FGS

PURE ENERGY

Technical Manual v.1.0

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1. Construction of sealed lead acid batteries

- **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.
- **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.
- **Electrolyte:** A high purity sulfuric acid solution, which is a reactant in the battery's main reaction and the conducting ions for electricity.
- **Separator:** The absorbent glass mat, which is placed between the positive and negative plates to prevent shorting and to store the electrolyte.
- **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.
- **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.

Battery Charged											
						Battery Discharged					
(+ plate)		(- plate)		(solution)		(+ plate)		(- plate)		(solution)
PbO_2	+	Pb	+	$2H_2SO_4$	$\rightarrow$	$PbSO_4$	+	$PbSO_4$	+	$2H_2O$
(lead dioxide)		(lead)		(sulfuric acid)		(lead sulfate)		(lead sulfate)		(water)

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 transport 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

- Battery capacity is expressed as ampere-hour (Ah), which is the product of discharged current and the discharged time in hours (A*h).
- Discharge rate is indicated by Ct, C is the nominal capacity of the battery, t is the discharge time.
- The nominal capacity of sealed lead acid battery is calculated according to JIS C8702-1 Standard with using 20-hour discharge rate. For example, the capacity of FG20451 battery is 4,5Ah, which means that when the battery is discharged with C_{20} rate, i.e., 0.25 amperes, the discharge time will be 20 hours.
- 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	Regular type	100%	95%	85%	75%	60%	50%	40%
	High rate type	100%	95%	85%	75%	60%	58%	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.

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

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

- The batterycapacity sometimes will be represented al watts. For example, the model 12FGHL34 is a 12V battery with constant power 35 watts/ Cell [equal to 210W (35W * 6cell)], which can be discharged for 15 minutes at such constant power.

3.2 Battery Voltage

- The open circuit voltage of lead acid battery is indicated the equilibrium voltage of the battery's main reaction. The concentration of the sulfuric acid participated in the main reaction and the condition of batteries are the major factors influencing the open circuit voltage.
- Right after charge or discharge, the concentration of sulfuric acid inside the plates is still changing due to the diffusion process. It takes at least 24 hours to stabilize the open circuit voltage.
- The concentration of sulfuric acid in finished battery is an indicator of battery capacity. Therefore, the capacity of 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

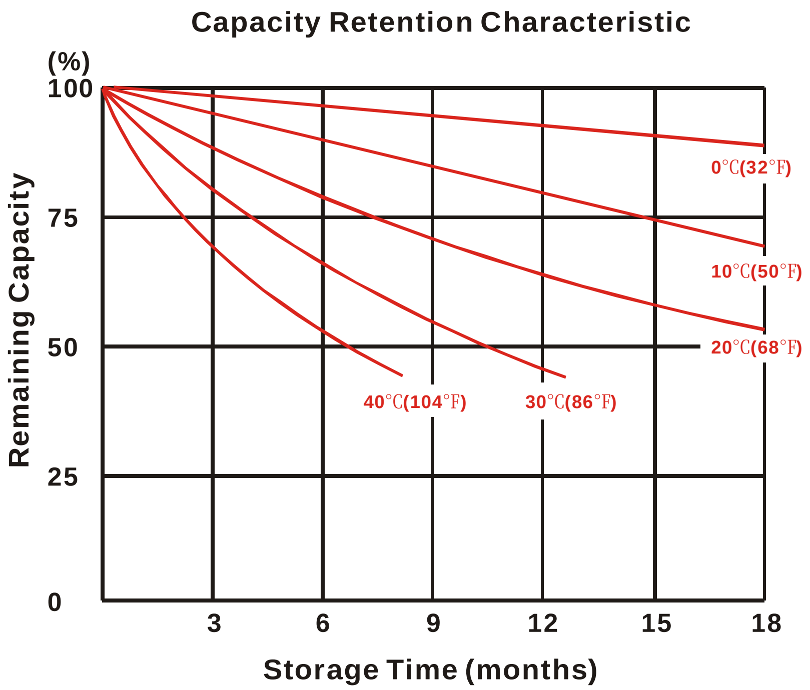
3.3 Battery Self-discharge

- The lead acid battery will have self-discharge reaction under open circuit condition, in which the lead is reacted 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.
- 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℃ ~ 5℃	96%	93%	90%	80%
5℃ ~ 20℃	92%	90%	80%	65%
20℃ ~ 30℃	90%	80%	65%	50%
30℃ ~ 40℃	83%	70%	50%	Not allowed

The above data is shown in the following graph:



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

3.4 Battery Internal Resistance

- 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.
- There are several internal resistance measurement methods, and their obtained values are sometimes different each other.
- 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

- Regular Type
  ◇ Standby use battery life:
  3 ~ 5 years under 2.3Vpc and 20℃ floating charge condition.
  ◇ Cycle use battery life: 200 cycles (100%DOD)
  225 cycles (80%DOD)
  500 cycles (50%DOD)

- High Rate Type
  ◇ Standby use battery life:
  3 ~ 5 years under 2.3Vpc and 20℃ floating charge condition.
  ◇ Cycle use battery life: 225 cycles (100%DOD)
  250 cycles (80%DOD)
  750 cycles (50%DOD)

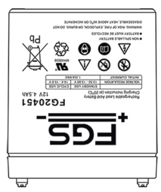
4. Operation of sealed lead acid batteries

4.1 Preparation prior to operation

- 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.
- 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.
- Tightly screw the connector with the terminal of the batteries.
- Do not lay metallic object on top of a battery.
- Insert insulation that is acid and heat resistant between the batteries and any metallic housing.
- Do not charge the battery with upside down position, it may cause acid leakage.

Upright (○)

Side(△)



Upside down(╳)

- Batteries must be stored or used in the temperature range of:

  Charging: 0℃ ~ 40℃

  Discharging: -15℃ ~ 50℃

  Temperatures above or below these ranges could result in damage or deformity of the battery.

4.2 Charging methods for standby use batteries

- The purpose of charging standby use batteries is to compensate self-discharge. The constant voltage charging method is commonly applied.

- 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.
- The float charge voltage is 2.25~2.3V/cell at 20℃. 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 be changed accompany with temperature changes, and the compensation coefficient is –3.0mV/℃/cell , or as the following table:

Temperature(℃)	0	5	10	15	20	25	30	35	40
Float Voltage(Vpc)	2.36	2.35	2.33	2.32	2.30	2.28	2.27	2.25	2.24

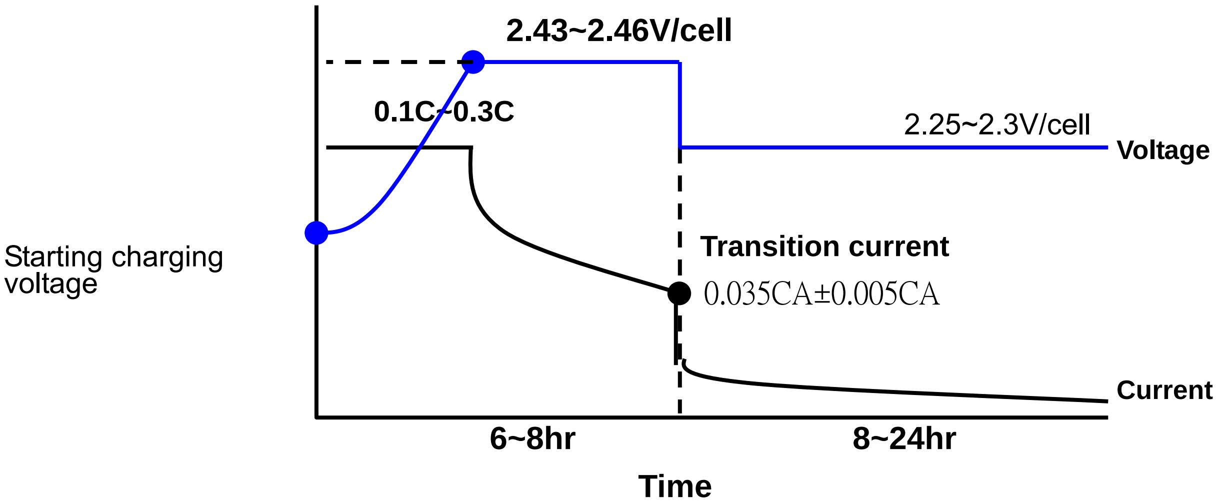
4.3 Charging methods for cyclic use batteries

- 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 which affects battery's cycle life.
- The charging voltage for the valve regulated lead acid battery should not be in excess of the gassing voltage, which is 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/℃/cell.
- The most effective charging method for VRLA battery is the constant voltage (CV) charging mode. To take the fully discharged (100%DOD) battery as an example, the recommend charge mode is to charge at 2.4 ~ 2.5V/cell, with the highest possible current limit, within about 16 hours. For the 50% discharged battery, the recommend charge mode is to charge within 8 to 10 hours using a CV of 2.4 ~ 2.5V/cell.
- The regular charging method for VRLA battery is the constant current/

constant voltage (CICV) charging mode. Please see the following diagram:

In the first stage, the constant current (0.1C~0.3C) charging is performed before reaching the voltage limit.

The voltage limit is 2.43 ~ 2.46V/cell



Generally, this kind of charging mode will take a bit longer time to have battery fully recharged. It is usually found that battery is over-discharged in a cyclic use device/application which results in less performance life. It is recommended to set the starting charging voltage at lower level (the lower the better), so that the battery can get recharging more easily after it's been over-discharged due to improper usage or device/application failure.

When battery is under overcharging, the chemical reaction of hydrolysis will accompany. Thus, if battery is recharged under high voltage for long time, it will lead battery water loss and battery life ends up. Therefore, while the second stage of float charging current reaches transition point, we recommend adjusting charging voltage into the third stage/floating charge process.

The more series connection of battery quantity is, the more accurate of voltage setting of charger will be requested, and the tolerance of charging voltage setting should be given smaller. So it can avoid the charging voltage becoming too high and then lead earlier battery life end up.

4.4 Discharge protection of batteries

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

Discharge current and final discharge voltage

Discharge current (A)	Final discharge Voltage(V/cell)
(A)≦0.2C	1.75
0.2C≦(A)＜0.5C	1.70
0.5C≦(A)＜3.0C	1.60
(A)≧3.0C	1.40

- To deeply discharge the battery to voltage under 1.60V/cell, or to leave the battery in a discharged condition for long period of time, the battery will be seriously damaged, so this situation should be avoided.
- The discharged batteries should be recharged or floating charged immediately. If batteries are over-discharged for a long time, their capacity can not be recovered to the original level

4.5 Description of torque value of hard ware for the terminals:

Diameter	Recommended torque value	Maximum allowable torque value
M5	2.94 N-m (30kg-cm)	4.90 N-m (50kg-cm)
M6	5.39 N-m (55kg-cm)	8.82 N-m (90kg-cm)

M8	7.35 N-m (75kg-cm)	9.80 N-m (100kg-cm)

4.6 Equalization charging

- 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.
- 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.

4.7 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 be happened 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:

- 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.
- 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.

- The internal oxygen cycle reaction is usually happened in the overcharging stage, where the originally decreasing current density may increase instead 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 continued to overcharge the battery until the thermal runaway happened.
- 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

- The storage temperature range: -30℃ ~ 50℃, the humidity range: 25%-85%.
- Fully charge the batteries before storage; if not, battery life will be shorter.
- 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.
- Batteries under storage at ambient temperature of 25℃ 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℃ rise in temperature above 25℃.
- Charge the batteries based on storage temperatures, as follows:

  <20℃(68℉) storage: charge every 9 months
  20℃~30℃(68℉-86℉) storage: charge every 6 months
  >30℃ (86℉) storage: charge every 3 months

RECOMMENDED RECHARGING INTERVAL & METHOD

STORAGE TEMPERATURE	RECHARGE INTERVAL & METHOD
Below 20℃(68℉)	9 months, charge for 16 hrs at 2.4V/cell
20℃-30℃(68℉-86℉)	6 months, charge for 16 hrs at 2.4V/cell
above 30℃(86℉) (avoid this storage condition)	3 months, charge for 16 hrs at 2.4V/cell

5.2 The detection and remedy of “defective” batteries

- This paragraph will describe how to differentiate the defective batteries from the restorable batteries when abnormal phenomena happened during the early usage or warranty period.
- 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.

- 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 is necessary before any measurements.
- If the fully recharging of batteries is not possible, battery with OCV or internal resistance values far from its average values can be classified as defective battery.
- 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.
- 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 recharge with proper charger. If this condition is not improved, the battery's capacity may have been reduced.
- The remedy method for charging the hard-to-recharge battery is available through contact with our Company.

5.3 The recycle of batteries

- The defective and used batteries should be recycled.
- When cycling 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.

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