GASTON GT-FA &GT-F

Front Terminal

Valve Regulated Lead Acid (VRLA) Batteries

Engineering Manual

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1. SAFETY

Do not handle, unpack or install batteries without a proper understanding of the safety risks.

- FA® Valve Regulated Lead Acid (VRLA) batteries contain sulfuric acid. Sulfuric acid can cause severe irritation and burns. Contact with sulfuric acid should be avoided. Do not handle batteries that appear to be damaged or leaking. If sulfuric acid comes in contact with the skin or eyes, flush immediately and thoroughly with water. Always have eye wash equipment available. Make sure to seek proper medical attention. Proper safety apparel should be worn to minimize exposure to sulfuric acid. Safety apparel should include rubber gloves, rubber apron, and goggles. Sulfuric acid can be neutralized with baking soda. Acid spills should only be handled by properly trained personnel. Contact GASTON BATTERY INDUSTRIAL LTD. for a copy of the MSDS sheet.

- Batteries generate hydrogen which is extremely explosive. GT-F VRLA batteries emit small amounts of hydrogen under normal operation, but can evolve significant amounts of hydrogen if any of the cells are charged at an excessive voltage (Operator error, charger malfunction, shorted cells in string, etc.). Never seal batteries in a room or enclosure where hydrogen can accumulate. Never smoke around batteries. Open flames and sparks should always be avoided to minimize risk of igniting the hydrogen and causing an explosion. Avoid incidental sparks by never wearing jewelry, and only using insulated tools when installing and handling batteries. Never drop or lay tools across battery terminals. Make sure all connections are properly cleaned and torqued. Electrically isolate the batteries for service and installation. Make sure to minimize voltage drops during connections to avoid sparks.

- Batteries are extremely heavy. Always use proper lifting techniques and equipment as specified by OSHA.

- Only personnel that have been properly trained on DC power safety should have access to the batteries for installation and maintenance.

2. INTRODUCTION AND FEATURES

The GT-F range of Valve Regulated Lead Acid (VRLA) batteries has been designed to meet the needs of the wireless communications industry. The success of the GASTON BATTERY GT-F range is based on a product design purpose-built for the needs of a wireless communications network, and industry leading manufacturing technology for product consistency. Safety, reliability and long service life in standby applications is the result. In addition, GASTON BATTERY offers a full line of racking solutions to accommodate the GT-F range of batteries. The front-terminal GT-F batteries provide easy access to the terminals for installation and maintenance. This eliminates the need to purchase expensive sliding mechanisms for terminal access. And the GT-F range includes 8 models – a revolutionary idea to further reduce space requirements and minimize the number of terminations – to make it easier to install and maintain these batteries. Other features of the GT-F range include:

No Water Addition	GT-F batteries require no addition of water throughout their life which reduces maintenance costs versus vented (flooded) batteries
Compatibility	GT-F was specially designed to meet the requirements of modern electronic equipment and is compatible with normally available recharging systems.
Good energy density	The compact construction and excellent performance at high rates of discharge provide big savings in volume and weight as compared to conventional flooded, vented batteries.

Office compatibility GASTON BATTERY GT-F batteries, which are valve regulated and virtually sealed, do not give off perceptible amounts of gas under normal operating conditions so they can be installed in the same environment where people live and work.

Savings GT-F batteries offer substantial savings in installation and maintenance costs compared to conventional vented batteries. In fact, no special rooms are required and only minimal maintenance is needed during the life of the battery.

Long life Rigorous laboratory tests and extensive field experience have enabled GASTON BATTERY to manufacture a highly reliable product with a five-year minimum design life.

Installation GT-F batteries are very easy to handle because they are designed with handles either molded into the cover or the end-walls of the container. Smaller, more compact and lighter than traditional batteries, FA batteries are supplied filled and charged so that they can be immediately installed directly into cabinets or on easily assembled racks also available from GASTON BATTERY.

Reliability GT-F batteries have been tested in the field for a number of years and fully comply with established international standards. The GT-F range has been fully tested with respect to charge and discharge characteristics, cycle life, recombination efficiency, mechanical strength, vibration life and flame retardancy.

3. MAIN APPLICATIONS

Wireless Communications GASTON BATTERY GT-F batteries have a proven track record of performance in many parts of the communications network including Central Office, Huts, CEV's and Remote Terminal cabinets.

U.P.S. The low internal resistance Absorbent Glass Mat (AGM) FA batteries make them a good choice for U.P.S. applications, especially for Industrial U.P.S. and extended run-time applications.

4. OPERATING PRINCIPLES OF VRLA TECHNOLOGY

The basic phenomenon behind VRLA technology is a process called *recombination*. During cycling of conventional flooded lead acid cells, water is lost from the cell due to electrolysis and results in the venting of hydrogen, oxygen and droplets of sulfuric acid entrapped in the gas stream. This results in the need for regular battery checks and periodic topping-up with water to maintain the electrolyte at the proper level. Valve regulated lead acid batteries eliminate this problem through continuous *recombination* of the oxygen during float charging and boost charging. The oxygen *recombination* process occurs if the separators are not completely filled with electrolyte. This allows some pores to be free for the oxygen diffusion from the positive plates (where it is generated) directly to the negative plates where it reacts to reform water.

During float charging and boost charging the following reactions occur:

1) Oxygen is evolved at the positive plate by the reaction: $\mathbf{H_2O \rightarrow \frac{1}{2}O_2 + 2H^+ + 2e^-}$ and diffuses through the unfilled pores of the separator to the surface of the negative plate.

2) At the negative plate oxygen combines with Pb and sulfuric acid: $\mathbf{Pb + H_2SO_4 + \frac{1}{2}\ O2 \rightarrow PbSO_4 + H_2O}$

3) The charging process electrochemically regenerates the lead in the negative plate, completing the cycle: $\mathbf{PbSO_4 + 2H^+ + 2e^- \rightarrow Pb + H_2SO_4}$

As a result (see also fig. 1), the recombination process (with an efficiency higher than 98%), completes and reverses the water oxidation. At the end of the process, the recombination has replaced the water, the electrolyte and the lead in the negative plates without having modified the state of charge of the plates.

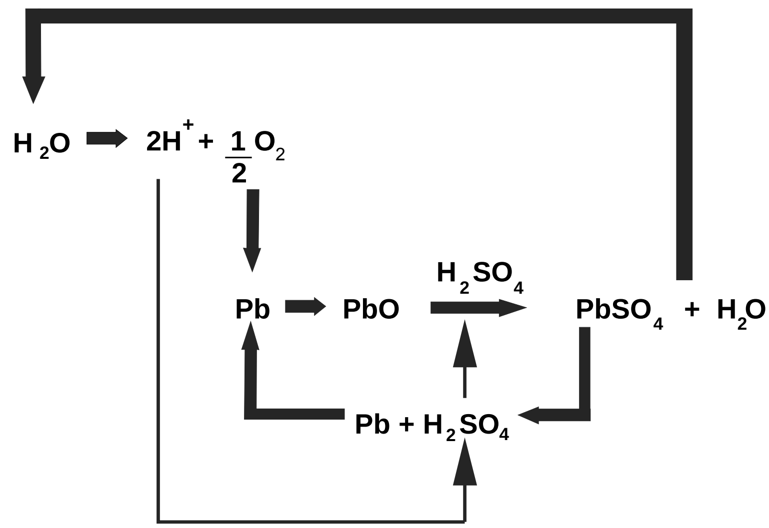

Figure 1: The Oxygen Recombination Process in VRLA Batteries

Special separators with high porosity and very small pore diameter are required to facilitate the oxygen recombination cycle. In addition, a carefully controlled quantity of electrolyte must be inserted into every single cell in order to maintain sufficient electrolyte to satisfy the discharge reactions while maintaining a sufficient quantity of pores free of electrolyte to maintain the gas diffusion. These unique requirements also result in the fact that all of the electrolyte is retained in the separator and plates and there is no free electrolyte.

The gas pressure within the cells during operation is normally above atmospheric pressure and consists of oxygen, hydrogen, nitrogen and carbon dioxide. It is thus necessary for each cell to have an outlet for the release of non-recombined gases to avoid excessive internal pressure. Safety valves are used for this purpose. The valves are also very important because they prevent air from entering the cell. from the surrounding environment. Oxygen in any outside air would cause the negative plates to oxidize and shorten the life of the battery. So, to allow excess internal gas to escape, while keeping external air from getting into the battery, each cell has a one-way pressure relief valve. For this reason these batteries are not always “sealed” batteries, so “valve regulated” lead acid (VRLA) batteries is used to give a more accurate description.

5. CONSTRUCTION FEATURES

Plates

Both positive and negative plates are of the flat pasted type. The active material is made of a paste of lead oxide, water, sulfuric acid and other materials needed to obtain the performance and stability required throughout the battery life. The grids are made of a high quality lead alloy with calcium and tin additives which assure good resistance against corrosion. The grids are sized to ensure a design life of 10 or more years at normal ambient temperature.

Containers

Battery cases and covers are made of a type of ABS plastic which complies with UL 94, class V-0 and with IEC 707, method FV0. It also meets the Telcordia requirement for 28% Limiting Oxygen Index (LOI). This material is shock resistant, self extinguishing and flame retardant. The containers and covers are also designed to fully withstand internal pressure variations during battery operation. Reinforced container walls and covers further ensure this. Handles have been designed into the covers or the battery end-walls to facilitate handling.

Separators The special separators, which ensure reliable operation of the oxygen recombination cycle, are one of the most important and basic components of GT-F batteries. These separators are made of microfibre glass sheets by a special process, which results in a high porosity with very small pore diameters to ensure maximum oxygen diffusion while maintaining high plate utilization and low internal impedance. Thanks to the chemical nature of the separator material (silica), it is fully inert to the sulfuric acid and the lead dioxide, and remains unchanged during the life of the battery. The excellent electrical and mechanical characteristics remain constant over a very wide temperature range. The very low internal resistance of the separator material combined with the special plates designed for GT-F batteries results in excellent utilization of the active materials in the plates over a wide range of high and low discharge rates. The plates are completely wrapped by the separator and the electrolyte is completely absorbed in the separator and plates. As a result, the shedding of active material, which can cause shorting with flooded batteries, is avoided.

Electrolyte The electrolyte is sulfuric acid with a specific gravity of 1.320 at 25°C with the same purity characteristics as other types of high quality lead acid batteries.

Valves Each cell has a one-way valve to permit the release of gases from the cell whenever the internal pressure exceeds the fixed safety value. The valve is rated at approximately 0.1 atmospheres (1.5 PSIG or 10 kPa).

Construction Suitable threaded pillars with solid or flexible connectors are provided to ensure low ohmic losses. Post-to-cover seals are designed to prevent leakage over a wide range of internal pressures and temperatures. Inter-cell connections in the GT-F design are electrically welded through the cell walls to minimize the internal impedance while maintaining complete separation of the individual cells.

6. OPERATING FEATURES

Capacity The battery capacity is rated in ampere hours (Ah) and is the quantity of electricity which it can supply during discharge. The capacity depends on the quantity of the active materials contained in the battery (thus on dimensions and weight) as well as the discharge rate and temperature. The European standard for nominal capacity is typically the C_{10} rate (ten hour discharge) to an end voltage of 1.80 VPC at 20°C. This Ah capacity is very close to the American standard which is often stated at the C_8 (eight hour discharge) rate to an end voltage of 1.75 VPC at 25°C, especially for Telecom batteries. Sometimes though, Manufacturers will present their nominal capacities at the C_{20} discharge rate, which is inherently higher than the C_8 rate. The user needs to be very careful when comparing batteries from different families or manufacturers to make sure that the Ah ratings are compared under the same conditions.

Cell Voltage The voltage of lead acid cells is due to the electrochemical potential differences between the active electrode materials (PbO_2 and Pb) in the presence of electrolyte (sulfuric acid). Its value depends on the electrolyte concentration in contact with these electrodes, but is approximately 2 Volts under most open circuit conditions. More precisely, it is a function of the state of charge of the battery; the open circuit voltage of a GT-F cell at ambient temperature can be represented by the following figure 2:

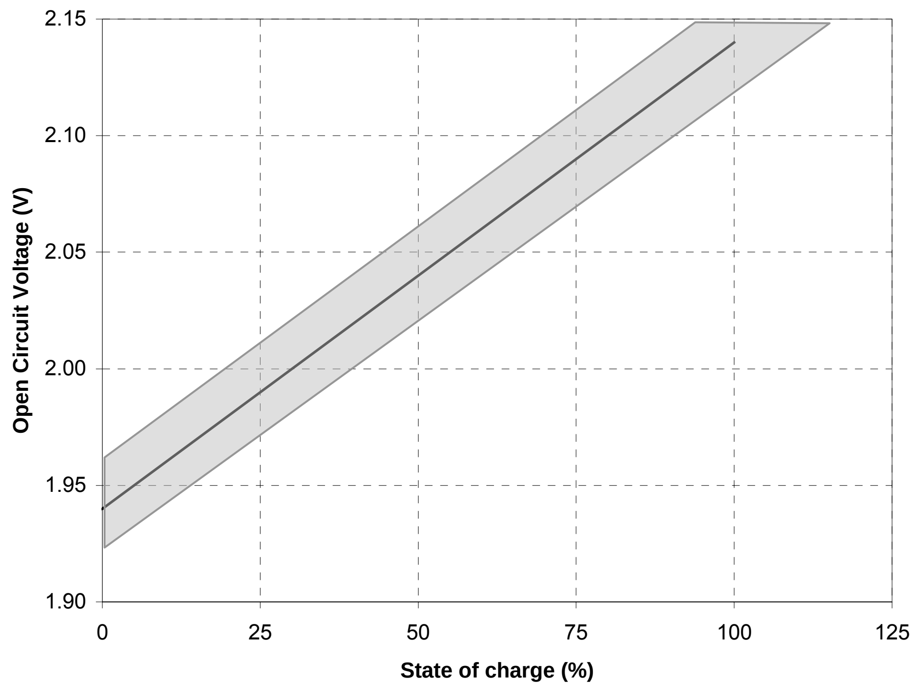

Figure 2: Open Circuit Voltage in Relation to the State-of-Charge of the Cell

Internal impedance

The internal impedance of a lead acid battery is a direct result of the type of internal construction, plate thickness, number of plates, separator material, electrolyte specific gravity, temperature and state of charge. The inverse of impedance is conductance. Larger batteries have lower impedance and higher conductance. There are devices available on the market that measure either impedance, or conductance, and estimate the capacity of the battery. It should be understood that neither conductance nor impedance are perfect predictors of battery capacity. A customer can pass many bad cells and reject many good cells using these instruments as “Go / No-Go” gauges.

The best way to use impedance or conductance instruments is to trend the change over long periods of time. The user should establish a baseline value for each block at the time of installation. Throughout the battery’s life, the impedance or conductance should be compared against this baseline. GASTON BATTERY INDUSTRIAL LTD. can provide guidelines for impedance and conductance values, but it is far more meaningful to establish the baseline for each individual block at the time of installation. Contact either the instrument manufacturer or GASTON BATTERY INDUSTRIAL LTD. to get more details on what change in impedance or conductance over time should trigger maintenance and/or replacement of the blocks.

Capacity in relation to the discharge rate

The capacity available from a battery depends on the rate of discharge. The higher the discharge rate, the lower the available capacity.

This relationship is described in the Peukert equation;

$I^n * t = C$ or $t = C / I^n$

Where I = current, t = time and C & n are constants that vary for each battery type. As I (the discharge rate) increases, the standby time of the battery decreases exponentially.

Suppose a certain battery had the constants C=185, and n = 1.25.

For I = 10 amps: $t = 185 / 10^{1.25} = 10.4$ hours for a total of 104 Ah

For I = 100 amps: $t = 185 / 100^{1.25} = 0.6$ hours for a total of 60 Ah

Life

The end of service life of batteries is defined as the point at which the battery's actual capacity has reached 80% of its nominal capacity. The life of a VRLA battery primarily depends on the following parameters: temperature, charging voltage, float voltage for a given temperature (temperature compensation), number of discharges, and AC ripple from chargers. In standby applications, the battery reaches end of life when there is no longer enough positive grid material to conduct electricity (grid corrosion), or there is not enough fluid left in the separators to support ohmic transfer between the plates (dry out). In cycling applications, the end of life can also be characterized by an irreversible sulfation of the plates. In a laboratory, it is easy to control all of these factors. Battery manufacturers typically talk about design life. The design life is usually stated under a rigid set of conditions. For standby applications, those conditions are usually: Constant voltage charging at 2.27 VPC; fixed temperature at 20°C; negligible AC ripple from chargers; minimal discharges (typically 10-12 cycles per year). Under these stringent conditions, the FA family of batteries will delivery 15 years of float life. Users cannot always control temperature, voltage and AC ripple to this extent. Therefore 15 years should not always be expected. A rule of thumb often used is that battery life will halve for every 8-10 °C above nominal (20°C). This relationship allows battery designers to accelerate the decay of battery life.

Life and Float Current

Float current can be a good measurement of aging, if measured accurately. The challenge is to find a good measurement technique that eliminates the noise on the bus from AC equipment. Options for measurement include shunts, Hall Effects sensors and specially designed Hall effects sensors for battery float determination. Float current primarily is the combination of energy required to support the following reactions inside the battery:

1) Self discharge
2) Grid Corrosion
3) Gassing / recombination

The float current will approximately double for every 8 to 10 °C above ambient, and/or for every 50 mV per cell above the recommended float voltage. GT-F batteries will normally float around 30 mA per 100 Ah at 2.27 VPC and 20 °C.

The relative portion of the float current going into the three reactions listed above (self discharge, grid corrosion and gassing/recombination) is not constant. The gassing/recombination reaction tends to dominate as the float current increases. It also is important to understand that grid corrosion contributes to dry out. Water in the electrolyte provides the oxygen for the oxidation of the lead (Pb) positive grid. That is why dry out is a major failure mode for VRLA in high temperature applications.

The relationship between float current and float voltage is typically displayed in a Tafel curve. These are complex curves that show the positive plate and negative plate polarization voltages as a function of the charging current on a fully charged battery. Contact GASTON BATTERY INDUSTRIAL LTD. for more information on Tafel curves.

Capacity versus temperature

The capacity available from a battery, at any particular discharge rate, varies with temperature. As batteries get colder, the available capacity is reduced. This is related to the kinetics of the electrochemical reactions and the resistivity of the electrolyte. The graph in Figure 3 shows the available capacity at different temperatures and discharge rates.

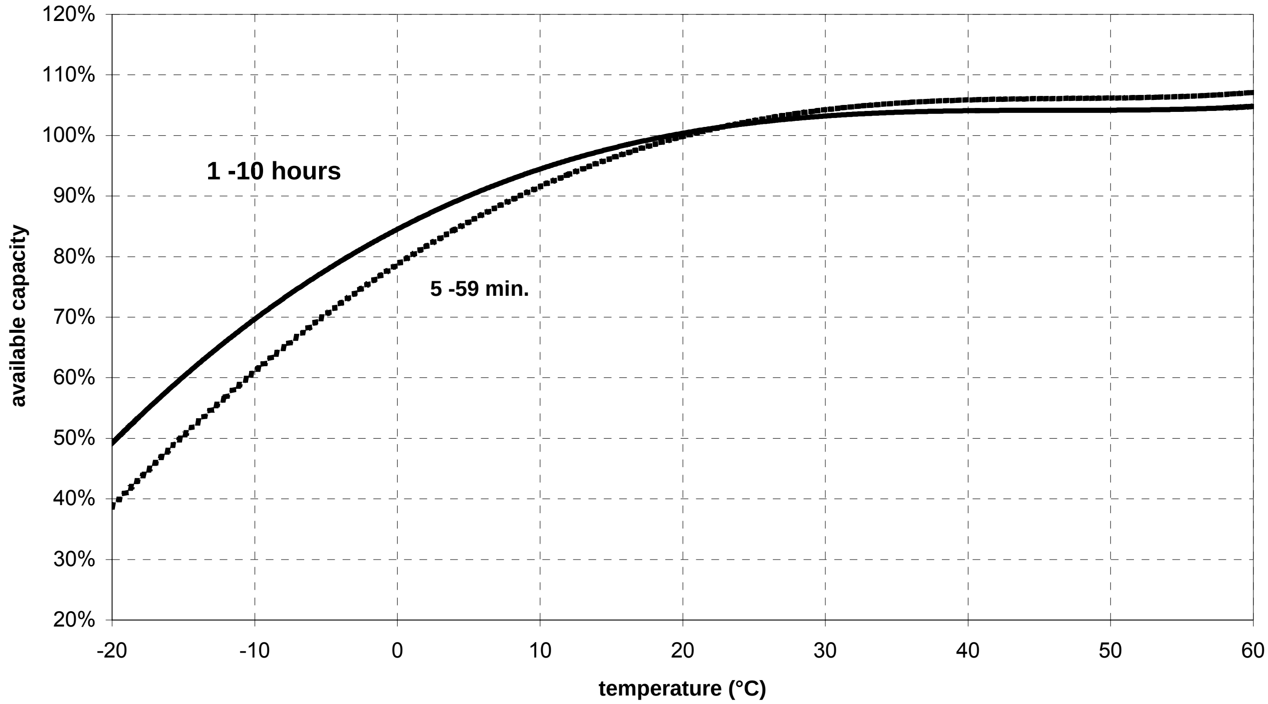

Figure 3: Capacity as a Function of Temperature and Discharge Rate

Short circuit

GT-F batteries are designed to withstand a short circuit current for 1 minute without damage.

Open circuit

When a battery is left open circuit, two major things are happening:

1) Sulfate is leaving the electrolyte and reacting with the plates causing a reduction in the State of Charge of the battery.

2) Grid corrosion is accelerated, especially when the open circuit voltage of the battery is allowed to go below 2.05 VPC.

The state of charge of lead acid batteries slowly decreases on open circuit due to self-discharge. In GT-F batteries, the rate of self-discharge is about 2 - 3% per month at 25° C. During prolonged storage it is necessary to boost- charge the battery at least every 6 months according to the instructions in paragraph 8 to maintain a fully charged condition of the battery.; Excessive open circuit storage of any lead acid battery without recharge will result in some permanent loss of capacity. When stored at higher temperatures, the boost interval should be more frequent. The key is to keep the open circuit voltage (measured in a fully rested state of at least 16 hours) at or above 2.05 VPC to minimize the amount of irreversible grid corrosion.

Storage Temperature	Boost Interval
25ºC	6 Months
35ºC	3 Months
45ºC	1 Month

Cycling

The GT-F range of batteries will deliver 200 cycles (at C_8 to 1.75 VPC and 25 °C). Cycle life varies greatly based on the amount of energy removed during each cycle. FA batteries will deliver thousands of shallow cycles, but only hundreds of deep cycles. Special care should be used when comparing various manufacturers' claims. Every manufacturer has slight variations in defining the "Depth of Discharge". A claim of 500 cycles might seem great, until the fine print is read and the User finds out that the Depth of Discharge on each cycle was for a very shallow discharge. When comparing cycle life, make sure to carefully define the conditions (e.g. C_8, 25 °C, to 1.75 VPC) for an "apples to apples" comparison.

Gassing

As previously stated, GT-F batteries have a high recombination efficiency (>98%) and for cells operated at 20°C under normal operating conditions venting is virtually negligible. Laboratory test measurements show the following gassing rates:

- 2 ml/Ah/cell/month at a float voltage of 2.27 V/cell
- 10 ml/Ah/cell/month at a recharge voltage of 2.40 V/cell.

The quantity of gas (it basically consists of 80-90% hydrogen) given off is very low and thus it is clear that GT-F VRLA recombination batteries can be installed in rooms containing electrical equipment with no explosion danger or corrosion problems under normal conditions. The only requirement is that these rooms or cabinets must have natural ventilation and not be fully sealed. Hydrogen should never be allowed to exceed 2% by volume in any enclosed space. Also, customers should be aware that hydrogen is very light, and can "pocket" in portions of the room or cabinet. Designers should take this into account when designing the room or cabinet.

Thermal Runaway

As previously discussed in the *Life* section, float current is primarily a function of voltage and temperature. As either voltage or temperature increases, the float current also increases exponentially. Much of the float current is going into the recombination reaction, which is exothermic. If the heat generated by recombination exceeds the rate at which heat can be transferred out of the battery (based on conduction, convection, and black body radiation), a dangerous cycle can begin. This condition is known as thermal runaway. The battery will continue to take very large amounts of current from the rectifier and excessive gassing and overheating will result. In the most severe cases, equipment can be damaged by sulfuric acid mist that escapes the battery, hydrogen can build up to dangerous levels, and battery cases can rupture because of weakening and melting of the plastic. Ruptured cases can lead to ground faults. The importance of minimizing risk of thermal runaway cannot be overemphasized.

The most effective methods for minimizing the risk of thermal runaway are:

1) Use temperature compensated chargers
2) Never allow the batteries to exceed 55 °C
3) Make sure cabinets are properly ventilated
4) Provide spacing between batteries to enhance convective cooling
5) Visit sites annually to check for shorted cells, improperly set voltages, filter cleaning on ventilation systems, etc.

Operation of batteries in parallel

When the required capacity is greater than the maximum available from our range, it is possible to connect batteries in parallel to obtain the desired capacity.

- Use only blocks of the same model
- Make all electrical connections of parallel circuits as equal and symmetrical as possible between the batteries (e.g., length and type of connector) to minimize possible impedance variations

7. CHARGING

Introduction

After installation, batteries are an energy source ready to be used whenever necessary. It is very important that batteries are:

- Float-charged in order to be maintained in a fully charged condition during the standby period.
- Completely recharged after a discharge. Recharge as soon as possible to ensure maximum protection against subsequent power outages. Early recharge also ensures maximum battery life.

Recharge can be done in many ways, depending on the needs of recharge time or life of the batteries. In general, charging is performed as follows:

- at recharge voltages equal to the float voltage and low currents (long recharge time);
- at recharge voltage not higher than 2.4 V/cell and high currents (faster recharge).

The IU recharge method, also known as modified constant potential, has been used for many years and in a variety of applications. It satisfies the need to have the battery quickly recharged while ensuring maximum battery life. With this method, recharge starts at a constant current rate. The voltage increases up to a pre-set value. The pre-set voltage is maintained and the current then decreases to a minimum defined value. Finally, the recharge is completed at a final constant voltage value equal to or less than that defined for float charge with the current decreasing to the value used in float.

Recommended procedure for charging and floating of GT-F batteries

It is important to recharge VRLA batteries using methods which do not cause excessive gassing. Such methods would cause excessive water consumption and a loss of battery life as well as present unsafe conditions do to the venting of gases. The only charging methods which should be used are those which operate automatically with a preset constant voltage value supplying a charging current whose maximum value cannot be exceeded; i.e., constant voltage charging with current limit and automatic crossover.

a) Float Charge and Temperature Compensation

The voltage recommended for float charge, which will ensure the maximum life of GT-F batteries is 2.26 V at 25°C. These batteries can operate over a temperature range of –20 to +60°C, as performance and life are greatly reduced outside of this temperature range. The recommended float voltages to maximize the battery life over the range of temperatures between -20 and +60°C are shown in Figure 5A.

Temperature	Recommended Float Voltage Per Cell
-20 °C	2.37
0 °C	2.32
20 °C	2.27
25 °C	2.26
60 °C	2.17

Figure 4A: Recommended Float Voltages at Various Temperatures

An acceptable range of float voltages is shown in the graph in Figure 4B. The equation for the midline of the acceptable float range in Figure 5B is:

$Y = 2.32 – 0.0025 * T$ (-2.5 mV per °C temperature compensation slope)

The minimum and maximum are 0.010 V on either side of this midline. Batteries floated at voltages above the range will have an increased risk of dry out, grid corrosion and thermal runaway. Batteries floated below the range will not receive enough charge, and will be subject to sulfation.

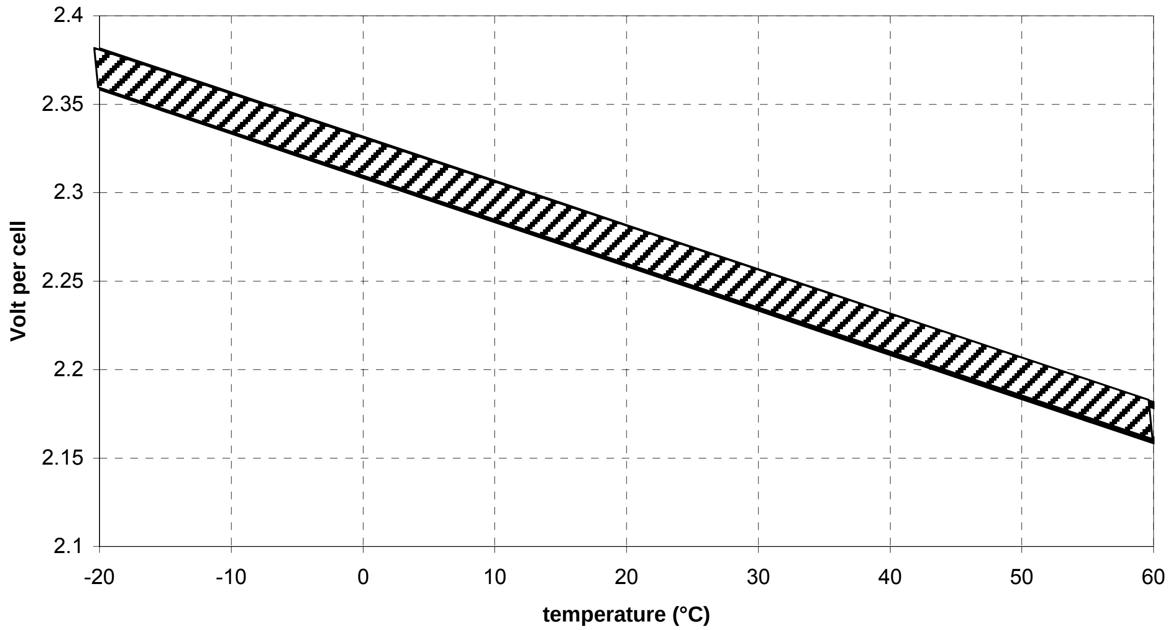

Figure. 4B Float Voltage vs. temperature

The normal float current observed in fully charged GT-F batteries at 2.27 VPC and a temperature of 20°C is approximately 30 mA per 100 Ah. Because of the nature of recombination phenomena, the float current observed in GT-F batteries is normally higher than that of vented batteries and is not an indication of the state of charge of the batteries**.**

b) Recharge following discharge

The recommended recharge method of GT-F batteries to maximize battery life is to use a constant voltage equal to the float charge voltage (2.27 VPC at 20°C) with a maximum charge current of 0.25 C_8 amperes. Users need to be careful of situations where excess current is available to recharge the battery. This happens in conditions when the DC load is low relative to the charger or maximum rectifier output, and the battery is fully discharged. If too much current is allowed to go into the battery, it can cause the battery to heat up excessively and be damaged. This scenario is especially likely at sites when the DC power plant has been fully installed and turned up before all of the DC loads have been attached to the bus.

Figure 5 demonstrates three recharge profiles using (3) different current limits.

Using a current limit of 0.1 C_{10}, it takes approximately 9 hours to restore 80% of the discharge, and 11 hours to restore 90%. This can be compared to a current limit of 0.25 C10, whereby 80% is returned in approximately 4 hours, and 90% within 5 hours.

When sizing the charger, keep the following in mind:

- More charger (rectifier) amps = More $

- Less charger (rectifier) amps = longer recharge time
- Too many charger (rectifier) amps can damage the battery

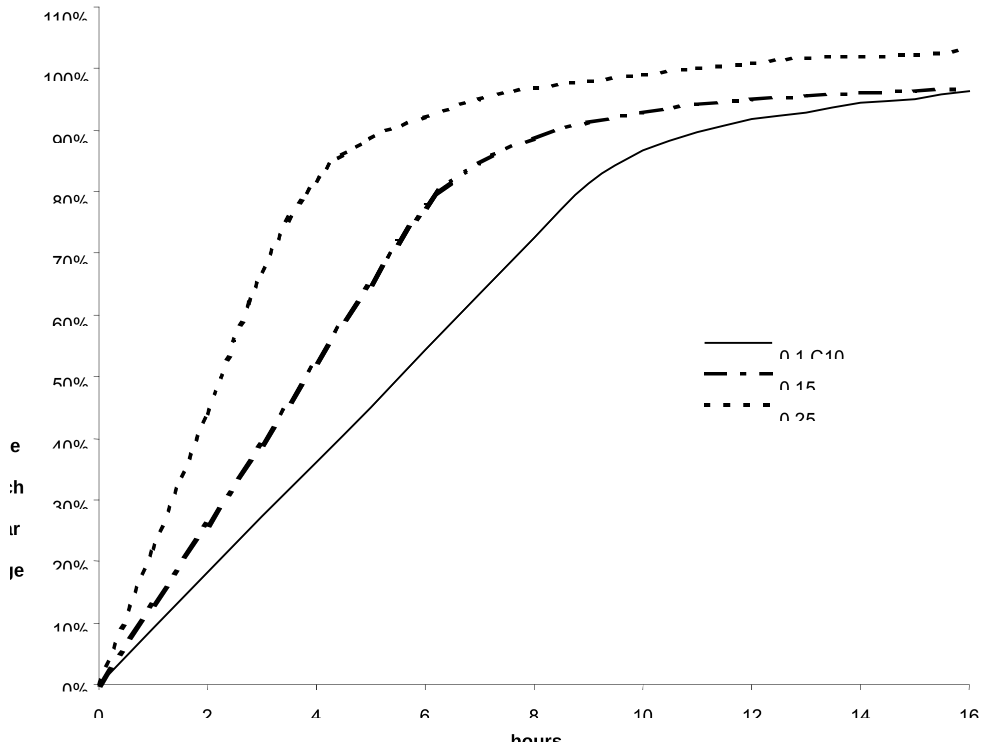

Fig. 5 Recharge Time and % Restored as a Function of Current Limit

If it is necessary to reduce the recharge time, the IU recharge method previously explained can be used with a maximum voltage of 2.4 V/cell at 25°C with a maximum current of 0.25 C_8. However this recharge should be limited to no more than once per month to ensure the maximum service life of the battery.

8. BATTERY SIZING

To use the GASTON BATTERY specification data tables, the User must determine the voltage per cell (VPC) at the end of discharge, the backup time and the required load. The constant current tables require the load amperage. The Constant Power tables require the load Watts per Cell (WPC).

Nominal Voltage

All lead-acid cells have a nominal voltage of 2 VDC per cell. Some typical nominal system voltages are:

<u>Typical Values</u>	
Telecom:	48 VDC
Cellular:	24 VDC
Utility:	120 VDC
Single Phase UPS:	48 and 120 VDC
Three Phase UPS:	240/360/480 VDC

Cells per String

When selecting the number of cells per string, the user must take into account the following:

- Operating temperature and charger maximum DC output voltage
- Minimum voltage of the load, inverter or low voltage disconnect
- Voltage losses in the cabling

GT-F batteries require different float voltages for different temperatures. Recalling Figure 5A, we know:

Temperature	Recommended Float Voltage Per Cell
-20 °C	2.37
0 °C	2.32
20 °C	2.27
25 °C	2.26
60 °C	2.17

The maximum number of cells per string is defined as the maximum DC output voltage of the charger divided by the required float voltage per cell for a given temperature.

Whenever possible, try and select a "Cells Per String" that is divisible by 2, 3 or 6 so that multi-cell blocks can be utilized.

<u>Application</u>

Telecom 48 VDC, Charger V_{max} ≥ 54 VDC:	24 cells per string
Telecom 48 VDC, Charger V_{max} < 54 VDC:	23 cells per string
Cellular 24 VDC, Charger V_{max} ≥ 27.5 VDC:	12 cells per string
Utility 120 VDC, Charger V_{max} ≥ 135 VDC:	60 cells per string
Utility 120 VDC, Charger V_{max}< 130 VDC:	58 cells per string

Low Voltage Interruption

Often times DC loads will shutoff if the voltage gets too low. Other equipment can be damaged if the DC bus voltage gets too low. As a battery discharges, the terminal voltage will drop. Many Engineers elect to use Low Voltage Disconnects (LVD's) to protect sensitive equipment from low voltages, and to prevent the battery from being over-discharged. LVD's can be placed on the load side, or on the battery side. Keep in mind that a string of batteries is a series of individual 2V cells working together. At the end of discharge, the voltages of the individual cells will vary based on the exact capacity of each cell. Most users try to terminate the load when the batteries reach 1.75 VPC to assure that no individual cells go below 0 VDC. Cells that go below 0 VDC are said to have been reversed, and usually need to be replaced. Other Engineers elect not to use any type of LVD. They are willing to sacrifice the battery to maximize the backup time, and to eliminate a potential failure point (i.e. an LVD that does not operate properly) in the DC power plant. GASTON BATTERY strongly recommends that any cells that have gone into reverse should be replaced immediately. To maximize battery life, GASTON BATTERY recommends that LVD's be used.

Voltage Losses

When sizing a battery, the Engineer must take into account that there are voltage losses between the battery terminals and the load or inverter. Therefore, to ensure that the voltage at the load is at the prescribed level, the cable losses must be added to the load cutoff voltage to properly arrive at the battery terminal voltage at end of discharge (required to use the Discharge Data Tables). The battery terminal voltage at end of discharge, divided by the total number of cells per string, is the required VPC to use the discharge tables.

VPC at End Discharge

Battery Terminal Voltage at End of Discharge / # Cells per String
where the Battery Terminal Voltage = Minimum Load Voltage + Cable Losses

Watts per Cell

For Constant Power discharges, the Watts per cell (WPC) is given by:

WPC = Battery Watts (kWb) / Number of Cells

Note: Make sure to get the inverter efficiency and Power Factor from the UPS manufacturer in order to convert the UPS kVA output to the required battery load kWb. Each UPS is different.

Aging Factor

As previously discussed, a battery has reached end of life when the capacity of the battery is 80% of the nominal capacity. Taking this into account, most Engineers will multiply their load by 1.25 to assure enough capacity at end of life.

Temperature Factor

Useful battery capacity is diminished as the battery gets colder. Consult Figure 4 to determine an appropriate de-rating factor. Most Engineers will multiply their load by a temperature capacity correction factor to take this into account.

Parallel Strings

If more than one string is to be used, the total load should be divided equally by the number of strings. Then do the sizing for one string, and remember to order all strings. The major issue with parallel strings involves voltage imbalances in the wiring scheme. If the strings are properly cabled, with equal voltage losses for each string, then there is not practical limit to the maximum number of parallel strings.

The easiest way to ensure that there are no voltage imbalances is to tie each string individually back to a heavy duty copper bus, and to make sure that the cable ampacity and length is the same for each string.

Type of cell to use

Once the minimum cell voltage has been calculated and the desired back up time has been defined it is possible to determine the most suitable cell type using the discharge tables listed at the end of this manual.

Examples

1) Constant power discharge - Telecom

<u>Required Info</u>
Maximum charger voltage = 53 VDC
Voltage Drop Between Load and Battery Terminals=1.24 VDC
Load Cutoff Voltage = 42 VDC
Nominal Load = 7300 Watts throughout the entire life
Minimum site temperature = 25°C
# of Strings = 1
Backup Time = 4 Hours

<u>Sizing</u>
1) Cells per String = 23 (Charger can’t reach 2.26 VPC * 24 cells)
2) Aging Factor = 1.25
3) No temperature de-rate
4) Corrected Load / String = 7300 Watts * 1.25 = 9125 Watts
5) WPC = 9125 Watts / 23 Cells = 397 WPC
6) VPC at End of Discharge = (42 VDC + 1.24 VDC) / 23 cells = 1.88 VPC

Going to the Constant Power Tables based on 4 hours, and 1.88 VPC, the GTS-1000 is selected. Since the GTS-1000 is 2 VDC per block, we would order a 23 cell system.

3) Constant power discharge - UPS

Required Info
Maximum charger voltage = 450 VDC
Voltage Drop Between Inverter and Battery Terminals= 5 VDC
Inverter Cutoff Voltage = 322 VDC
Nominal Battery Load = 14.7 kWb (not kVA!)
Minimum site temperature = 25°C
# of Strings = 1
Backup Time = 1 Hour

Sizing
1) Cells per String Maximum = 450 VDC / 2.26 VPC = 200 cells
2) Cells per String Minimum = (322 VDC + 4 VDC) / 1.65 VPC = 198 cells
3) Aging Factor = 1.25
4) No temperature de-rate
5) Corrected Load / String = 14.7 kWb * 1.25 = 18.4 kWb
6) Maximum WPC = 18,400 Watts / 198 cells = 92.9 WPC
7) Minimum WPC = 18,400 Watts / 200 cells = 92.0 WPC

Going to the Constant Power Tables based on 1 hour, and 1.65 VPC, the GT12-75F is selected. Since the GT12-75F is 12 VDC per block, and six cells per block, it would be best to size the system using (33) GT12-75F's in series which gives us (198) cells.

4) Constant Current discharge - Utility

Required Info
Maximum charger voltage = 140 VDC
Battery Side LVD Voltage = 105 VDC (negligible cable losses)
Nominal Battery Load = 50 amps
Minimum site temperature = 25°C
# of Strings = 1
Backup Time = 1 Hour

Sizing
1) Required Float Voltage = 2.26 VPC
2) Cells per String Maximum = 140 VDC / 2.26 VPC = 62
3) Cells per String = 60
4) VPC at End of Discharge = 105 VDC / 60 cells = 1.75 VPC
5) Aging Factor = 1.25
6) No temperature de-rate
7) Corrected Load / String = 50 amps * 1.25 = 62.5 amps

Going to the Constant Power Tables based on 1 hour, and 1.75 VPC, the GT12-105F is selected. Since the GT12-105F is 12 VDC per block, and three cells per block, 10 units would need to be ordered.

IEEE Sizing

The IEEE has a recommended procedure for sizing batteries. This technique takes into account dynamic or changing loads throughout a discharge. Contact Stand Power Industrial Co.,Ltd. for additional information regarding IEEE sizing methodologies.

9. APPLICABLE STANDARDS

FA batteries fully comply with:
- British Standards N° 6290 Part 4: "Specification for lead acid batteries"

- IEC 896-2 - Part 2 Stationary lead-acid battery - General requirements and test methods - Part 2: Valve regulated types
- Norme CEI 21.6 fascicolo 1434: Batterie di accumulatori stazionari al piombo
- Eurobat Guide to the specification of valve regulated Lead acid stationary cells and batteries: Group I: 10 + year-high integrity
- Australian Standard AS 4029.2 – 1992 Stationary batteries - Lead-acid - Part 2: Valve - regulated sealed type.

10. STORAGE

- Batteries are delivered filled, charged and ready for installation.
- No operation such as filling, commissioning or other type is required.
  They need only to be connected in series and/or in parallel as required by the particular application.
- If they cannot be installed immediately, batteries are to be kept in fresh, clean dry rooms. Furthermore, considering that on open circuit batteries lose part of their capacity due to self discharge (2-3% per month at 25°C), a float recharge is recommended at least every 6 months. If the batteries are stored at temperatures above 25°C, then the boost interval will be more frequent. Float recharge consists of applying a voltage of 2.26 V/cell for approx. 48 hours with a current limit of 0.25 * C_8. Never allow the terminal voltage of any blocks to go below 2.1 VPC to avoid the risk of open circuit corrosion or irreversible sulfation.
- Never double stack pallets
- Never store batteries in direct sunlight.
- Avoid exposure to salt laden air.

11. INSTALLATION

FA valve regulated recombination batteries can be fitted on stands or into cabinets. GASTON BATTERY offers a wide selection of stands, from one tier/one row to six tiers/three rows, to suit most applications. Cabinets are available with or without circuit breaker and its relevant compartment. GASTON BATTERY does not recommend pre-installing the batteries into racks or cabinets prior to shipment.

Location Considerations

1) The battery should be installed in a cool, dry location with plenty of access for installation and maintenance. Pick a location that has the temperature maintained around 25°C, that is not in direct sunlight, underneath an air duct, or any other location that would cause temperature variations within the battery.
2) The work area should have plenty of ventilation. There must be enough Air Changes per Hour (ACH) to keep hydrogen from reaching 2% by volume. Never place any batteries in a sealed cabinet or enclosure.
3) Batteries are heavy. Make sure the flooring is designed to accommodate the weight. GASTON BATTERY can provide floor loading data for each system. Make sure the floor is level. If the rack needs to be anchored for seismic ratings, then make sure the floor is rated for anchors.

Unpacking

1) Carefully check the Bill of Lading against the shipment to make sure everything has arrived. Carefully inspect the batteries for any sign of damage during transit. Immediately report damage to the Carrier. Damaged batteries should be replaced immediately.
2) Batteries are very heavy, and should be lifted with care. Whenever possible, use (2) or more people to lift.
3) Care should always be taken to avoid shorting the positive and negative terminals.
4) Make sure not to throw away any of the hardware or accessories that accompanies the battery shipment.
5) Dispose of the packing material properly.

Loading Cabinet or Rack

1) Special precautions must be taken to avoid accidental short circuits during the installation. Only used insulated tools, and never wear jewelry.
2) Upon installation of GT-F blocs into a cabinet or on a stand, first place the single units at their correct position according to the electrical layout.
3) Start with the lowest shelf to ensure stability. Carefully preserve the sequence: positive, negative, positive, negative throughout the whole battery.
4) Flexible cable connectors for connecting from one shelf to the one below, will be applied once all the blocs have been connected. Connect inter-shelf or inter-row cable connectors at the final user's premises only.
5) Torque all terminal connections to the specified values. Improper torquing can result in loose connections or damaged terminals.