VALVE REGULATED LEAD ACID BATTERIES

1. Introduction

The conventional lead acid batteries used in signalling circuits as a source of D.C supply suffers from number of maladies which enclosed regular topping-up a separate storage arrangement which amount to increases maintenance and reduced reliability. The new improved valve regulated lead acid (VRLA) battery over come much of these earlier deficiencies.

As the name suggests, these are sealed valve regulated batteries with absorptive glass mat (AGM) separator to permit the oxygen evolved from the positive plate to the fuse to the negative plate. The microporous glass separator as used in VRLA is not completely saturated with electrolyte and the wide space thus available allows an unimpeded access of oxygen to the negative plate. The oxygen gas gets reduced at the negative plate surface, thereby effectively suppressing the evolution of hydrogen. Consequently, Power stacks cells do not loose any water under normal operation and therefore, no topping-up is required.

Valve regulated lead acid battery (VRLA) use a patented MFX alloy for the positive grid, which exhibits excellent deep discharge performance. In addition it has a universally acclaimed maintenance free lead calcium alloy for the negative grid. The power stack cells so formed require very little maintenance and have longer life duration.

2. Salient features and advantage

VRLA batteries are based on “Starved electrolyte design and Oxygen recombination principle.” The important functional features and advantages are as under.

- ♦ No periodic topping up of electrolyte is required.
- ♦ No spillage of electrolyte as it is sealed.
- ♦ These cells are supplied in fully charged condition, therefore, no initial charging is required.
- ♦ These have very low self-discharge the order of 20% to 25% of conventional lead acid batteries.
- ♦ These can be used as either vertically or horizontally. They are available in stackable steel trays capable of being mounted one over the other. Therefor, they occupy very less space.
- ♦ They do not emit any toxic, corrosive acid fumes, hence can be installed in the equipment room itself, saving the battery room.
- ♦ They are lighter in weight by about 25% when compared to conventional lead acid batteries.
- ♦ They have 30% to 40% longer life than the conventional lead acid batteries.

3. Constructional features

The main components of lead acid cell are as under.

3.1 Positive plates

Positive plate consists of a number of flat tubes, containing patented MFX alloy.

3.2 Negative plate

It is made of lead-calcium alloy.

3.3 Container

Container of battery is made of suitable flame retardant Polypropylene Copolymer plastic (PPCP) with high insulating strength to resist acids and low permeability to water vapors. The container is enclosed in epoxy coated steel trays. The steel tray is so designed as to permit both vertical and horizontal stacking of cells.

3.4 Electrolyte.

The sulfuric acid and water used as electrolyte for the battery confirming to IS 266-77 and IS 1069-64 respectively.

3.5 Separators

Separators consists of either of microporous glass mat or synthetic material having high acid absorption capabilities and also resistant to sulfuric acid.

3.6 Safety Vent Plug

The plug is explosion resistant and is of pressure regulating type. Safety Vent Plug does not permit ingress of air into the unit.

3.7 Terminals

The terminals of the battery generally comprise of solid copper core.

3.8 Nuts and Bolts

Nuts and bolts used to connect the cells are made of copper, brass or stainless steel. These are effectively lead coated in order to prevent corrosion.

4 Recombination Principles

Under typical charging conditions, oxygen at the positive plate occurs before the evolution of hydrogen at the negative plate. This feature is utilized in the design of VRLA batteries.
The oxygen gas evolved at the positive plate instead of bubbling upwards is transported in the gaseous phase through the separator medium to the negative

plate. The separator which is of highly absorbent glass mat type has very high porosity designed to have pore volume in excess of the electrolyte volume (starved electrolyte design), due to which the Oxygen gas finds an unimpeded path to the negative plate. Reaction reduces the Oxygen gas with the spongy lead at the negative plate turning a part of it into a partially discharged condition, there by effectively suppressing the hydrogen gas evolution at the negative plate. This is what is known as the Oxygen recombination principles.

4.1 Principle of VRLA Battery

The VRLA battery is designed so that the negative plate does not have to be fully charged even when the positive plate is charged fully. Here no H_2 gas is generated from the negative plate though O_2 gas is generated from the over charged positive plate. The O_2 gas so generated from the positive plate reacts with charged spongy lead (Pb) of the negative plate and forms Lead Monoxide (PbO). The Lead Monoxide in turns reacts with Sulfuric Acid (H_2SO_4) in the electrolyte and forms Lead Sulphate ($PbSO_4$), thus allowing the negative plate to be discharged. In other words, O_2 from the positive plate is absorbed by the negative plate without being expelled to the outside. Since the negative plate develops discharging with the help of O_2 evolved at positive plate during charging, the negative plate as a result never generates H_2. This completely prevents the loss of water. The over all reactions may be expressed as follows.

$Pb + \frac{1}{2} O_2 \longrightarrow PbO$ (-ve plate)
(-ve charged)

O_2 generated from positive plate

$H_2O + PbSO_4 \longleftarrow H_2SO_4 + PbO \downarrow$

$PbSO_4 + 2e^- + 2H^+ \longrightarrow H_2SO_4 + Pb$

(All above reactions are exothermic reactions)

Manufacturers supply duly charged batteries and thus no initial charging is required and therefore these are ready to use. Such a battery requires no topping up and maintenance except for periodic cleaning of the terminals. The battery has self sealing vent plug, which normally does not open out in service. Under normal conditions they emit no corrosive fumes or gases.

5. Receiving the shipment

- Check the packing boxes carefully for any damage during transportation and handling.
- Check the number of packages as per packing slip.
- During unloading, care must be taken to prevent dropping the packing boxes on the ground since this can cause damage to the batteries.
- Protect the packing cases from sunlight or other sources of heat exposure even for short periods as it can cause permanent damage to the battery.
- Protect the packing cases from rain or other sources of water.

6. Storage

6.1 General

- Batteries should be stored in a cool and dry location, protected from direct sunlight and rain.
- Do not stack the packing boxes one on top of the other.
- As far as possible store the battery at temperatures of 25°C to 32°C.

6.2 Effect of temperature on VRLA batteries

The lead acid batteries (both conventional as well as VRLA) are normally designed to give the full rated capacity and the expected life at the operating temperature of 27°C. When the operating temperature is higher than 27°C, the corrosion rate at the positive grid increases. This is due to Arrhenius principle, which states that, the rate of chemical reaction doubles for every 10°C rise in the ambient temperature. The effect of increased temperature is more pronounced on VRLA batteries as less volume of electrolyte is available and also because there is no addition of electrolyte during the use of the battery. It is said that for every 10°C rise, the reduction in life of VRLA batteries is up to 50%.

6.3 Effect on capacity when stored for long duration

A fully charged battery losses certain capacity when stored. This process of capacity loss is called as “self discharge”. The capacity loss for VRLA batteries is around 1% per week. The various parameters that effect the self-discharge include.

- Alloys used for positive and negative grids.
- Purity of raw materials used in the manufacturing process for grids.
- Processing techniques employed in manufacturing of grids.
- Also storage conditions of batteries at the site.

6.4 Storage interval

- Batteries in storage lose capacity, due to its self-discharge. The rate of self-discharge increases with temperature. The loss in capacity becomes permanent due to sulphation of battery.
- Batteries may be stored for a period up to six months before installation. (i.e. from the date of shipment and the date of installation).
- In case the batteries are to be stored for longer duration, then the batteries must be unpacked at the intervals of six months and they must be given charged a fresh as per para no. 8.2.
- The storage interval at the various elevated temperatures before which the battery is due for freshening charge is shown in the table below.

Sr.No	Temperature	Storage interval.
1	32°C	6.0 Months
2	37°C	4.5 Months
3	42°C	3.0 Months
4	47°C	2.25 Months
5	52°C	1.5 Month

7. Installation

For installation of VRLA batteries, the following instructions should be followed.

7.1 Location

- ♦ Install the battery in a clean, cool and dry location, an ideal temperature being 27° C.
- ♦ Free space of one meter should be provided on all sides of the battery for carrying out periodic checks.

7.2 Ventilation

- ♦ Under normal operating conditions, natural ventilation is adequate.

7.3 Floor arrangement

For the purpose of stacking the batteries the floor mounting channels have holes with diameter 13 mm for anchoring, these channels can be anchored to the floor with the help of suitable bolts. For preparation of floor anchoring the following instruction may be adopted.

- ♦ Carefully mark the location and install the floor anchors to match the holes in the floor mounting channels.
- ♦ Check that the floor mounting channels are in the correct position and at a uniform level.
- ♦ Tighten the bolts to anchor the floor mounting channels.
- ♦ Use shims for leveling.
- ♦ Check that the floor is capable of with standing the weight of the batteries. The recommended stacking limitations are as under.

SN	Module arrangement.	Maximum modules.
1	Horizontal single stack	8 High
2	Horizontal multiple stack	8 High

- ♦ Batteries are to be stacked in horizontal position with single stacks or multiple stacks as shown in the fig.1

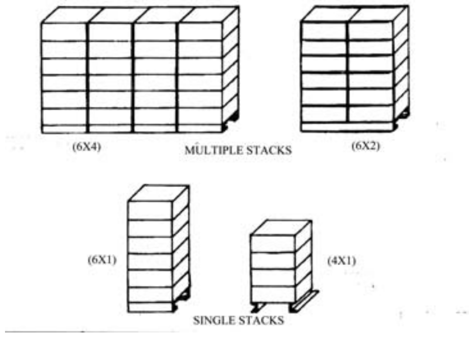

Fig No. 1

7.4 Module stacking

- ♦ Place the first module on the floor mounting channels after checking the position of the terminals as per the wiring diagram (Red washer indicates positive terminal and blue washer indicates Negative terminal).
- ♦ Align the holes and securely bolt the module to the floor mounting channels as shown in the fig 2,3 & 4.

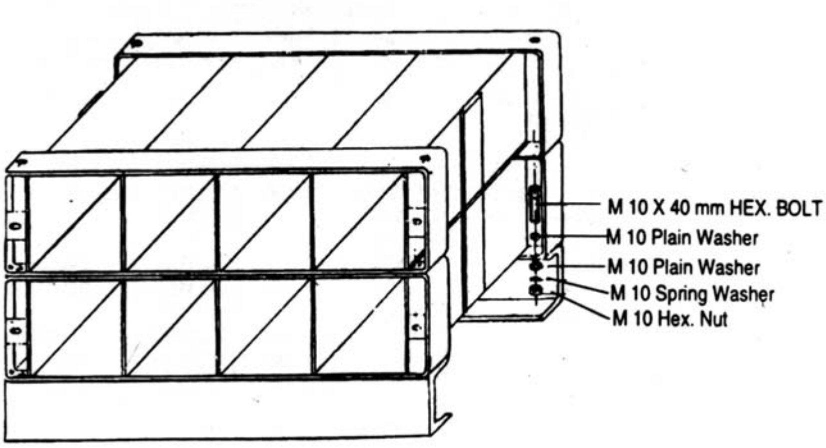

Fig No. 2

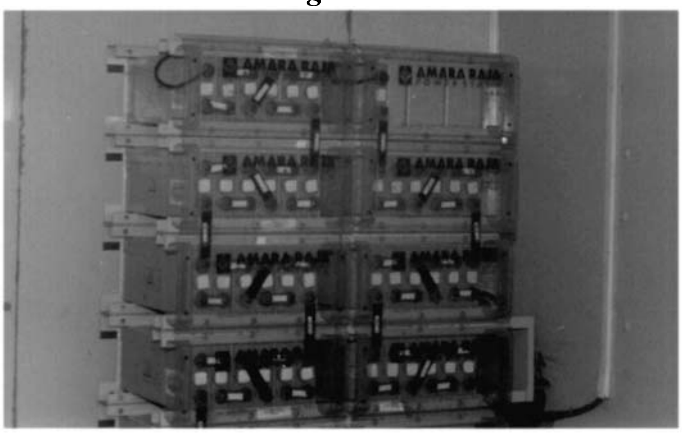

Fig No. 3

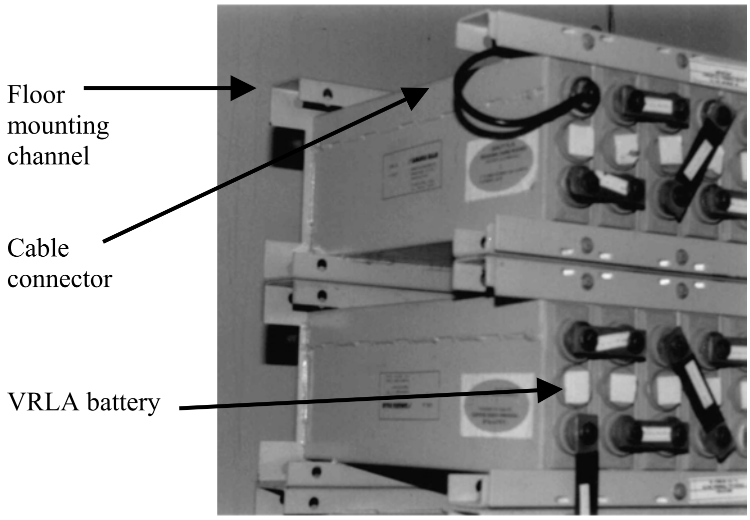

Fig No. 4

- Securely bolt each module before placing the next module in position.
- Use a torque of 30 Numbers for tightening the M-10 (10 mm metric size) bolts.
- Place additional modules as per the wiring diagram.

7.5 Connections

- All module terminals are brushed at the factory. Bolts and washers used for fastening are installed finger tight.
- Remove only his hardware and clean it with clean-dry cloth. Using a brass brush, brighten copper terminal surfaces to insure connections with least resistance.

7.5.1 Inter module connections

- Assemble the inter module connectors as per the wiring diagram with the help of the insulated tools. The inter module connections are shown in figure 5.

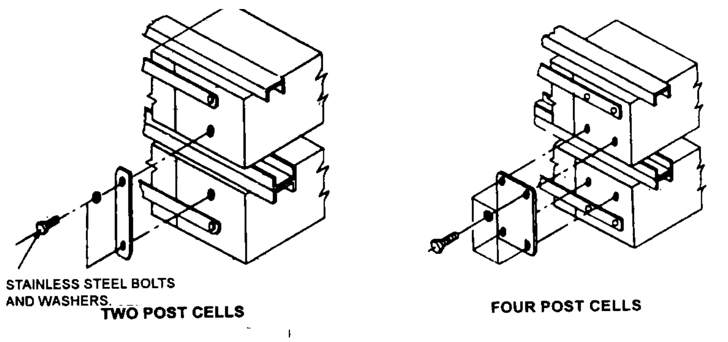

Fig No. 5

- It is recommended when installing connectors on horizontal arrangements, that the upper bolts be installed first to reduce accidental shorting.

7.5.2 Inter stack connections

- Multiple horizontal stacks side by side are interconnected as shown in figure below.

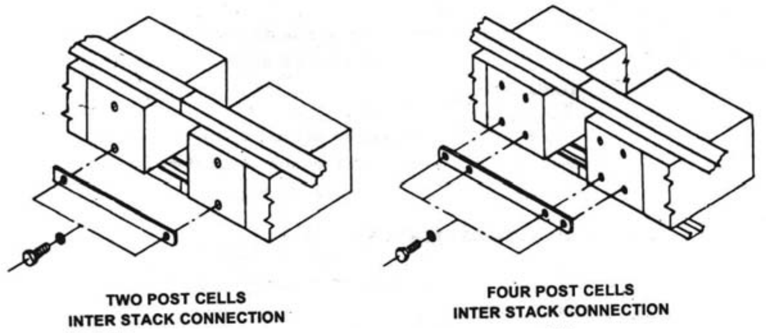

Fig No. 6

7.5.3 Connections torque

- When module connections are made, tighten all the connections to the torque of 11 N-m.
- When inter-cell connections are made at factory, the connections should be checked for torque to 11 N-m.

7.5.4 Checking of connections

- Visually check to see that all module terminals are connected from positive (+) to negative (-) through the battery.
- Measure the total open circuit voltage between the two terminals. This should be 2.13 to 2.20 Volts times the number of cells in the system.
- Apply a thin film of petroleum jelly to prevent oxidation.

8. Battery charging

8.1 General Instruction

For a good performance, it is better to follow the procedure defined by the manufacturer for charging. The procedure is as under.

- Ensure that the entire cell in the battery set is of the same type and capacity. Charging individual cell separately is not advisable.
- Correctly connect the battery charger output terminals to the battery set i.e. positive to positive and negative to negative.
- Ensure that all electrical connections between the battery charger and the battery are tight and offer good conductivity.

♦ **Voltage settings of power plant**

In the float mode, the float Voltage is 2.25 V per cell. In normal cases, the float voltages work out to be as under.

(i) 56 Cells battery bank - 126.0 +1.0 –0.5 Volts

(ii) 54 Cells battery bank - 121.5 +1.0 –0.5 Volts.

8.2 Freshening Charge

In case the batteries are to be stored for longer duration, the battery must be charged for the freshening charge.

- ♦ Charging must be carried out at constant potential with the current limited to the maximum 0.2 C10 Amperes (where C10 refers to the numerical value of the nominal capacity of the battery).
- ♦ In charge mode, at a charge voltage of 2.3 Volt per cell for a period of 16 hours.
- ♦ In the float mode, at a float voltage of 2.25 Volts per cell for a period of 72 hours. Say, for 48 Volts, 400 AH battery consisting of 24 cells, charging must be carried out in the charge mode at a charge voltage of 55.2 Volts ± 0.1 Volts for a period of 16 hours. Or charge in the float mode at a float voltage of 54 Volts ± 0.1 Volts for a period of 72 hours. The current should be limited to maximum of 80 Amps. (400X0.2 = 80).
- ♦ The above charging procedure is to be used for giving a freshening charge to the battery for extending the storage period.
- ♦ This charging procedure is also valid for charging the battery to determine the rated capacity of the battery after installation.
- ♦ Battery located in areas having very low average ambient temperatures (below 15° C) will require the charging time recommended above to be doubled in order to fully charge the battery.

8.3 Float charging method.

Under normal condition the batteries are charged with float charge method. This type of charging sustains the battery in a fully charged condition and also makes it available to resume the emergency power requirements in the event of an AC power interruption or charger failure.

- ♦ Float charging of battery is carried out as under.
- ♦ The battery is connected in parallel with a constant voltage charger and the critical load circuits. The charger should be capable of maintaining the required constant voltage at battery terminals and also supply normal connected load.
- ♦ After the batteries has been given its freshening charge the charger should be adjusted to provide the recommended float voltage at the battery terminals.

- ♦ Adjust the charger voltage to 2.25V per cell. (i.e. in a 24V system, 12 Cells are floated 27 Volts).
- ♦ During charging as the cells approach full charge, the battery voltage rises to approach the charger out put voltage.
  (i.e. 27 Volts in the above case).
  The charging current decrease to the float current value of around 50 mA per 100 AH.
- ♦ When the charging current has stabilised at the float current for three consecutive hours or the voltage across the battery bank terminals is constant for six consecutive hours, the battery bank can be considered as having reached the fully state of charge.
- ♦ Recommended float charge voltage for state of charge is given the table below.

Sr No.	Item	Nominal required value
1	Float Voltage setting at battery terminals.	2.25 X No. of cells
	(i) 24 V system	27 Volts
	(ii) 110 V system	123.75 Volts
2	Normal battery charging current when battery put into charge after discharge.	10% of AH capacity i.e. for 100 AH battery to be charged at 10 A current.
3	Maximum battery charging current when battery put in to charge after discharge.	20% of AH capacity.
4	Ripple content in DC voltage.	Should be less than 2% rms
	(i) 24 V system	0.48 V rms (Max.)
	(ii) 110 V system	2.20 V rms (Max.)
5	Battery charging voltage (High protection).	Charger should trip at 2.37 Volts per cell
	(i) For 24 Volts system	Charger should trip at 28.44 Volts
	(ii) For 110 V system	Charger should trip at 130.35 Volts.
6	Battery under voltage (Trip on discharge).	Charger should trip 1.75 Volts per cell
	(i) For 24 Volt system	Disconnect the load at 21 Volt
	(ii) For 110 Volt system	Disconnect the load at 96.25 Volt

8.4 Equalize charging

Under normal operating conditions an equalizing charge is not required. An equalizing charge is a special charge given to battery when non- uniformity in voltage has developed between cell. An equalizing charge should be given when the following conditions exist.

- ♦ The float voltage of the pilot cell is at lest 0.05 V below the average floats voltage per cell in the bank.

- A recharge of battery is required in a minimum time amount of following an emergency discharge.
- Accurate periodic records of individual cell voltage show a sudden variation from the previous readings.

8.4.1 Equalizing charging method.

- Equalizing charging is made using constant voltage method.
- Determine the maximum voltage that may be applied to the system (i.e. 2.30 X No. of Cell)
- Establish the maximum Voltage apply to the system for equalizing charge in shortest time duration as per the table below.

SN	Temperature	Volts/Cell	Time
1	Below 15°C	2.30 V	30 Hours
2	15-32° C	2.30 V	20 Hours
3	Above 32°C	2.30 V	12 Hours

8.5 Discharging battery

- The discharge duration for the determined rated capacity of the battery is 10 hours. Discharged the battery for 10 hours so as to get an end voltage of 1.75 Volts per cell at an average ambient temperature of 27° C.
- It is important to immediately charge the battery in the charge mode after every discharge and maintain the battery in the charged condition by keeping it connected to the battery charger in the float mode.
- Ensure that the battery is charged optimally and no over charging, over gassing or heating takes place.

9. Difference between conventional flooded batteries and VRLA batteries

Sr. No	Conventional flooded batteries.	VRLA batteries
1	Constant current charging method is normally used for charging these batteries.	Constant voltage with current limiting method is the recommended for charging these batteries.
2	As excess of free acid is available. Hence electrolyte stratification takes place. To maintain uniform specific gravity of electrolyte equalizing/extended charging is required.	As there is no stratification of electrolyte, no equalizing charging is required.
3	Frequent topping-up of distilled water and acid is required since equalizing/extended charge method is used which results in loss of water.	Under normal recommended operating conditions there will no loss of water. Hence the periodic topping- up is not required if the voltage, current, ripple and regulation are in specified limits.

Sr. No	Conventional flooded batteries.	VRLA batteries
4	Post corrosion is observed due to acid mist.	No post corrosions in normal operation since there is no acid mist.
5	These batteries are needed to be placed only vertically since they required frequent topping-up with distilled water and can lead to spillage's as free and floating acid is present inside the battery.	The batteries can be mounted in any position (normally horizontal position is recommended) since they do not require any periodic topping and are both spill and leak proof.

10. Maintenance

General maintenance

- In order to detect and correct abnormalities, if any the performance of the battery is to be monitored at weekly intervals or as per instructions issued by the Railways.
- Care must be taken to ensure that the working circuits do not get affected during general cleaning of the battery.
- In all cases which require disconnecting as re-charging or replacement of the battery, disconnection notice must be issued to the ASM on duty and work commenced after the same is allowed and necessary precautions have been taken as laid down in SEM.
- After the maintenance and works are completed, test must the immediately be carried out to ensure that connected gears are functioning properly.
- Check each cell voltage of the battery set once every week, or as per instructions issued by the Railways.
- Avoid sources of heat or cooling directed on to the battery.
- Check that physical condition of the battery is good, i.e. there are no cracks, bulges and heating marks on it.
- The battery rooms and location box should be kept well ventilated and also free from water, oil and dirt.
- Since the voltage to be measured require an accuracy of 0.05 Volts, only digital multimeters are to be used for this purpose.

General Cleaning

- Remove dust or dirt from the batteries. Clean the entire battery box, terminals and connectors etc.
- Gently clean the terminal post sulphation by using fine emery paper. After that clean the terminal post with dry cotton cloth.

Record maintenance

- Record individual cell voltage after 30 minutes discharge on load.
- Maintain the record of the battery terminal voltage and the individual cell voltage using the service record formats as given below.

1. Nominal capacity of battery. ---------------
2. Nominal voltage of the battery. ------------
3. Date of installation. --------------------------

Date	Cell No.	Voltage	Total voltage of the battery	Charger voltage in float /charge mode	Charger current	Average ambient temperature	Remarks	Signature of supervisor
1	2	3	4	5	6	7	8	9

- The end cell from which the positive terminal has been connected to the power plant is designated as cell number one.

Battery charger Voltage / Current setting.

Float mode

- Check the setting of battery charger. The battery voltage is 2.25± 0.05 volts per cell in float mode.
- Special care must be taken to ensure that the voltage of the power plant has been set exactly to a value within the specified range is given below.
- **Voltage setting**
  - a) 2V, 56 Cells — 126 V
  - b) 2V, 54 Cells — 122 V
- **Charging voltage** — 2.25 V per cell
- **Voltage ripple** — 5% rpm
- **Ripple current** — 10% rpm
- **Charging current** — Max 20% of AH rated current
- **Voltage regulation** — Set voltage + 3%

- Ensure that the battery charger is so adjusted that charger trip at 2.35 V per cell to avoid over voltage of the battery.

Boost mode

- Check for cell voltage, if it is falling below 2.0 Volts, boost charge should be given with the following settings.
  - (i) Set the power plant voltage to 2.3 Volts per cell.
  - (ii) Set the maximum charging current limit to 20% of AH rating and charge the battery for 12 hours.
  - (iii) Recommended voltage setting during boost charging is as under.

♦ **Voltage setting**	
a) 2V, 56 Cells	128.8 V
b) 2V, 54 Cells	124.2 V
♦ **Charging voltage**	2.3 V per cell
♦ **Voltage ripple**	Less than 5% rpm
♦ **Ripple current**	Less than 10% rpm
♦ **Charging current**	Max 20% of AH rating, current limit to be set between 10 to 20% based on the time for recharge.

Torque of terminal bolts

- Torque each terminal bolts in every six months or as per directives issued by the Railways.
- It is recommended to torque all terminal bolts, to 11 N-m to avoid loosing of terminal bolts provided with spring washer.
- Use insulated torque wrench for tightening.

Safety precautions.

Before proceeding with the unpacking, handling, installation and operation of the valve regulated lead acid storage battery, the following information and the recommended safety precautions are to be followed.

- Wear a rubber apron, rubber gloves and safety goggles or other eye protection to prevent injury if contact is made with the acid.
- Under abnormal usage batteries can generate explosive gases. Under such conditions, the safety vent opens while the gases are being generated so keep sparks, flame and smoking materials away from the battery area.
- Ensure that tools are adequately covered with insulation tape or suitable non-conducting material to minimise possibility of shorting across connections.

11. Trouble shooting

SN	Trouble	Cause	Remedy
1	Over - charging	Continuous charging of batteries at a higher voltage.(i.e more than specified value)	Adjust the float voltage to 2.25V per cell at 20%(max.) current limit of the rated capacity.
		The higher voltage can be due to. • Either set point in the charger it self is higher. • Or it is connecting more or less number of cells than required.	Adjust the power plant or connect the required number of cell.
		Over voltage protection in charger is not provided or is defective.	Attend charger or replace with the proper charger.
2	Under - charging	Continuous charging of batteries at a lower voltage (i.e. Less than the specified value.)	Charge the cells at 2.25 V until all the cells reach the normal condition.
		Terminal bolts are not properly tightened.	Tighten the terminal bolts properly.
		Malfunctioning of charger or sudden failure of charging voltage controlling circuit or higher ripple current.	Attend the charger and rectify it.
3	Corroded terminals.	Sulphation formed on the terminal post or both positive and negative plates got sulphated (i.e. forming of $PbSO_4$)	Remove the connectors and clean the terminals with brush. After making connections apply a thin film of petroleum jelly.
4	Total voltage of battery suddenly drops	Showing negative voltage when measured across terminal of a cell.	Charge the cell separately at 2.30V with maximum current of 20% of its rated capacity.

12. Power Plant compatibility

The following power plants are compatible with VRLA batteries:

- TP 130 F93 (VRLA)
- S/PR 116B/EM
- S/PR116B/EL
- TP 120 M91
- TP 130 F93
- RAX Power plant TQ 110090
- RAX Power plant TB 310 DRI
- S/PR 133

13. Do's and Don'ts

13.1 Do's

- ♦ Unload the batteries carefully and place them upright on the floor in the single tier.
- ♦ Store the batteries in cool and dry location.
- ♦ Charge the batteries every six months for the storage period.
- ♦ Unpack the batteries as per the unpacking instructions.
- ♦ Install the batteries in cool and dry location.
- ♦ Monitor the charge and float voltages of the power plant at monthly intervals and adjust, if required.
- ♦ Check the tightness of all electrical connections at monthly intervals.
- ♦ Always use a spring washer wherever bolt connections are provided
- ♦ After a discharge, re-charge the batteries immediately.
- ♦ Check the compatibility of power plant and replace with the modified one if required.
- ♦ Maintain service record as per the instructions.

13.2 Don'ts

- ♦ Do not exceed the charging voltage above 2.30V maximum per cell.
- ♦ Do not open the safety valve for adding water or acid.
- ♦ Do not attempt to dismantle the battery.
- ♦ Do not boost charge the batteries for more than 12 hours.
- ♦ Do not mix ordinary conventional, low maintenance batteries with maintenance free VRLA batteries.
- ♦ Do not expose the packed batteries to rain and sunlight.
- ♦ Do not install the batteries in rooms with varying temperature pockets due to sun light or ventilation ducts.

- ♦ Do not keep the cells in idle condition for more than the specified storage period without charging the batteries.
- ♦ Do not short-circuit the battery or cells during assembly.
- ♦ Do not over tighten the terminals.
- ♦ Do not charge the batteries in sealed cubicles.
- ♦ Do not mix batteries of different types or makes.
- ♦ Do not make tap connections.
- ♦ Do not tamper with the cell vents.

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