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LEAD-LINE

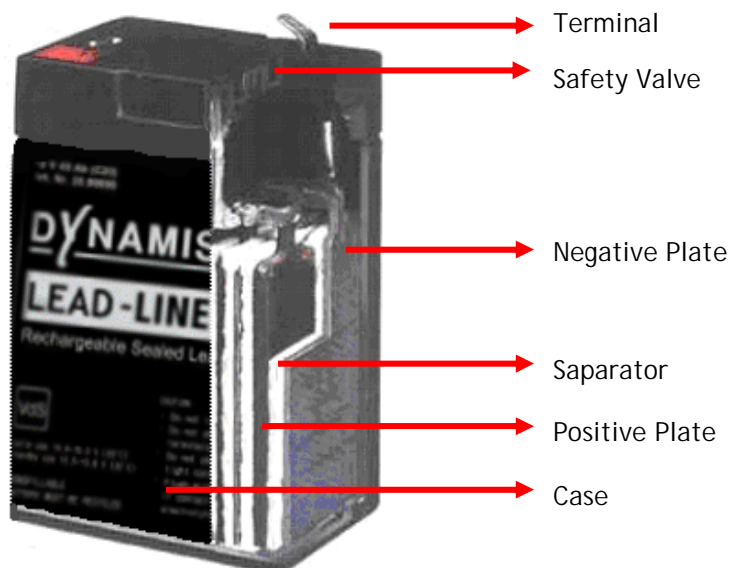
Rechargeable Sealed Lead-Acid Battery

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1. Construction of sealed lead acid batteries

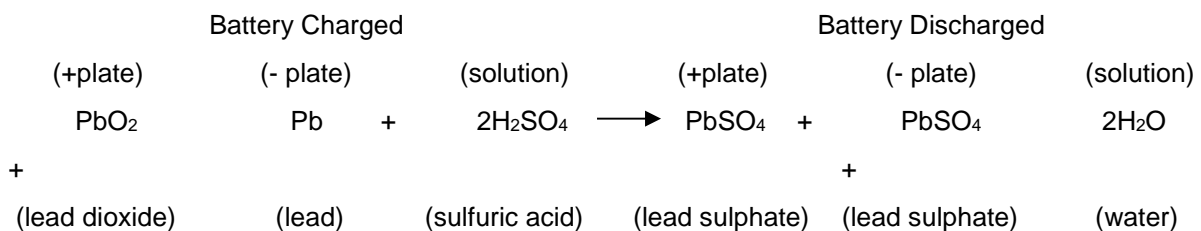
- I Positive plate: Pasting the lead paste onto the grid, and transforming the paste with curing and formation processes to lead dioxide active material. The grid is made of Pb-Ca alloy, and the lead paste is a mixture of lead oxide and sulfuric acid.
- I Negative plate: Pasting the lead paste onto the grid, and transforming the paste with curing and formation processes to sponge lead active material. The grid is made of Pb-Ca alloy, and the lead paste is a mixture of lead oxide and sulfuric acid.
- I Electrolyte: A high purity sulfuric acid solution, which is a reactant in the battery's main reaction and the conducting ions for electricity.
- I Separator: The absorbent glass mat, which is placed between the positive and negative plates to prevent shorting and to store the electrolyte.
- I Safety Valve: A one-way valve made of chloroprene rubber, which is to prevent the oxygen ingress into the battery and to release gas when internal pressure exceeds 0.5kgf/cm^2 .
- I Case: A container made of ABS plastics, which is filled with plates group and electrolyte.



2. Reactions of Sealed Lead Acid Batteries

When the lead acid battery is discharging, the active materials of both the positive and negative plates are reacted with sulfuric acid to form lead sulfate. After discharge, the concentration of sulfuric acid in the electrolyte is decreased, and results in the increase of the internal resistance of the battery.

On charging, the battery reactions are reversed, i.e., the lead sulfate of the positive plate is converted to lead dioxide, and the lead sulfate of the negative plate is converted to sponge lead, with the production of sulfuric acid and results in the increase of electrolyte concentration.



As the charge nears completion little lead sulfate remains to convert to lead dioxide or lead. The charging current begins to decompose water into oxygen and hydrogen, i.e., the oxidation of water into oxygen at the surface of positive plate and the reduction of proton into hydrogen at the surface of negative plate. For the conventional flooded lead-acid battery, the evolved oxygen and hydrogen bubble to the top of the electrolyte and escape to outside, and water loss is resulted. For the valve regulated lead-acid battery, the evolved oxygen from the positive plate is easily transported to the negative plate to be absorbed through the gas tunnel in the glass mat separator with starved electrolyte. The absorbed oxygen depolarizes the negative plate with the formation of lead sulfate, and no hydrogen is generated in this condition. With very little gas evolution, the water loss of VRLA battery is minimized.

3. Sealed lead acid batteries characteristics

3.1 Battery Capacity

- I Battery capacity is expressed as Ampere-hour (Ah), which is the product of discharged current and the discharged time in hours.
- I Discharge rate is indicated by C/t, C is the nominal capacity of the battery, t is the discharge time.
- I The nominal capacity of the sealed lead acid battery is a capacity using 20 hour discharge rate. For example, the capacity of WP5-12 battery is 5Ah, when the battery is discharged with C/20 rate, i.e., 0.25 amperes, the discharge time will be 20 hours.
- I The battery capacity is varied with the discharge rate. The larger the discharge current, the smaller is the battery capacity. The relation between the battery capacity and the discharge rate is as follows:

Discharge rate		20HR	10HR	5HR	3HR	1HR	1CA	3CA
Capacity type	Regular type	100%	100%	85%	77%	60%	45%	35%
	High rate type	100%	100%	85%	80%	75%	70%	50%

The information about the discharge current or power within specific discharge time of our regular or high rate types sealed lead acid batteries products are available through our product specification catalogues.

- I The temperature influences the battery capacity. The relation between the capacity and temperature is as follows:

Temperature		0°C	10°C	20°C	30°C	40°C
Capacity	1HR~3CA	82%	91%	100%	106%	113%
	20HR~1HR	87%	93%	100%	105%	110%

- I The battery capacity may be also expressed by discharge power (Watt), which is the available discharge power within 15 minutes.

3.2 Battery Voltage

- I The open circuit voltage of lead acid battery indicates the equilibrium voltage of the battery's main reaction. The concentration of the sulfuric acid participated in the main reaction is the major factor influencing the open circuit voltage.
- I Right after charge or discharge, the concentration of sulfuric acid inside the plates is still changing due to the diffusion process. It takes several hours to several days to stabilize the open circuit voltage.
- I The concentration of sulfuric acid in the battery is an indicator of battery capacity. Therefore, the state of charge of the battery is available through measuring the open circuit voltage. The relation between the battery capacity and open circuit voltage is as follows:

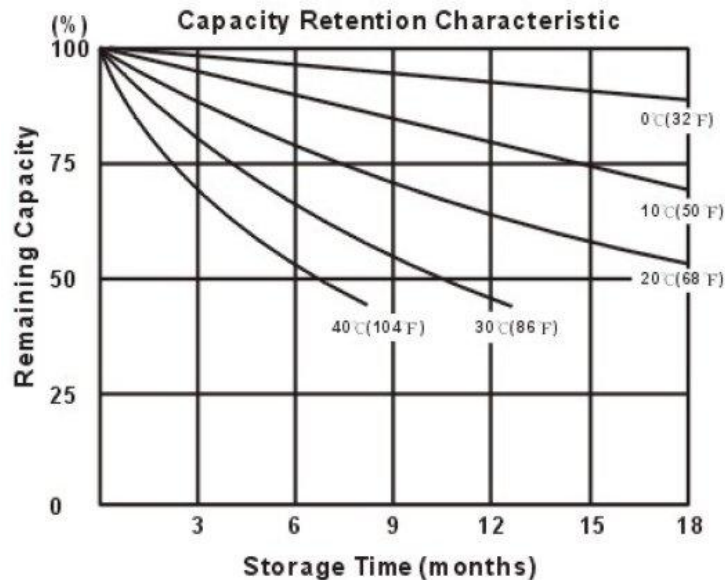
Capacity	6V OCV	12V OCV
100%	$V > 6.5V$	$V > 13.0V$
90%	$6.40 < V < 6.50$	$12.80 < V < 13.00$
80%	$6.33 < V < 6.40$	$12.65 < V < 12.80$
70%	$6.25 < V < 6.33$	$12.50 < V < 12.65$
60%	$6.18 < V < 6.25$	$12.35 < V < 12.50$
50%	$6.10 < V < 6.18$	$12.20 < V < 12.35$
40%	$6.03 < V < 6.10$	$12.05 < V < 12.20$
30%	$5.95 < V < 6.03$	$11.90 < V < 12.05$
20%	$5.88 < V < 5.95$	$11.75 < V < 11.90$
10%	$5.80 < V < 5.88$	$11.60 < V < 11.75$

3.3 Battery Self-discharge

- I The lead acid battery will have self-discharge reaction under open circuit condition, in which the lead is reacts with sulfuric acid to form lead sulfate and evolve hydrogen. The reaction is accelerated at higher temperature. The result of self-discharge is the lowering of voltage and capacity loss.
- I Batteries will lose capacity due to self-discharge through packing, transportation and storage process at various temperatures. The relation between battery capacity and storage temperature and time is as follows:

Time \ Temperature	1 month	3 month	6 month	12 month
0°C ~ 5°C	96%	93%	90%	80%
5°C ~ 20°C	92%	90%	80%	65%
20°C ~ 30°C	90%	80%	65%	50%
30°C ~ 40°C	83%	70%	50%	Not allowed

The above data is shown in the following graph:



- I The remaining capacity of battery after storage can be obtained by measuring its open circuit voltage and referring to the capacity verse OCV table. Obviously, the OCV should be measured before recharge.
- I Batteries stored longer than three months should be recharged before shipping.

3.4 Battery Internal Resistance

- I As the capacity of lead acid battery decreased or the battery is aged, its internal resistance will be increased. Therefore, the internal resistance data may be used to evaluate the battery's condition.
- I There are several internal resistance measurement methods, and their obtained values are sometimes different each other.
- I Conductance, i.e., the reciprocal of internal resistance, which is expressed as mho or Siemens, has some kind of positive proportionate relationship with the battery capacity.

3.5 Battery Life

- I Standby use battery life: 3 ~ 5 years under 2.3Vpc and 25°C floating charge condition.
- I Cycle use battery life: 200 cycles (100%DOD)
225 cycles (80%DOD)
500 cycles (50%DOD)

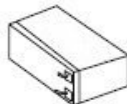
4. Operation of sealed lead acid batteries

4.1 Preparation prior to operation

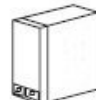
- I Batteries should always be fully charged prior to use, especially when use it for the first time right after purchasing or after long period storage. Batteries after long period storage will lose some capacity due to self-discharge, and need recharge to restore its full performance.
- I Do not put sealed lead acid batteries in airtight containers, or install the batteries in a room without ventilation. Gas generated by over charging reactions in the battery may explode if ignited by sparks from machinery or switches.
- I Tightly screw the connector with the terminal of the batteries.
- I Do not lay a metallic object on top of a battery.
- I Insert insulation that is acid and heat resistant between the batteries and any metallic housing.
- I Do not charge the battery with upside down position, it may cause acid leakage.



upright (○)



side(△)



side(△)

- I Batteries must be stored or used in the temperature range of:
Charging: 0°C ~ +40°C
Discharging: -15°C ~ +50°C
Temperatures above or below these ranges could result in damage or deformity of the battery.

4.2 Charging methods for standby use batteries

- I The purpose of charging standby use batteries is to compensate self-discharge. The constant voltage charging method is commonly applied.
- I Standby batteries are continuously overcharged at a voltage only slightly above their open circuit voltage, called float voltage. The low float voltage

induces low float current and minimum grid corrosion, which are the requirements for long battery's float service life. Such charging mode, which is called floating charge, allows batteries to be continuously overcharged all the year round in order to provide full and stable capacity.

- I The float charge voltage is 2.25~2.3V/cell at 25°C. However, when the ambient temperature is too high or too low, the above voltage setting may induce either too high side reaction rates or not enough charge. Therefore, the float voltage is suggested to change with temperature, and the compensation coefficient is -3.0mV/°C/cell, or as the following table:

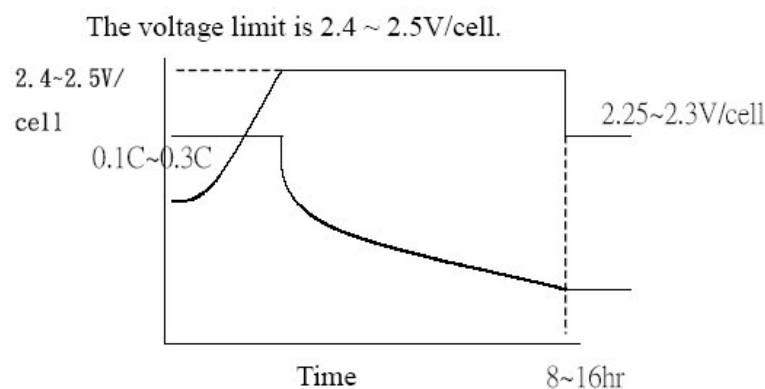
Temperature(°C)	0	5	10	15	20	25	30	35	40
Float voltage(Vpc)	2.35	2.34	2.32	2.31	2.30	2.28	2.26	2.25	2.23

4.3 Charging methods for cyclic use batteries

- I The cycle life of batteries is influenced by the following factors: the charging mode, the battery's temperature, the battery's charging frequency, and the depth of discharge. Proper charging mode is the most important factor affecting battery's cycle life.
- I The charging voltage for the valve regulated lead acid battery should not be larger than the gassing voltage, i.e., 2.4~2.5V/cell. The gassing voltage varies with temperature, and is decreased as the temperature is increased. Its temperature coefficient is -5.0mV/°C /cell, or as the following table:

Temperature(°C)	0	5	10	15	20	25	30	35	40
Gassing voltage(Vpc)	2.58	2.55	2.53	2.50	2.48	2.45	2.43	2.40	2.38

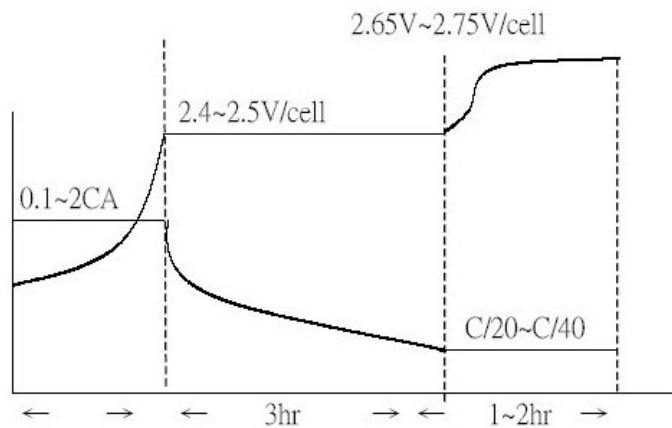
- I The most effective charging method for VRLA battery is the constant voltage (CV) charging mode. For the fully discharged (100%DOD) battery, for example, it may be charged at 2.4 ~ 2.5V/cell, with the highest possible current limit, in about 16 hours. For the 50% discharged battery, it may be charged in 8 to 10 hours using a CV of 2.4 ~ 2.5V/cell.
- I The popular charging method for VRLA battery is the constant current/ constant voltage (CICV) charging mode. In the first stage, the constant current (0.1C~0.3C) charging is performed before reaching the voltage limit.



The above charging mode needs long enough time to fully charge the battery. However, for charging the electric vehicle battery system with limited time, the CICV charging mode may sometimes not be able to fully charge the battery. If one battery is not fully charged in a long string of batteries, that battery will have faster degradation and then cause a capacity loss of the long string after many cycles of deep discharge. Such result comes from the little differences in charging efficiency among different cells. In the constant voltage charging stage, the current density is gradually decreased to a very small value; it is difficult to allow all cells to have the same amount of charge unless charging with long enough time. In discharge, all cells should deliver the same amount of charge. In consequence, the lower capacity cells will experience deeper discharge and faster degradation.

- I A three-stages charging mode is introduced for long string and deep discharge cyclic applications, which would allow every cell to be fully charged in short duration. The first two steps are the same as the CICV method, with the modification that the constant current should be larger than 0.6CA and may be as high as 2CA for some electric vehicle battery applications. The constant voltage step may be lasted for 1 to 3 hours with voltage limit of 2.4~2.5V/cell.

A third stage is added and it is the constant current charging with current density smaller than 10-hour rate (10-hour to 40-hour rate), and with duration limited to 1 to 2 hours. In this third stage, there is no voltage ceiling, although the cell voltage will always be finally flattened around 2.65 ~ 2.75V/cell. The voltage of the final stage may seem too high, however, with the small current and short duration restriction, the negative effect on the battery is minimized.



4.4 Discharge protection of batteries

- I The discharge cut off voltage of lead acid batteries should be decreased when the discharge rate is increased. The recommended values for 12 volts batteries are as follows:

Discharge rate	20HR	10HR	5HR	4HR	3HR	1HR	1 ~ 3CA
Discharge cut off voltage	10.8V	10.8V	10.5V	10.2V	10.2V	9.6V	9.6V

- I To deeply discharge the battery to values below 1.60V/cell, or to leave the battery in a discharged state for long period, the battery be will seriously damaged, and this situation should be avoided.
- I The discharged batteries should be recharged or floating charged immediately.

4.5 Equalization charging

- I Cyclic use batteries after charge and discharge for 20 to 40 cycles are suggested to perform one equalization charge. Before such equalization charge, it is beneficial to allow the battery to be deep discharged with small current. The purpose of this treatment is to activate the plates and to restore the capacity of the battery.

- I The discharge / charge treatment starts with further discharging the already high rate discharged battery with constant current of 40 hour rate (C/40 Amp) to 1.75V/cell. After rest for one hour, a proper equalization charge to fully charge the battery is performed. A two-stage constant current charging is suggested. The first stage is the charging with 0.3CA constant current to 2.4V/cell. The second stage is the charging with 20-hour rate (C/20 Amp) constant current to maximum voltage until the voltage is leveled up for three hours.

4.6 Thermal runaway phenomena

Thermal runaway is an abnormal phenomenon happened in charging process, which is shown as a bloated battery. Thermal runaway means a state of operation where heat generation increases faster than heat dissipation, which may happen on severe overcharging or electrolyte dry-out. The result is an increase of the battery's temperature. At elevated temperature, the internal oxygen cycle is accelerated, and the developed heat causes further increase of the battery temperature. With this self-accelerating cycle, the thermal runaway is resulted, and the battery will be severely deformed and bloated. Several precautions are listed as follows to prevent the thermal runaway:

- I Avoid the dry-out of batteries: Do not charge at voltage higher than gassing voltage (2.4V/cell) for too long duration, e.g. >12 hours.
- I Any defective battery, e.g., the short-circuited or aged battery, in a long string of batteries should be removed immediately to prevent the overcharging of other batteries.
- I The internal oxygen cycle reaction usually happens in the overcharging stage, where the originally decreasing current density may increase instead of in the constant-voltage-charging mode. If the cut-off condition for the charger is relied on the smallness of the current density, this setting may be too low to be fulfilled when the battery is aged. The charger is continues to overcharge the battery until the thermal runaway happens.
- I Always avoid the local overheating of batteries. Be equipped with heat dissipating devices or temperature sensors in order to stop charging when necessary.

5. Maintenance of sealed lead acid batteries

5.1 The storage and maintenance of batteries

- I Storage temperature range: -30 °C ~ 50°C
humidity range: 25% - 85%
- I Fully charge the batteries before storage; if not, battery life will be shorter.
- I Use the batteries on a first-come basis, as batteries gradually deteriorate even under proper storage conditions. Batteries stored for over long periods may not restore to their initial capacity even after recharging.
- I Batteries under storage at ambient temperature of 25°C should be recharged every six months to maintain their quality, performance and reliability. The interval of this charge should be reduced to 50% by each 10°C rise in temperature above 25°C.
- I Charge the batteries based on storage temperatures, as follows:
 - <20°C storage: charge every 9 months
 - 20°C ~ 30°C storage: charge every 6 months
 - >30°C storage: charge every 3 monthsRecharge method: To charge with constant voltage of 2.4 ~2.5V/cell and initial current of 0.4CA and total duration of 5 ~ 8 hours.

5.2 The detection and remedy of "defective" batteries

- I This paragraph will describe how to differentiate the defective batteries from the restorable batteries when abnormal phenomena happen during the early usage or warranty period.
- I Measuring the following parameters may disclose the battery's condition: open circuit voltage, internal resistance, battery capacity and the charging behavior. Using one parameter for criterion is better double-checked by other parameters. The most commonly method is the measurement of open circuit voltage.
- I The OCV of new batteries should be above 6.45V(for 6V battery) or 12.9V(for 12V battery). After transportation, storage and different discharge factors, batteries' OCV will have values from 12.9V to even 0.0V. If the battery's OCV is below 1.93Vpc, or 5.79V(for 6V battery), or 11.58V(for 12V battery), this battery is a defective battery due to over-discharging or some kind of deterioration. This kind of battery has permanent damage even after recharge.
If remedy of such kind of battery is desired, please contact our Company.
To evaluate batteries with voltages higher than the above-mentioned value,

fully recharge the battery before any measurements.

- I If the fully recharge of batteries is not possible, batteries with OCV or internal resistance values far from its average values can be classified as defective batteries.
- I The OCV should be measured one hour (24 hours is better) after recharge. The fully charged battery with OCV smaller than 6.2V(for 6V battery) or 12.5V(for 12V battery) is a defective battery.
- I The fully charged battery should have OCV higher than 6.45V(for 6V battery) or 12.9V(for 12V battery). If the battery has values between 6.2 ~ 6.45V(for 6V battery) or 12.5 ~ 12.9V(for 12V battery), it may not be fully charged, and may need a recharge with proper charger. If this condition is not improved, the battery's capacity may have been reduced.
- I The remedy method for charging the hard-to-recharge battery is available through contact with our Company.

5.3 The recycling of batteries

- I The defective and used batteries shall be recycled.
- I When recycling batteries, the battery terminals should have insulation treatments. The batteries have residual capacity even for the used batteries. Batteries with terminals not insulated may cause danger of explosion or fire.
- I It is lawful for people to return the scrap batteries to the sale store for recycling.

