fig.1-2 Lead carbon battery working principle sketch map

It forms a new active center in negative electrode by adding active carbon, that can reduce lead deposition overpotential, the lead sulfate will be translated into lead more easily. Growing up of lead sulfate can be suppressed efficiently through this technology.

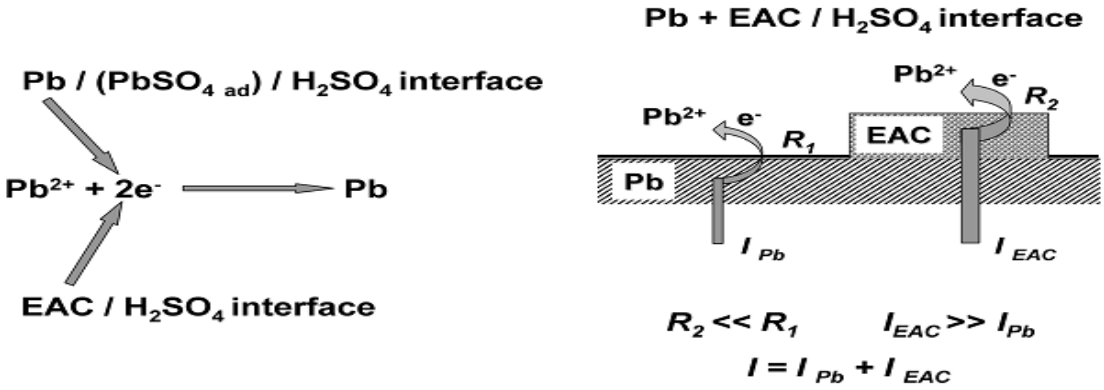


Fig.1-3 Lead carbon negative electrode surface current distribution sketch map

The chemical reaction taking place in lead carbon battery is as follows:
positive electrode:

$$PbO_2(s) + HSO_4^-(aq) + 3H^+(aq) + 2e^- \underset{charge}{\overset{discharge}{\rightleftharpoons}} PbSO_4(s) + 2H_2O(1)$$

negative electrode:

$$nC_6^{x-}(H^+)_x(aq) \underset{charge}{\overset{discharge}{\rightleftharpoons}} nC_6^{(x-2)-}(H^+)_{x-2}(aq) + 2H^+(aq) + 2e^-$$

Because of the reaction is based on double layer capacitance which caused from carbon electrode/electrolyte interface, thereby the lead carbon battery has part characteristic of super capacitors. Thus the lead carbon battery can possess large current and long cycle life performances.
REXC battery adopts a design of barren-liquor and utilizes AGM (micro porous glass fiber) separator. Thus there is a path existing between the positive and the negative.

Also special alloy grid is chosen to increase vent hydrogen over-potential gassing on the negative plate, which prevents generation of hydrogen. Otherwise, the oxygen generated from positive diffuses through separator to the negative and the oxygen gas reacts quickly and is recombined into water. The reactions are as follows: :

$2Pb + O_2 \longrightarrow 2PbO$;

$PbO + H_2SO_4 \longrightarrow PbSO_4 + H_2O$;

So it is possible to build REXC battery in sealed structure.

Chapter Two Technical characteristic

1. Discharge Curve and Discharge Data

Fig. 2-1 REXC Battery Discharge Performance Curves at Different Discharge Rates

（25℃）

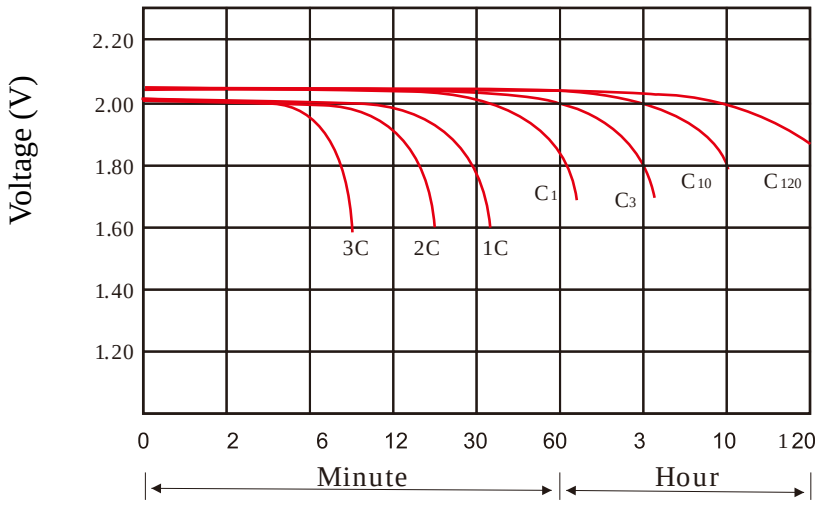


Fig.2-1 Discharge characteristic curve

2. Charge Curve

Fig.2-2 Recharge characteristics of REXC battery with current of $0.1C_{10}A$ and limit voltage of 2.30V/cell (25℃). The 100% DOD battery can be recharged 105% of capacity after charging for 24 hours. Imaginary line is the recharge curve of 50%DOD.

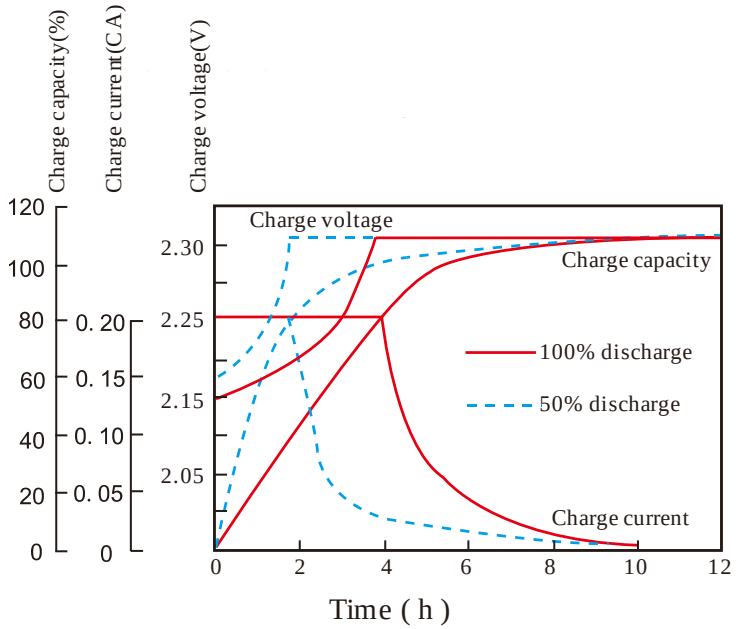


Fig.2-2 Charge characteristic curve

3. Internal Resistance and Short-Circuit Current

The internal resistance of the battery is a dynamic nonlinear parameter that is continuously changed along with the temperature and discharge state. The internal resistance is the lowest when battery is fully charged. The table 2-3 shows the internal resistance and short circuit current of REXC battery in fully charged state according to the IEC60896 standard. Pay attention to the battery to short-circuit causes the battery voltage to reduce to 0V, and will cause the battery internal component damaged.

Table 2-3 Referenced Internal Resistance and Short Current

Battery Type	Internal Resistance (mΩ)	Short Current (A)
REXC-200	0.55	3700
REXC-300	0.39	4752
REXC-400	0.30	6107
REXC-500	0.28	7211
REXC-600	0.23	8614
REXC-800	0.18	10873
REXC-1000	0.15	12835
REXC-1200	0.14	13874
REXC-1500	0.12	16882
REXC-2000	0.10	20660

Chapter Three Operation and Maintenance

1. Parameters Setup

Table3-1 Energy storage system parameter setup table (600V system)

Parameter name	Unit	Grid	Off-grid
Floating Voltage per cell	V/cell	2.25	2.25
Equalization Voltage per cell	V/cell	2.30	2.30
Charging Current	A/cell	$0.1C_{10}$	$0.2C_{10}$
Discharge under-voltage protection per cell	V	Please refer to table 3-2	
Condition To Change Equalization Charge To Float Charge	mA/Ah	< 5	< 5
Condition to Change Float Charge To Equalization Charge	mA/Ah	> 50	> 50
Pack equalization voltage	V	690	690
Pack floating voltage	V	675	675
Pack charging current	A	0.1C10	0.2C10
Pack discharge under-voltage protection	V	Please refer to table 3-2	
Temperature Compensate Ratio With Floating Voltage	mV/℃ / cell	-3	-3
Temperature Compensate Ratio With Equalization Voltage	mV/℃ / cell	-5	-5
High Temperature Warning	℃	35	35
Short circuit protection current	A	Please refer to table 3-2	

1. The voltage in above table is at 25℃. Please adjust the data according to table 3-3 at other temperature.

2. Energy storage system can be off-grid power supply and grid power supply according to real situation. The off-grid defined as tough power supply, to protect the battery better, please set refer to above table or contact to manufacture.

3. Above are standard setup parameters in table 3-1. We suggest you to set up end voltage (LVBD) based on different load current to make the battery life longer. Please refer to table 3-2.

Table 3-2 Voltage setup parameter of LVBD and LVLD

Load current（A）	End voltage（V/cell）	LVBD（V/pack）

$I < 0.025C_{10}$	1.97	594
$0.025C_{10} \leq I < 0.05C_{10}$	1.92	579
$0.05C_{10} \leq I < 0.1C_{10}$	1.87	564
$0.1C_{10} \leq I < 0.2C_{10}$	1.83	552
$0.2C_{10} \leq I < 0.5C_{10}$	1.75	528

If the battery is not recharged in time after discharge, or the power is off again during recharge, the insufficient-charged batteries will be frequently discharge, thus the batteries will lose part of capacity in short period. And it may cause capacity loss at initial stage and the batteries will be rejected if the situation is serious.

2. Capacity and Influence Factor

The capacity of battery is the capacity that battery can be discharged in the established conditions, expressed as signal C. The usual unit of capacity is ampere-hour, shortened as AH. The rated time is marked in the right and low corner of C, i.e. C_{10} is the capacity at 10 hours rate; C_3 is the capacity at 3 hours rate.

The capacity can be expressed in Rated Capacity or Actual Capacity. For Rated Capacity of REXC, please see Table 1-1. The Actual Capacity is the actual output capacity in certain discharge conditions, which is equal to product of the discharge current and the discharge time, the unit is AH. The actual capacity is effected by discharge rate, discharge mode, end voltage and temperature.

3. Ambient Temperature vs. Battery

The recommendation temperature for REXC is 15 ℃ ~ 25 ℃. Used at high or low temperature, battery performance will be affected. Table 3-3 is the working temperature range for battery.

Table 3-3 Working temperature range for battery

Working condition	Temperature range	Recommended temperature
Discharge	-40℃ ~ 50℃	15℃ ~ 25℃
Charge	-20℃ ~ 50℃	15℃ ~ 25℃
Storage	-20℃ ~ 40℃	15℃ ~ 25℃

Temperature affects capacity of the battery. Fig. 3-1 is the available capacity (10h rated, end voltage 1.80Vpc) curve vs. ambient temperature. When the temperature is low, the capacity will decrease, for example, the capacity will decrease 10% if temperature

decreases from 25 ℃ to 0℃; And too low temperature will cause battery long term insufficient charged, also will make negative plates sulfate and make battery unable to discharge.

The capacity will increase at some range when temperature rises. For example the capacity will increase 5% if temperature raises from 25℃ to 35℃. But when the temperature go up further, the capacity will increase slowly, and at last stop increasing. However, high temperature will quicken up plates' corrosion and cause water loss, thus shortens battery's life.

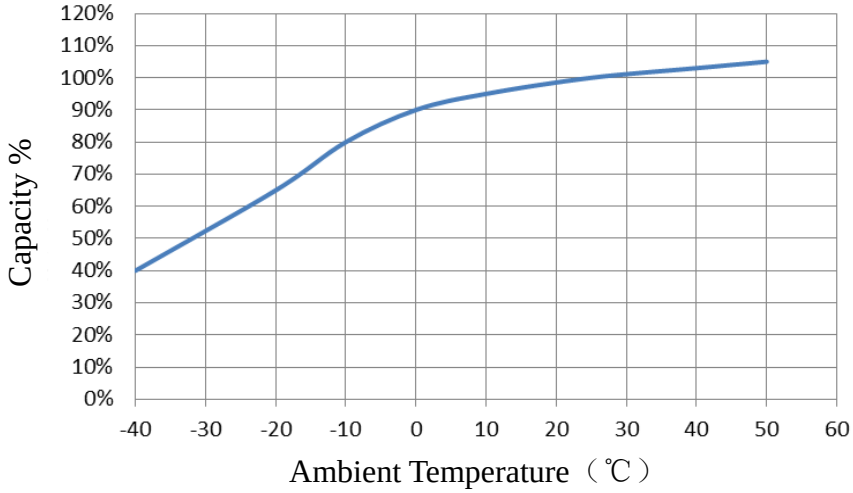


Fig.3-1 Available Capacity Curve VS. Ambient Temperature

3.1 Temperature and Floating Voltage, Equalization Voltage

The purpose to select certain floating voltage is make the battery operate in best conditions. If the floating voltage is higher, the floating current is also higher; it will accelerate the corruption of grids and shorten the life of the battery. If the floating voltage is lower, the battery can't be kept in fully charged state, this will crystallize $PbSO_4$, decrease the capacity, and also shorten the life of the battery. At 25℃, the floating voltage is 2.25V, at other temperature, please adjust according to Table 3-4. The temperature compensation coefficient for float charge is -3mV/℃/cell. Valve regulated sealed lead acid battery need to be equalized charge regularly, in order to guarantees the battery normal operation. REXC battery's equalization voltage is 2.30V/cell.

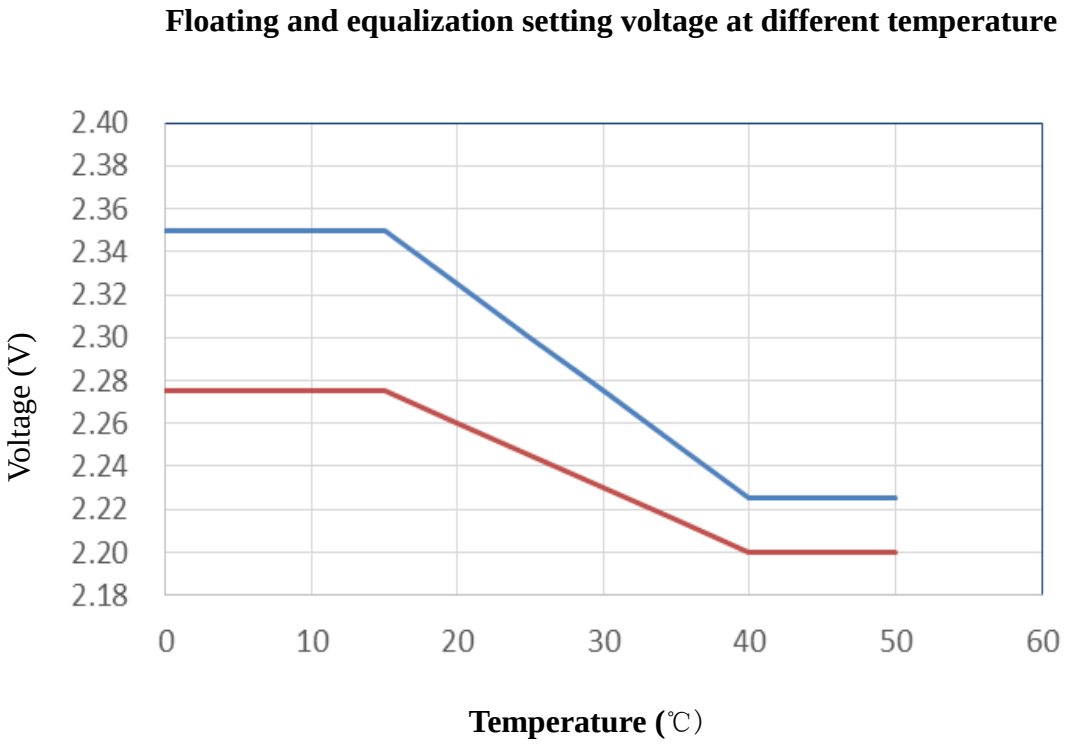


Fig. 3 - 2 The Voltage Setting Curve Vs. Ambient Temperature

If the voltage lower than 2.225 or higher than 2.35 after temperature correction, the suggesting adopted can be charging by 2.25V or 2.35V directly without using temperature compensation.

Table 3-4 Relationship of ambient temperature and voltage

Ambient Temperature(℃)	Equalization Voltage(V/cell)	Float Voltage(V/cell)
≤15	2.350	2.275
20	2.325	2.260
25	2.300	2.245
30	2.275	2.230
35	2.250	2.215
≥40	2.225	2.200

3.2 Ambient temperature vs. Battery Life

The high temperature will damage the battery, reduce the battery life. When temperature exceeds 25℃, the battery life will decrease half per 10℃ temperature raise. For example, the design life of battery is 20 years at 25℃, if the battery is

operate at 35℃ for long term, the life will be 10 years. Below is the formula:

$$L_{25} = L_T \times 2^{(T-25)/10}$$

Notes：T is the actual ambient temperature;

L_T is designed life at T ambient temperature

L_{25} is designed life at 25℃ ambient temperature

Ambient temperature elevating, also will accelerate the battery grids corrosion and the battery water loss, thus will greatly reduce the battery life. So it is important to control the ambient temperature. When heat is accumulated to a certain degree, it will damage the battery, seriously will lead to thermal run away. If indoor temperature reaches too high, please improve the ambient temperature by making room ventilated, etc. The battery spacing cannot to be less than 10mm, at the same time regulating cell floating and equalization voltage value according to handbook's request.

3.3 Conductance, Resistance vs. Capacity

There is a certain corresponding relationship between conductance & resistance and battery capacity. We suggest to test battery conductance and resistance data at different stage with same type instruments from same factory. Conductance and resistance data is only a reference to judge whether battery is good. These data cannot replace loading test to judge whether battery is good. Narada recommend to test these data on the surface or side of battery post. If there are several pairs of post, please test on nearest pair of post.

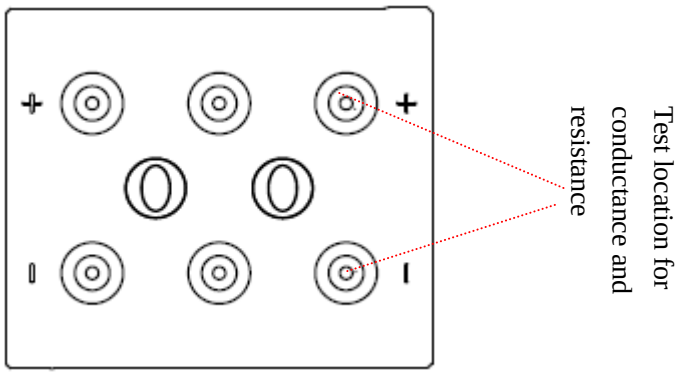


Figure 3-3 Test location for conductance and resistance

4. Requirement for Charge

4.1 Periodically Equalization Charge

The battery needs an equalization charge after floating operation over three months, or the voltage of at least two batteries are lower than 2.18V. The method of equalization charge is constant current and limited voltage, as follows: charge with constant current of $0.1C_{10}A$ ~ $0.15C_{10}A$ till the average voltage reaches equalization charge voltage of 2.30Vpc (25℃), then keep charging with

equalization charge voltage, meanwhile, the current is reduced, till the charge finished. The charging time is 24 hours.

4.2 Charge after discharge

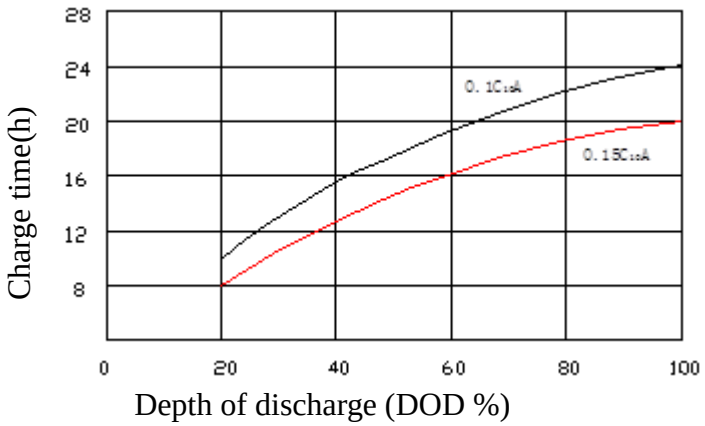
After discharge, the batteries should be charged in time. The charge method is constant current limit voltage as follows: charge with constant current of $0.1C_{10}A \sim 0.20C_{10}A$ till the average voltage reaches a certain voltage, then keep charging with this voltage, meanwhile, the current is reduced, till the charge finished.

The certain voltage could be equalization voltage or float voltage. When the depth of discharge is larger (normally larger than 10%), equalization voltage is recommended so as to give fully charge to the battery. We can also determine charge voltage according to initial current. When the current is larger than 0.05C10A (reference current to change to equalization charge), equalization voltage is recommended. The charge time is 24 hours. We can also setup the charge voltage according to different DOD, different charge current shown in figure 3-4, or we can judge according to charge current value.

Normally, the batteries are fully charged when the value of charge current is not changed for continuous three hours at the stage of constant voltage charge.

Sometimes, we need to charge a battery in a short time, we can raise charge current, but not higher than $0.25C_{10}A$.

Fig .3-4 The relationship between DOD and charge time



4.3 Battery recharging method

This method is used for battery charging for the first time after installing or battery recharging after long time storage.

- Recharging parameter

  We use equalizing charge to recharge the batteries, the parameter is as below:

1 Charging mode: equalizing charge;

2 Charging voltage: (2.30±0.002)V/cell;

3 Charging current limited: $0.05C_{10}A$;

4 Cut-off condition: the charging current is less than $0.005C_{10}$ with another extended 3 hours or charging time reached 24 hours (alternative);

- Recharging procedure

1 Connect the batteries in series with cables or copper bars, and make sure that all the screws tightened with each joint, then connect the anode of battery group to the anode of charging equipment (charger), and the cathode of battery group to the cathode of charger.

Pay attention: A breaker or fuse should be connected in the circuit in order to protect the batteries and charger, the capacity of breaker or fuse should be 1.5 times of circuit maximum current.

2 Turn on the charger, set the charging voltage and current according to 4.1 recharging parameter.

3 Turn the breaker or fuse, and then turn on the charger to recharging batteries.

4 Stop charging when reaching the cut-off condition. At the last one hour before finishing, test the battery voltage one by one, the battery which voltage is below 2.16V/cell should be dealt with the method in chapter 3.3, if that battery can not accord with the requirement, it should be rejected.

- Cycle procedure

We can use the method as below to recharge the batteries after long time storage (for example: more than 1 year):

First connect the batteries in series to the charger, discharge batteries with constant current $0.25C_{10}$ (A) for about 3 hours. Then use the method above to charge the batteries. Stop charging when reach the cut-off condition.

If the capacity still can't be renewed by this method, this means the batteries fail because of long time storage or other reasons.

4.4 Maintenance of wind/solar generating energy storage system

It is necessary to recharge one time every two months for maintenance because of the under-filling state of the batteries used in home energy storage system and wind/solar generating energy storage system. The battery maintenance method can operate as below:

In the case of mains supply, the maintenance and battery recharge methods be the same as clause 4.1.

In case of without mains supply, should cut off the load, then the solar and wind generating can charge the battery, but maximum limited voltage 2.30V/cell, maximum current 0.20 C_{10} A. The battery fully charged on condition that the charging current is less than 0.005C_{10} or the charging voltage stay constant for four hours.

5. Storage

The storage area of REXC series batteries must be clean, ventilated, dry and without direct sunshine. All lead acid batteries lose capacity when standing on open circuit because of self-discharge. The result is that the voltage of open circuit is decreased, and the capacity also decreased. The self-discharge rate is related with ambient temperature. The self-discharge degree is smaller when the ambient temperature is lower, otherwise is larger. Batteries should be supplementary charged if they have been stored for six months or the open circuit voltage is lower than 2.10V/cell. The equalization charge method should be adopted. All batteries, which are ready to store, should be fully charged before storage. It's suggested to record storage time in periodic maintenance record and record the time when another necessary supplementary charge should be made. The quality certificates of REXC series batteries record the latest charge time of the batteries, next charge time can be calculated according to this charge time.

6. Maintenance

In order to assure service life, the batteries should be correctly inspected and maintained. The maintenance methods of REXC batteries are recommended as follows:

6.1 Monthly Maintenance

- Keep the battery-room clean.
- Measure and record the ambient temperature of the battery-room.
- Check each battery's cleanness; check damage and overheating trace of the terminal, container and lid.
- Measure and record the total voltage and floating current of the battery system.

6.2 Quarterly Maintenance

- Repeat monthly inspection.
- Measure and record floating voltage of every on-line battery. If more than two cells' voltage is less than 2.18Vpc after temperature compensation, the batteries need to be equalization charged.

6.3 Yearly Maintenance

- Repeat quarterly maintenance and inspection.
- Check whether connectors are loose or not every year and tight them
- Make a discharge test to check with exact load every year, discharging 30-40% of rated capacity. Make an 80%DOD capacity test every year after three years' operation.

6.4 Operation and Maintenance Precautions

Insufficient Charge

If the floating voltage is not set correctly (too low or not compensate according to temperature), the battery system will in an insufficient charge state for a long period of time. When the electricity is out, the battery may not be able to work because the acid is satirized and the capacity is decreased.

Over Charge

If we neglect the performance of rectifier to transfer floating charge to equalization charge. If the rectifier cannot transfer charge modes because of its wrong performance or no adjustment, the battery system is always in an equalization charge state. Thus may cause serious problems for battery, such as water loss, life decrease, thermal runaway, deformation, etc.

Too low or too high temperature

We have mentioned that too low temperature will affect the capacity of battery. While too high temperature will also cause problems, such as water loss, life decrease, thermal runaway, deformation, etc.

Too low end voltage

The end voltage is also an important parameter for battery. The battery shall stop discharge when reach a certain voltage (The normal end voltage is 1.8Vpc for 10 hours rated). If the end voltage is too low, it will be difficult to recharge the battery and decrease the charge efficiency, thus reduce the life of battery.

Long time storage after discharge

If the battery is put aside without charge for a long time after discharge, it will affect the capacity and life of the battery, because some large size $PbSO_4$ will be created in the negative, which are difficult to transfer to active Pb. Thus it will affect battery life and capacity

Annex 1

VRLA Battery Regular Maintenance Record

Type		Place	
Status		Number of battery	
Total Voltage（V）	Current (A)	Temperature	
No.	Voltage（V）	No.	Voltage（V）
1		13	
2		14	
3		15	
4		16	
5		17	
6		18	
7		19	
8		20	
9		21	
10		22	
11		23	
12		24	
Check by sight			
Result:			
Tester:		Date:	