RAYLITE M-SOLAR BATTERIES

INSTALLATION AND MAINTENANCE INSTRUCTIONS

SAFETY WARNINGS

 **NO CHILDREN.** Children must be kept away from batteries at all times.

EXPLOSION HAZARD, NO SMOKING, NO NAKED FLAMES. Batteries generate highly explosive gasses during charge. No smoking, sparks or any form of naked flame is to be allowed near the battery at any time. Assume that there is explosive gas present above the cells at all times. Keep the battery tops clear from all conductive objects that may cause a spark. Use an insulated torque wrench when assembling the battery. To avoid electrostatic build-up use a damp cloth when cleaning cells. In order to prevent electrical tracking between cells keep the cell tops clean and mop up any spillage.

ELECTRIC SHOCK. The battery remains live at all times, even if isolated and discharged. The threshold voltage for fatal electric shock is lower with Direct Current than with alternating Current.

CORROSIVE ACID. Battery electrolyte contains dilute sulphuric acid. This is highly corrosive and can cause severe skin burns. If spilt or splashed onto skin or clothing, neutralise with a solution of baking powder and water. If splashed into the eyes wash for at least 15 minutes with copious amounts of water and consult a doctor as soon as possible.

PROTECTIVE CLOTHING. Wear eye protection (goggles or face mask) and rubber gloves when working on the battery. An acid resistant (rubber or plastic) apron and thick rubber soled shoes are also recommended.

SIZING OF M-SOLAR INSTALLATIONS

It is recommended that the battery be sized to limit the daily depth of discharge to 20% of the 100-hour rate capacity. This caters for up to 5 days of cloudy weather whilst giving optimum life expectancy.

The daily consumption can be calculated by taking each electrical item's wattage and estimating the maximum time in hours that it is likely to run each day. The product of these two figures will give the Watt-hour consumption each day. Totaling the result for each item will give the system consumption per day. Alternatively many web sites give the expected consumption for household appliances.

The total daily Watt-hour consumption divided by the overall nominal battery voltage will give the Ampere-hours required each day. Multiplying this by 5 will indicate the size of battery required.

The solar array must be able to deliver sufficient power to supply the load and recharge the battery on an average day of irradiation plus have reasonable excess to cater for the recharge over a few days when the battery is more deeply discharged due to consecutive days of poor weather.

PREPARING THE BATTERY FOR SERVICE

UNPACKING

Clean off any packing material from the cells and trays. Examine carefully to see if there has been any damage in transit.
Check that all components have been supplied.

- Cells may be supplied loose or pre-assembled in 4 volt (2 cell) or 6 volt (3cell) trays. If in trays, inter-tray cables and two take-off cables will be supplied. If loose cells, inter-cell cables and two take-off cables are supplied.
- One electrolyte level indicator per cell.
- One Installation and Maintenance Manual (this document).
- One battery log book.
- One hydrometer.

Important: Any damage or shortages must be reported to the carrier and First National Battery must be notified.

PREPARING THE CELLS

- Open all vent filler plugs and examine the electrolyte levels in all cells.
- Check all specific gravities (25°C).
- Batteries can be put into service immediately, provided the specific gravities are above 1.240 (25°C) and electrolyte levels are correct.

If the specific gravities are below 1.240 it is necessary to give the battery an equalizing charge. This consists of charging at a constant current of 2.5% to 5% of

the C_{100} capacity until the voltages and specific gravities have remained constant over 3 x 1 hourly readings.

If the battery is not required immediately for service, it should be stored under roof in a cool, clean, dry and well-ventilated area. Where connection has not been made to the cell terminals, remove the covers, wipe the terminals clean and apply a thin layer of Vaseline to the outer surface. Replace the terminal covers. Equalize charge at three monthly intervals or whenever the cell voltage drops below 2.05Vpc (Volts per cell) or the specific gravity drops below 1.210. The electrolyte levels should be adjusted as required by topping up with approved water.

WIRING STANDARDS

Comply with all local regulations concerning codes of practice that apply to electrical/battery installations.

BATTERY ASSEMBLY

If the cells have been supplied loose assemble the battery in the container/s. If (for whatsoever reason) cells are not in plastic moulded trays or steel tanks, it is essential that cells be strapped together so as to support the internal plates of the cells while in operation. This should be done as follows.

1 Wooden boards ≥18mm thick should be used as support when strapping the cells.

2 Note: In all cases, the wooden boards must be fitted against the 158mm ***width*** face of the cells / or 198mm in case of DIN cells. See Figure 3 below.

3 It is not necessary to place boards against the ***length*** of the cells.

4 It is not recommended to strap more than 2 rows of cells together as this can potentially reduce the support on the ends of the rows as well as prevent adequate air cooling to the cells.

5 Cell packing spacers must be placed between cells. A minimum of at least one spacer should be used to separate four strapped cells.

6 Note: Fitting spacers between each cell will give the cells a better chance of working cooler in operation, which is beneficial to the life of the cell.

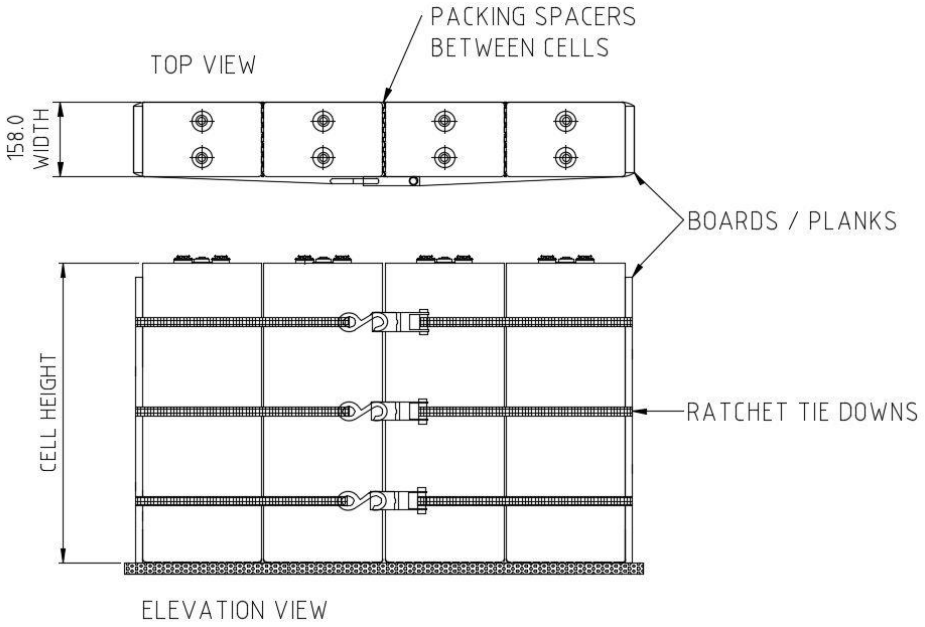
7 Cells must be firmly strapped, reducing any bulging of the cells on the supported ends.

8 Do not over tighten the strapping. The walls of the cell container must be perpendicular and square and not bow inwardly or push inwardly due to over tightening of the support boards.

9 Caution: strapping the cells will cause acid levels inside the cells to rise, especially with taller cells. If the electrolyte levels rise above maximum, any surplus acid should be removed.

10 It is important to support the cell adequately across the full height of the cell. Depending on the cell height, 2 to 3 ratchet tie down should be used.

11 Failure to provide this support will nullify any warranty.



Where connectors have not yet been fitted remove the bolts, wipe the terminals clean and apply a light coating of Vaseline to the outer surface of the terminal. Connect the cells together using the inter-connectors provided ensuring that the cells are connected negative to positive throughout. When numbering the cells always begin at the positive end as cell number 1.
Connect the take-off cables one at a time, terminating both ends of the first cable before connecting the second. When connecting the second take-off connect at the battery first before connecting to the charger side. This minimises the chance of creating a spark close to the battery.
Fit the float level indicators. Check that the indicators move freely and are at the ‘full’ level. If the levels are low do not top up until the battery has been fully charged.

COMMISSIONING

Switch on the solar array. Check that all regulator settings are correct (see Solar System Set Points). Allow the battery to be fully charged before applying any loads. When fully charged take and record temperature corrected individual specific gravity and cell voltage plus pilot electrolyte temperature readings (see Temperature Correction of Specific Gravities). These readings provide a base that can be referred to when assessing the condition of individual cells during the battery life.

SOLAR SYSTEM SET POINTS

Whilst there can never be hard and fast set points for a solar system due to variations in operating modes the following data is given as a guide.

Normal recharge maximum voltage:	2.45Vpc
Absorption time:	3 to 4 hours
Float voltage:	2.27Vpc
Equalisation voltage:	2.60Vpcl
Equalisation interval:	20 days
Duration of equalise charge:	2 hours
Low voltage cut-off (100% DOD)	1.85Vpc*
Temperature compensation coefficient:	2mVpc per ^{O}C

* Based on the assumption that the system has been designed to give 3/5 days autonomy and that recharge will be commenced within 48 hours of reaching fully discharged condition.

In addition we recommend that batteries be fully equalised when individual cells become out of step. This condition is present when:

(i) The end of charge voltages of individual cells differ by more than 0.10 Volt from the lowest to the highest voltage.

(ii) The specific gravities at completion of charge vary by more than 0.030 or do not rise to within 0.030 of the normal recommended top of charge value.

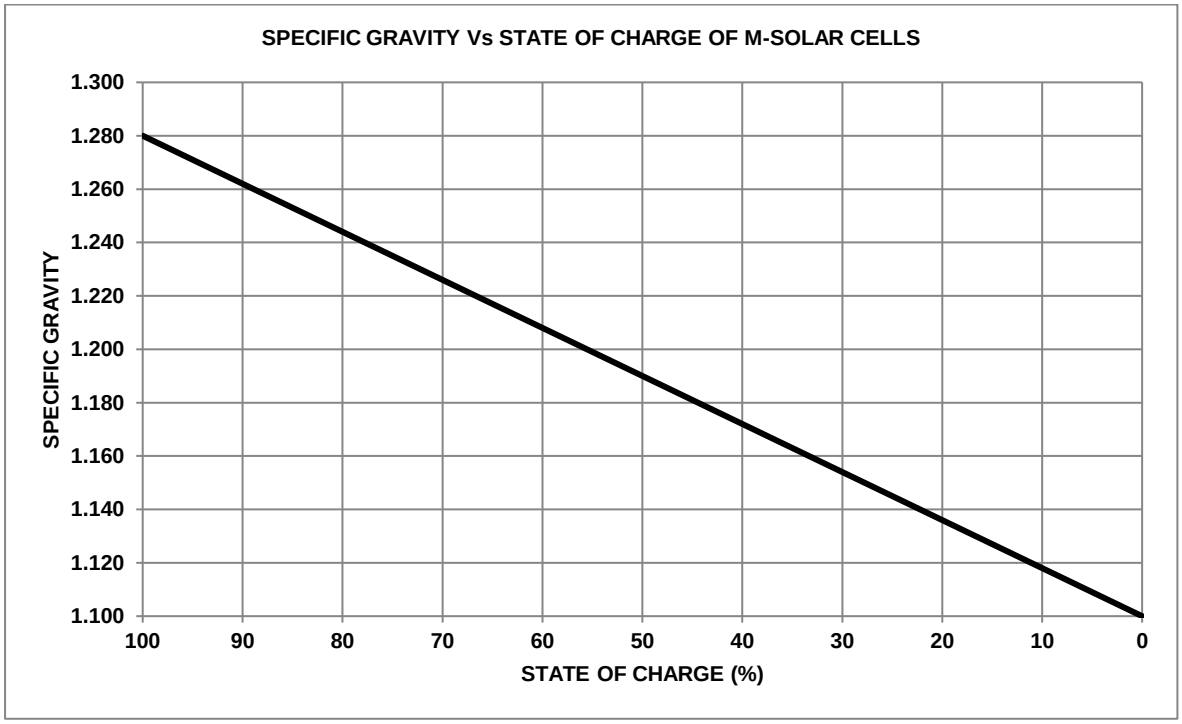
Equalising implies charging at approximately 3.5% of the 100 hour capacity. At this rate of charge, voltages of 2.60 to 2.75Vpc should be achieved (when new at temperatures of 20/25 degrees C), the voltage will be lower at higher temperatures and as the battery ages). If the solar panels do not have the power necessary for equalising, other means, such as a generator should be provided. Equalisation is regarded as complete when there is no rise in voltages or specific gravities over three one hourly readings.

The PV array should be sufficient to supply the daytime load while maintaining the battery in a charged state on days of average irradiation plus have reasonable excess to cater for the recharge over a few days when the battery is more deeply discharged due to consecutive days of poor weather.

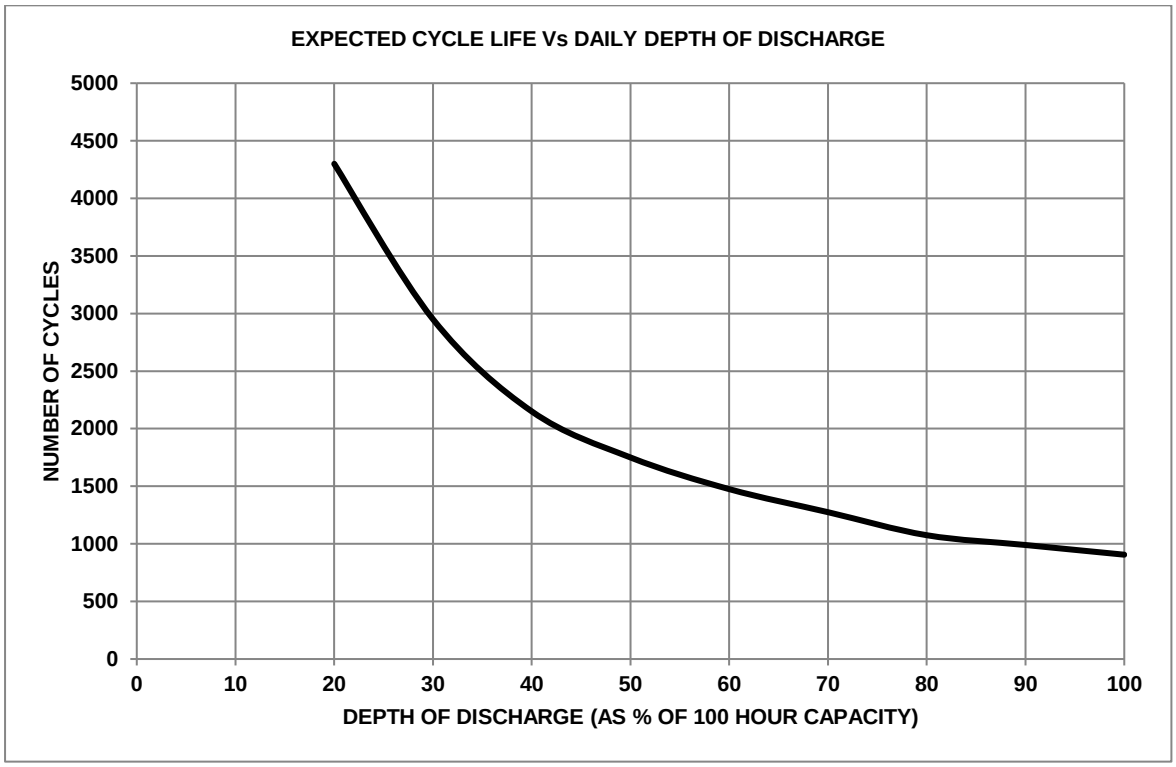
BATTERY OPERATION

DISCHARGE

Immediately after the solar array output falls below that being consumed by the load the battery begins supplying the load. This will initially result in a rapid fall in voltage. Assuming the battery was on float charge at 2.27Vpc it will drop to the open circuit voltage of about 2.12Vpc even if there is no load. Depending on what the actual load is at the time it is possible that the voltage could drop to around 2.00Vpc. After this the voltage will stabilise and only drop slowly over time. Assuming the battery has been sized to give 3 to 5 days autonomy it is permissible to fully discharge on those rare occasions to 1.85Vpc.
Whilst discharging, acid is absorbed by the plates and the specific gravity drops in proportion to the depth of discharge. From a fully charged condition the specific gravity will drop from 1.280 to approximately 1.100.



The life of the battery is very dependent on the depth of discharge (DOD) that it is subjected to on a daily basis. When used in a purely standby application where there are virtually no discharges the expected life is 10 to 12 years. When cycling it would be unrealistic to expect any longer life than that achieved on float, therefore the maximum life to be expected would be 4380 cycles (i.e. 365 cycles x 12 years). From the graph below it can be seen that this would be attained if the battery had a daily 20% DOD. The occasional deeper discharges would have marginal effect on the life to be expected.



RECHARGE

The normal method of solar charging is to charge at the current available from the solar array up to a maximum of 30%C_{100}Amps until the battery voltage reaches 2.40/2.45Vpc. This period is referred to as the 'bulk charge'. The regulator then controls the charge voltage at 2.40/2.45Vpc for a set period of 2 to 4 hours. This is termed 'absorption time'. The charge then reverts to the 'float charge' at 2.27Vpc. During this charge, acid is released from the plates and because it is heavier than the surrounding electrolyte it sinks to the bottom of the cell.

With the above charging regime the battery may receive sufficient charge on a good irradiation day to fully convert the active materials but, because there is no vigorous gassing of the electrolyte, the acid that has been released from the plates remains at the bottom of the cell. This results in weak acid at the top of the cell and strong acid at the bottom. This is called stratification and can cause deterioration of the plates. To prevent stratification damage it is recommended that the battery be given an equalisation charge every 20 days. This mixes the electrolyte and brings weaker cells into line with those that are stronger.

Initially, top of charge specific gravities should be in the range 1.250 to 1.270 but these may rise above 1.270 over the first few weeks of operation. This is normal and is not detrimental to the performance of the battery. However if the specific gravities rise above 1.300 they should be adjusted downward (see Adjustment of Electrolyte Specific Gravity).

TEMPERATURE

The operating temperature of the battery affects the capacity available and the life of the battery.
When temperatures are higher than the nominal 25^{o}C the capacity increases and at lower temperature, decreases. However, increases in temperature can drastically reduce the expected life. A 10^{o}C increase in the average operating temperature can reduce the life of the battery by 50%.
It is therefore important to install the battery in as cool an area as possible and to provide good ventilation.

BATTERY MAINTENANCE

The maintenance of the battery is a major factor in the service life achieved. It is therefore important that the following instructions are followed.

WEEKLY

- Check to ensure the charging system is operating within specified limits and reset if necessary.
- Check that the level indicators move freely and that the electrolyte levels are between the full and low marks. If levels are low, top up with distilled or deionised water (see Specification for Purity of Topping-up Water) .
- Inspect the cells for any apparent signs of failure or problems requiring immediate repair.
- Clean the cell lids with a damp cloth.

MONTHLY

As weekly plus:-

- Apply equalising charge.
- At the end of the equalise charging period measure and record the cell voltages, corrected specific gravities and pilot cell electrolyte temperature in the log book provided.
- At end of night discharge period measure and record the cell voltages, corrected specific gravities and pilot cell electrolyte temperature in the log book provided.
- Check for signs of loose connections and re-tighten where necessary.

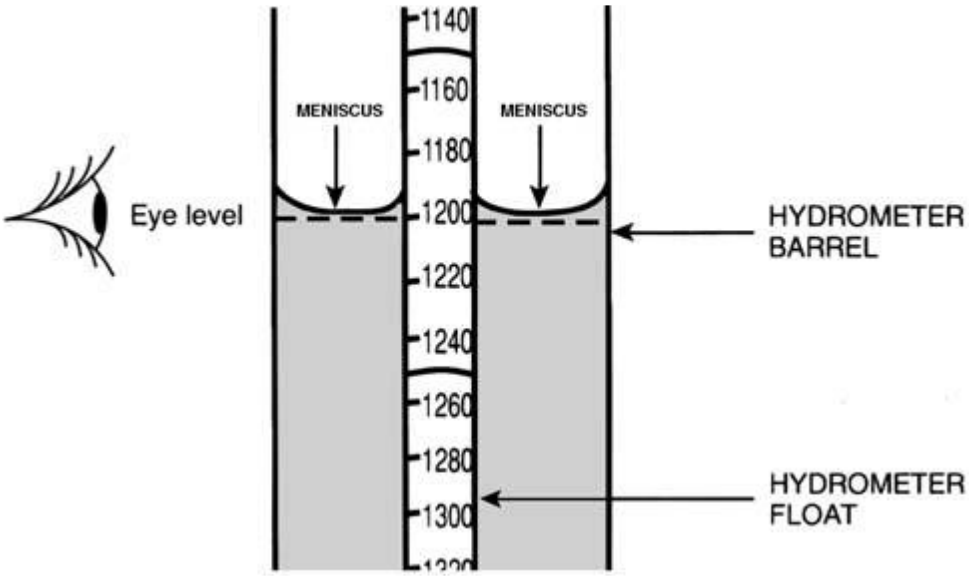
SPECIFIC GRAVITY MEASUREMENT

DETERMINING THE STATE OF CHARGE OF THE BATTERY

Dilution of the electrolyte during discharge is a useful guide to the state of charge of a lead acid cell. The less acid there is in the electrolyte, the less dense it is, and the lower its specific gravity. One cubic centimetre of water has a mass of 1 gram. In other words, its density is 1 gram per cm3 at 4°C. Specific gravity is the ratio of the density of the substance measured to the density of water. The density of water at 4°C is 1.000 g/cm3. The specific gravity of water is therefore usually expressed as 1.000.
Density could also be expressed as the mass of the liquid divided by the mass of an equal volume of water.
Specific gravities are usually measured with a hydrometer. This works on the principle that a float will sink further into a liquid of low specific gravity than of high specific gravity because the latter is denser and provides greater support.

USING THE HYDROMETER

From one of the cells, draw acid into the barrel until the hydrometer float moves freely. Now read the specific gravity at the point where the scale emerges from the acid. Afterwards, make sure the acid is returned to the cell from which it was drawn, or the specific gravity and acid level of both cells will be altered.



When taking a reading
• Make sure that there are no air bubbles under the float.
• Bring your eye level with the acid surface in the barrel of the hydrometer.
• Ensure that the hydrometer is in a vertical position.
• If necessary, shake the hydrometer gently to enable the float to move freely.
• If the ambient temperature differs from the battery temperature, draw in electrolyte to warm the hydrometer first.
• Read off against the lower meniscus.

Wash the hydrometer barrel and float with soap and water on a regular basis. Rinse thoroughly with water after washing to prevent soap transfer to the battery electrolyte.
The change in specific gravity of the acid is directly proportional to the ampere hours taken out of the cell on discharge.

The minimum recommended specific gravity is 1.140. Select a different pilot cell each month to serve as a useful, general indicator of the condition of the battery during charge and discharge.
Note: The specific gravity of a cell will decrease with any increase in temperature. Always record the electrolyte temperature when specific gravity readings are taken.

TEMPERATURE CORRECTION OF SPECIFIC GRAVITIES

All specific gravities quoted relate to temperature at 25^{o}C and have to be corrected if read at other electrolyte temperatures.
Specific gravities decrease as the temperature increases. To provide a standard, the specific gravity can be corrected to 25^{o}C in the following manner:
Take the temperature of the electrolyte and
• add 7 points (0.007) to the specific gravity reading for every 10^{o}C above 25^{o}C or
• subtract 7 points (0.007) from the specific gravity reading for every 10^{o}C below 25^{o}C.
For example:
A reading of 1.255 at 35^{o}C corrected to 25^{o}C gives 1.255 + 0.007 = 1.262
or
A reading of 1.275 at 15^{o}C corrected to 25^{o}C gives 1.275 - 0.007 = 1.268

ADJUSTMENT OF ELECTROLYTE SPECIFIC GRAVITY

Charge the battery at the equalising rate until specific gravities have been constant over three successive readings taken at hourly intervals.

Should the specific gravity be high, remove a little of the electrolyte and replace with an equal volume of distilled or deionised water. Add a small amount at a time, forcing it well down into the cell, with the cells gassing, to help mix the water with the acid. Allow the electrolyte to thoroughly mix by leaving on a vigorous gassing charge for at least 1 hour. When mixed, read the specific gravity. Repeat this process until the specific gravity is within the specified tolerance.

It is essential that the battery has been on charge at a voltage high enough to cause vigorous gassing over 3 hours with no increase in specific gravity before attempting to adjust the specific gravity upwards. If in doubt First National Battery should be contacted for advice. When these conditions have been met and specific gravity is still low remove a little of the electrolyte and replace with an equal volume of stronger sulphuric acid (e.g. 1.400) while agitating as described above. Once again, repeat the process until the specified tolerance is achieved.

When the adjustment has been completed, ensure that the level of the electrolyte in each cell is correct by removing excess acid or topping up to the correct level with acid of the same specific gravity.

BATTERY WATER

Water used for topping up batteries must comply with the following specifications:

- It shall be clear, colourless and odourless.
- The pH shall be between 5 and 7.
- Impurities shall not exceed the limits below.
- It shall, wherever possible, be stored in a glass or plastic container.
- Conductivity shall be less than 30 µS/cm

IMPURITY	MILLIGRAMS PER LITRE
DISSOLVED SOLIDS	25
ARSENIC (As)	1
CHLORIDE (Cl)	5
COPPER (Cu)	0.1
IRON (Fe)	0.2
MANGANESE (Mn)	0.1
NITROGEN (as NH_4)	5
NITROGEN (as NO_3)	5
HEAVY METALS (as Pb)	5
$KMn0_4$ REDUCING SUBSTANCES*	10

*As determined by F.N.B. test method LTM - 31 -01

TROUBLE SHOOTING

The following notes are provided to assist in identifying symptoms and causes of possible system problems.

SYMPTOMS	CAUSES	SOLUTIONS
Low or irregular voltages and/or specific gravity.	Undercharge. Faulty regulator settings.	Reset regulator settings.
	Battery requires equalise charge.	Apply equalise charge.
	Undercharge. Insufficient solar panels to recharge.	Install more panels or reduce load.
	Overdischarge. System undersized for the load.	Reduce load or increase capacity.
	Faulty cell/s.	Replace cell/s unless battery is near end of life.

	Battery reaching end of life.	Replace battery.
Battery fails to supply load.	Undercharge.	See above.
	Overdischarge. System undersized for the load.	Reduce load or increase capacity.
	Faulty cell/s.	Replace cell/s unless battery is near end of life.
	Battery reaching end of life.	Replace battery.
High operating temperatures.	Overcharge. Faulty regulator settings.	Reset regulator settings.
	Poor ventilation or batteries in sun.	Improve ventilation, re-site to shade.
Excessive water consumption.	On one cell, suspect leaking cell container or faulty cell.	Confirm and re[lace.
	On complete battery. overcharge.	Reset regulator settings. Reduce equalise charge.
Growth of positive post.	Early in life: overcharge.	Reset regulator settings. Reduce equalise charge.
	Towards expected end of life normal. Indication that failure may occur soon.	Budget for. replacement