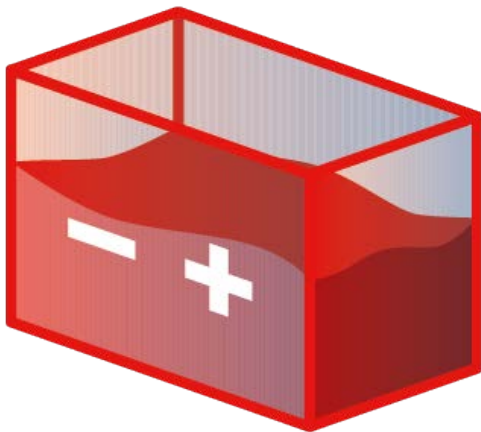




ENGINEERING MANUAL



VENTED LEAD ACID
BATTERIES

FLOODED
TECHNOLOGY

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INTRODUCTION

In a high technological environment, it is extremely important to have a backup power source whenever possible. In fact, mains power failure could cause severe losses and damage anytime.

FIAMM ENERGY TECHNOLOGY (FET) has been developing throughout years of research and experience, several ranges of Flooded Lead Acid Batteries to ensure the best reliability and quality.

1. CONSTRUCTION FEATURES

The main construction features of FET Flooded batteries are shortly described in the below section.

1.1 Plates

FET flooded lead acid batteries can be offered in three different positive plate types to fit all customer needs as performance and type of application as given below:

FIAMM Battery range	Type of positive plate	Type of negative plate
LM - LM/S	Tubular (A)	Flat (B)
SD - SDH	Flat	Flat (B)
SGL - SGH	Planté	Flat (B)

1.2 Containers

Battery cases and lids (C) are made of SAN (Styrene acrylonitrile) with high transparency, very good dimensional stability, heat and chemical resistance.

1.3 Separators

These separators (D) are made of microporous PVC material which assures a good ionic exchange in the electrochemical process.

1.4 Electrolyte

The electrolyte is diluted sulfuric acid with a specific gravity below indicated:

FIAMM Battery range	Electrolyte Specific Gravity at 20°C [kg/L]
LM – LM/S	1,24
SD - SDH	1,27
SGL - SGH	1,22

1.5 Vent plugs

Each cell has one or more vent plugs (E) to permit the release of gases from the cell during the charging process; the ceramic part prevents explosion of the gases inside the battery; they are fix by bayonet lock or by screw. A plain vent without the ceramic part is available for some types as an option.

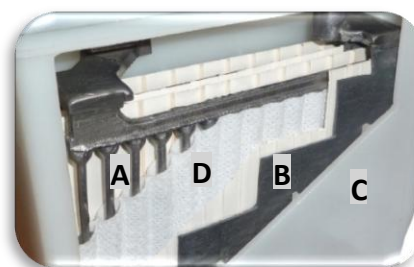
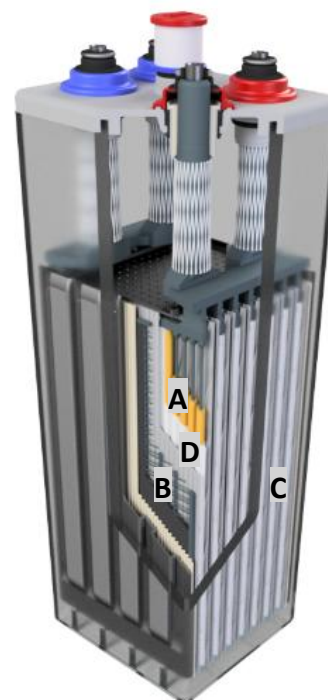
1.6 Terminal posts

Suitable threaded or flag post (F) are provided to ensure low ohmic losses. Post-to-lid seals are designed to prevent leakage over a wide range of internal pressures and thermal cycling conditions. Special plastic terminal caps (G) are provided for transportation, assuring protection against short circuits during transportation.

1.7 Inspection Hole

A special hole (H) is provided in models SGL-SGH to control the electrolyte density and temperature without removing the recombination plugs.

Cutaway drawing of FIAMM cells with positive tubular plate



Rectangular
"nut and bolt"
Terminal



Female (Bolt)
terminal



E



G



H

2. OPERATING FEATURES

2.1 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, temperature, and minimum voltage.

The nominal capacity of FIAMM batteries refers to the 10 hours discharge rate (indicated with C_{10}) with constant current at 20°C to 1,80 volt per cell.

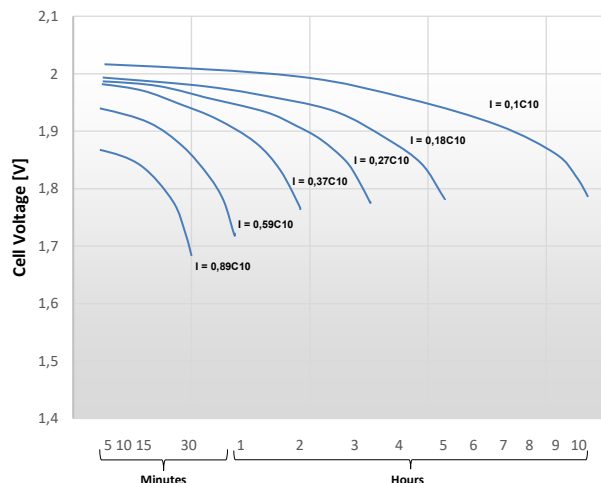


Fig. 1:
Typical discharge curves for FIAMM Lead Acid Flooded batteries.

2.2 Capacity in relation to discharge rate

The available capacity of all lead acid batteries depends on discharge rate (discharge current); this is due to internal electrochemical process and type of construction (i.e. type of positive plate).

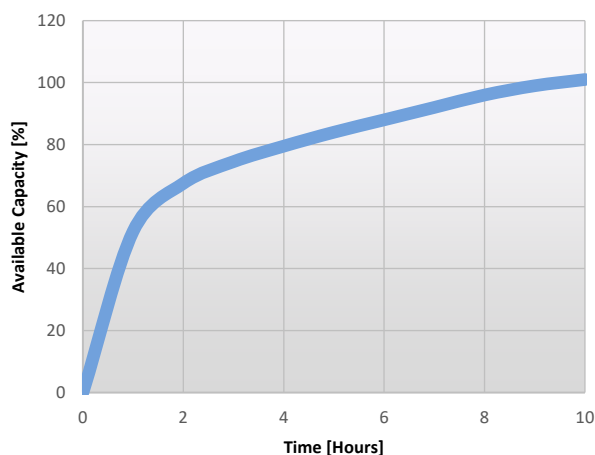


Fig. 2:
Average available capacity versus discharge rates for FIAMM Lead Acid Flooded batteries.

2.3 Capacity range of FET Flooded Lead Acid Batteries

FIAMM Battery range	Capacity Range 10h 1,80 VPC 20°C [Ah]
LM	from 108 to 3500
LM/S	from 150 to 5000
SD	from 83,3 to 458
SDH	from 493 to 2380
SGL	from 78,3 to 470
SGH	from 550 to 2860

2.4 Capacity in relation to the temperature

The capacity available from a battery at a given discharge rate changes with temperature.

When operating at temperatures different from the nominal 20°C, the required capacity must be adjusted (required capacity at 20°C is selected multiplying the capacity at temperature "X" by the correction factor in the graph).

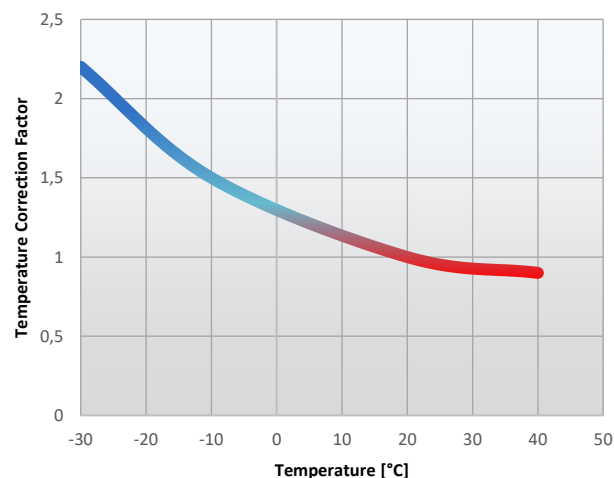


Fig. 3:
Capacity Correction factor versus temperature for a 10 hours discharge rate for FIAMM Lead Acid Flooded batteries.

2.5 Internal impedance and short circuit current

The internal impedance of a lead-acid battery depends on its design (plate type and thickness, number of plates, separator, electrolyte sp. gr.), as well as temperature and state of charge. For FET flooded batteries at 100% SOC and 20°C, internal resistance and short-circuit current values are provided in the Product Sheet and calculated according to IEC 60896-11.

Measurement instruments may use different methods, so their readings can differ from the values reported by FIAMM Product Sheet.

2.6 Service life

According to the main international standards a battery is considered at the end of its service life whenever delivering less than 80% of its nominal capacity. The recommended operating temperature range is between 10°C to 30°C. FIAMM flooded batteries can operate in a temperature range of -20 to +50°C; operation at temperature higher than 20°C reduces life expectancy according to the graph in figure 4.

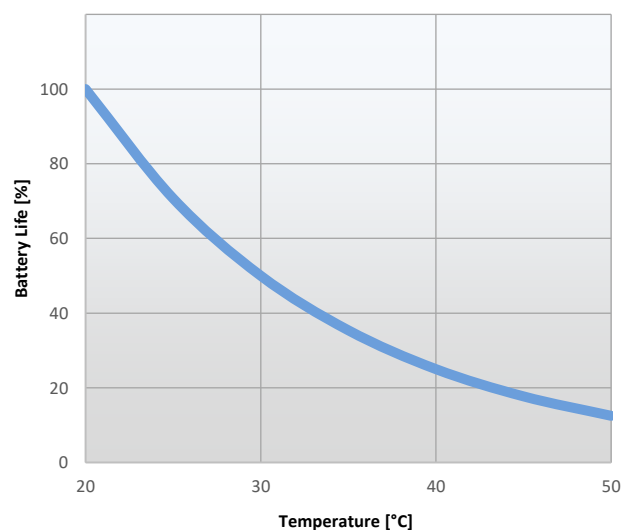


Fig. 4:
Expected service life vs working temperature.

2.7 Storage of filled and charged cells

The state of charge of lead acid batteries slowly decreases in open circuit conditions, due to self-discharge.

FIAMM Battery range	Max storage time @10°C (80% capacity)	Max storage time @20°C (80% capacity)	Max storage time @30°C (80% capacity)
LM - LM/S	9 months	5 months	3 months
SGL - SGH	9 months	5 months	3 months
SD - SDH	6 months	3 months	2 months

A refresh charge is required once the MAXIMUM STORAGE TIME is reached (recommended: boost charge according to the instructions in chapter 4 “Charging”) to keep the battery fully charged. Prolonged open circuit storage without recharge can cause permanent capacity loss. A maximum of one refresh charge shall be performed.

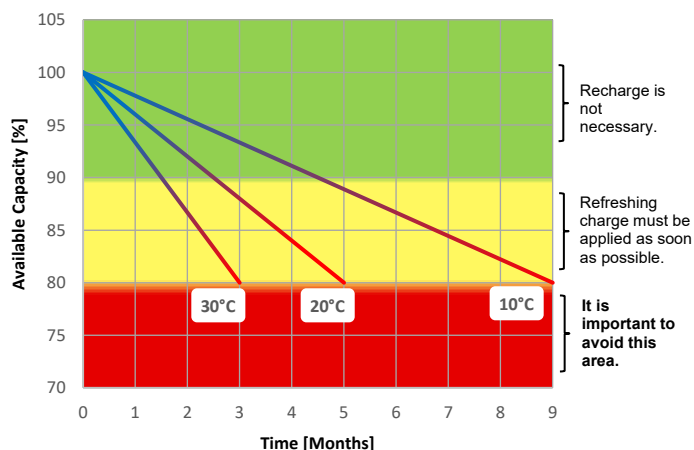


Fig. 5:
Storage time vs temperature for LM – LM/S, SGL – SGH cells.

2.8 Storage of dry charged cells and electrolyte

In this situation there is no electrolyte inside the cells so no electrical reaction can take place. In this condition the batteries can be stored for many years under the following conditions:

- Storage the cells in clean, cool, dry rooms that are adequately protected against condensation and the effects of high humidity (>90%).
- Storage temperature between -20 to 50°C; direct sunshine has to be avoided.; atmospheres with chemical contaminants have to be avoided.
- Avoid storing unpacked battery cells.

2.9 Gassing

All Lead Acid Batteries emit gases during the charge process. Please refer to chapter 11 “Ventilation” for information on required air exchange.

2.10 Operation of batteries in parallel

When the required capacity exceeds the capacity of a single string of batteries, it is possible to connect more strings in parallel, paying attention to the following guidelines:

- In each string only cells or monoblocks of the same type, model and quantity should be used. Please be aware that a difference of a few months in the manufacturing date is acceptable. In such cases, ensure that the OCV and storage-time requirements described in paragraph 2.7 are always observed prior to installation.
- A symmetrical layout of the batteries should be designed (i.e. length and type of connector) to minimize possible resistance variations.
- The quantity of strings in parallel should be reasonable in terms of layout and application. Usually, 4 strings could be connected in parallel. However, depending on strings voltage and cables length, a higher number of strings could be safely connected to reach required total capacity.

2.11 Electrolyte Specific Gravity - State of charge

The measurement of the specific gravity of the electrolyte (when it is at the MAX level) provides an approximate indication of the state of charge of the cells.

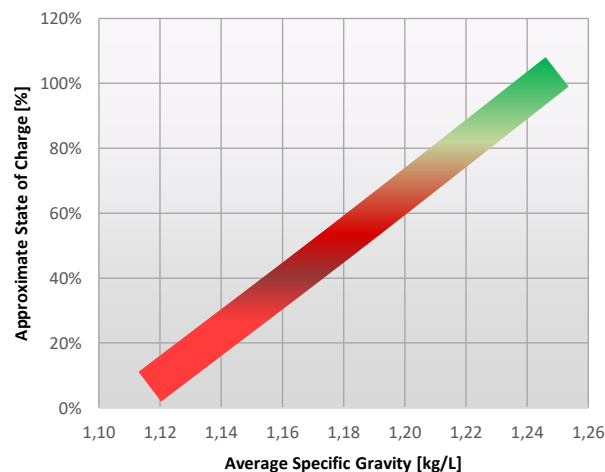


Fig. 6:
Electrolyte specific gravity in relation to the state of charge of the cell (LM - LM/S cells).

2.12 Applications

The table below summarizes the main (■) and secondary (□) applications for each battery range.

	LM	LM/S	SD - SDH	SGL - SGH
Data Center & UPS			■	□
Telecom	■			
Industry & Utilities	■		■	■
Motion	■			
Security & Emergency				
Renewable		■		

3. COMMISSIONING CHARGE / FIRST CHARGE

Lead acid flooded batteries can be offered in two different conditions:

- **Dry charge cells** can be stored for long time (many years).
- **Filled and charged** cells should be installed and connected to a rectifier as specified in paragraph 2.7 "Storage of filled and charged cells".

Be sure that ventilation equipment is "ON" when charging a battery.

3.1 Dry charge cells

For **locally sourced electrolyte**, follow the chapter 10 "Electrolyte" for the required specific gravity and impurity limits; purchase about 10% extra to account for handling losses.

For **FIAMM-supplied electrolyte**, check and adjust the specific gravity if needed (water to lower sp. gr., acid to raise sp. gr.).

1. **Fill the cells** after rack installation; the required electrolyte quantity per cell is shown in the Product Sheet.
2. Remove vent plugs and fill using only plastic or funnels, never metallic materials.
3. Fill the cells with electrolyte to the "MAX" level line and leave to allow the acid to soak into the separators and plates.
4. If electrolyte spills, neutralize with a mix of 1 kg soda in 10 liters of water. Keep soda OUT of the cells.
5. After ~3 hours, if needed, top up the electrolyte to the "MAX" level line.
6. Give the initial charge as soon as possible after 3 hours stand, and never let the cells stand for more than 18 hours before charging.
7. Before charging, record voltage, specific gravity and temperature of each cell.
8. Perform the **initial charge** at 0,10 C₁₀ for 16–17 hours, ensuring rectifier voltage reaches $V_n = 2,70 \times \text{number of cells connected in series}$. Monitor every 1 hour the total string voltage to ensure it remains stable, the string current in order to calculate the injected capacity, and the battery temperature to make sure it does not exceed 45 °C. If the temperature reaches 45 °C, stop the charging process and resume only once the temperature has decreased to approximately 35 °C. If the charger is unable to reach 2.7 Vpc, consider dividing the string.
9. The total Ah input must reach 1,6–1,7 × the rated C₁₀ capacity (i.e. 160 to 170 Ah for a 100 Ah cell).
10. When the total amount of Ah has been injected, set the battery voltage to the FIAMM recommended float voltage.

4. CHARGING

In order to ensure the best protection against power failures in any moment, it is necessary that batteries are kept in the following conditions:

- In float charging throughout all their standby period.
- Fully recharged soon after a discharge.

4.1 Floating charge

Floating charge battery systems are those where the charger, the battery and the load are connected in parallel.

The "float" setting will maintain the battery in a fully charged state with minimal water consumption.

The recommended float voltage setting for FIAMM lead-acid cells is indicated in the following table:

Cell type	Float voltage at 20°C
SD – SDH LM – LM/S SGL – SGH	2,23 volts per cell

The normal float current observed in fully charged FET batteries at 2,23 VPC and a temperature of 20°C is approximately 0,3 mA/Ah.

FIAMM recommends no compensation for a limited temperature difference ($\pm 10^\circ\text{C}$) compared to nominal 20°C. Flooded tech is not as sensitive to temperature as other lead-acid techs are.

If the temperature difference is higher, especially for low temperatures, you can apply compensation using the following formula:

T ≤ 10°C: +2,5mV/cell/°C (e.g. at 0°C: 2,28 Vpc)

T ≥ 30°C: -2,5mV/cell/°C (e.g. at 40°C: 2,18 Vpc)

4.2 Boost charge (Recharge following a discharge)

Boost charge has to be used to recharge a battery after a discharge (it will restore the battery to a fully charged state within relatively short period).

Boost charge has to be carried out at 2,40 volt per cell with a current limited to 0,15 C₁₀. Lower current will increase the recharge time. Generally, setting the current limitation to 0,15 C₁₀ is merely a safety parameter for overheating; charging time is not limited if there is such limitation. Charging must be stopped when the charging current reaches 0,001 C₁₀ or 24 hours after the start of charging, whichever occurs first. Electrolyte density has to reach the nominal value and remain constant for at least 2 hours.

For temperature compensation, follow the floating charge criteria.

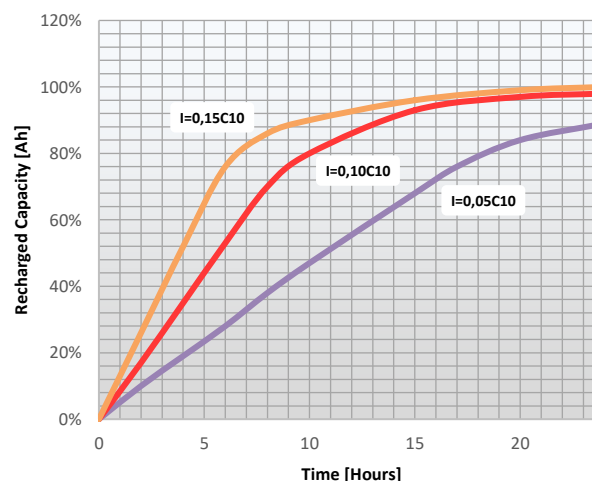


Fig. 7:

Boost charge curves at 2,40 V per cell with different limits of current.

4.3 Equalizing charge

Equalizing charge is not a standard charging method and therefore must be supervised by FIAMM technician.

Equalizing is required to reduce the spread of float voltage among the cells under float charging conditions. Consider that equalizing charge is not a standard charging method and therefore should not be applied automatically after a discharge.

A short equalizing charge (from 30 minutes to some hours) could be also required after addition of distilled water to make sure the acid and water are well mixed (check electrolyte density value).

Equalizing should be carried out at 2,70 volts per cell, to simulate constant current between 5% and 10% of the cell nominal capacity in Ah. During this charge vent plugs have to be removed, and safety precautions must be strictly observed.

Temperature of the electrolyte has to remain lower than 45°C.

5. BATTERY INSTALLATION

All necessary precautions must be taken when working with lead acid batteries as per electrical risk, explosives gasses, heavy components, corrosive liquids. Use insulated tools and wear protective equipment.

5.1 Installation

1. Ensure that all containers and cell covers are thoroughly clean and dry.
2. Use only cotton cloths slightly moistened with mild soap for cleaning; avoid synthetic cloths.
3. Clean the terminal contact surfaces with a dry cloth. For acid residues, use a cotton cloth moistened with mild soap or a mild alkaline solution, ensuring that no liquid enters the cells, then dry.
4. In case of white deposits, lightly sand with Scotchbrite or fine sandpaper, remove the particles, and apply a thin layer of No-Oxide grease along the entire length of the terminal.
5. Since the cells are heavy, use straps and mechanical lifting devices; do not lift the cells by the terminals to avoid injuries or damage.
6. Place the cells or blocks properly on the rack, respecting the spacing for connectors (**10–15 mm**) and the container tolerance (**+2 mm**). Maintain the series sequence: +, –, +, –, etc.
7. For double-tier racks, start with the lower tier at the section intersections; any free space goes on the upper tier.
8. Prepare the connectors by lightly sanding with Scotchbrite or fine sandpaper; do not use a wire brush and avoid damaging the lead coating.
9. Apply a thin layer of No-Oxide grease on the connector contact surfaces, working the grease into the ends, if possible, without covering the central area.
10. Fasten the intercell and inter-tier connectors with the supplied bolts, nuts, and washers, tightening them with the provided insulated wrenches.

Battery Range	Thread Type	Standard Value [Nm]
LM-LM/S (OPzS) SGL - SGH	M10 Female	20÷25
SD - SDH	Flag Ø8,5	10÷12

11. Take care to avoid short circuits between the cells and any battery materials.
12. Connect the positive terminal of one cell to the negative terminal of the next, leaving the main terminals free for connection to the charger. Maintain the +/– sequence, including when using flexible connectors.
13. Insulate all connectors with supplied plastic caps. Connect the battery + to the charger + and the battery – to the charger –.

14. Remove and dispose of any plastic protective caps provided for transport.
15. Install the FIAMM explosion-proof fans.
16. Label the cells with their numbers on clean, dry surfaces, starting with #1 at the positive end and following the electrical connection sequence to the negative end.

5.2 Ripple

Voltage ripple: Residual AC ripple is usually present in the output voltage of chargers; amplitude and frequency depend on charger design, and it can affect negatively battery life. Ripple could increase water loss, battery temperature and accelerate corrosion with a result to reduce the battery life. It is recommended therefore, that voltage regulation across the system including the load, but without the battery connected, under steady state conditions, shall be better than $\pm 1\%$ through 5% to 100% load. Transient and other ripple type excursions can be accommodated provided that, with the battery disconnected but the load connected, the system peak to peak voltage, including the regulation limits, falls within 2,5% of the recommended float voltage of the battery.

Current ripple: under no circumstances should the current flowing through the battery when it is operating under float conditions, reverse into the discharge mode.

5.3 External Devices on Battery System

In case devices of any kind are connected to the batteries and draw energy from them, the following conditions must be strictly observed:

1. The current draw must be balanced, ensuring that energy is evenly drawn from each battery block.
2. The battery power supply must never be turned off. If it is necessary to interrupt the power supply for more than a couple of days — and not in a cyclical or temporary way — all devices consuming energy must be disconnected, in order to prevent deep discharges or damage to the system.

5.4 Battery room requirements

- The battery room should be dry, well-ventilated and have its temperature as moderate as the climate will allow, preferably between 10°C and 30°C.
- **DO NOT permit smoking or the use of open flames in the battery room.**
- Adequate ventilation to change the air in the battery room is essential to prevent an accumulation of the gases given off during charge (for further information please refer to chapter 11 "Ventilation").
- The battery will give the best results and life when working in a room temperature of 20°C but will function satisfactorily when operating in temperatures between -20°C and +50°C. High temperatures increase the performance but decrease the life of the cells; low temperatures reduce the performance.
- Do not allow direct sunlight to fall on any part of the battery.
- If a rack is not supplied by FIAMM, suitable racks should be provided to support the cells. These should be arranged to provide easy access to each cell for inspection, topping up and general maintenance. Suitable racks may be made of wood or metal with a coating of acid-resistant paint. If metal racks are used, they must be fitted with rubber or plastic insulators to prevent the cells coming in contact with the metal.
- To facilitate proper battery operation, maintenance, and care, post a battery data card/ instruction table in a conspicuous place near the battery to provide the attendant with service information and data.

6. SAFETY

It is recommended that full precautions be always taken when working on batteries. The safety standards of the country of installation must be risk, explosives gasses and heavy components.

6.1 Protective Equipment

Make sure that the following equipment is available to personnel working with batteries:

- Instructions manual.
- Tools with insulated handles.
- Fire extinguisher.
- PPE (Personal Protective Equipment) must be worn (glasses, gloves, aprons, etc.).
- **First aid equipment must be available.**

6.2 Safety Precautions

Always observe the following precautions:

- Batteries are no more dangerous than any other equipment when handled correctly.
- Do not allow metal objects to rest on the battery or fall across the terminals.
- Never wear rings or metal wrist bands when working on batteries.
- Do not smoke or permit open flames near batteries or do anything to cause sparks.
- Do not try to remove the battery cap to add water or acid into the cell(s).
- Air exchange must be provided to prevent the formation of explosive hydrogen concentration.
- Voltage and electrolyte density measurements shall be taken respecting the safety distance indicated in EN50272-2; measures can be taken at lower distance only when:
 - Battery is under discharge.
 - Battery is disconnected from the charge for at least two hours.

6.3 Battery Disposal

Lead acid batteries must be disposed according to the country's law. It is strongly recommended to send batteries for recycling to a lead smelter. Please refer to the local Standards for any information.



Pb

7. APPLICABLE STANDARDS

FET flooded batteries comply with:

- **IEC 60896 – 11:**
Stationary lead-acid battery – Part 11: Vented Types – General requirements and methods of tests.
- **EN 62485 – 2:**
Safety requirements for secondary batteries and battery installations Part 2: Stationary batteries.
- **DIN 40736 – 1:**
Lead acid batteries; stationary cells with positive tubular plates; cells in plastic-containers; rated capacities, main dimensions, weights (for LM – LM/S range).
- **DIN 40738:**
Lead storage batteries; stationary cells with positive Plante plates, narrow plate distance; rated capacities, main dimensions (SGL - SGH ranges).
- **BS 6290 – 3:**
Lead-acid stationary cells and batteries. Specification for lead-acid pasted positive plate type (SD - SDH range).
- **BS 6290 – 2:**
Lead-acid stationary cells and batteries. Specification for lead-acid high performance Planté positive type (SGL - SGH ranges).
- **BS 6290 – 1:**
Lead-acid stationary cells and batteries. Specification for general requirements.

8. MAINTENANCE

8.1 Battery care

GASES GIVEN OFF BY BATTERIES ON CHARGE ARE EXPLOSIVE!

DO NOT SMOKE OR PERMIT OPEN FLAMES OR DO ANYTHING TO CAUSE SPARKS NEAR BATTERIES.

1. Check the electrolyte levels in all cells regularly and if necessary, top up with distilled water. Never allow the electrolyte level to fall below the "MIN" line. Do not overfill the cells. For information about quality of water to be added please refer to chapter 10 "Electrolyte". When water has been added, perform a boost charge to help mix the electrolyte.
2. Keep the battery and surroundings clean and dry. Wipe the cells with an antistatic clean soft cloth dampened with clean water. If necessary, a small amount of mild detergent may be added to the cleaning water to remove any greasy films. Do not use any special powders or solvents for cleaning the battery cells, as scratching or damage to the plastic could occur.
3. Make sure that bolted connections are properly tightened (see table in chapter 5 "Battery Installation").
4. Keep connectors, posts and bolted connections covered with "No-oxide" grease for protection against corrosion.
5. Should any corrosion of the connections occur because of spilled acid, etc., carefully remove corrosion materials, thoroughly clean and neutralize with diluted ammonia or baking soda.
6. Dry the parts before coating them with "No-oxide" grease to protect them from further corrosion. Do not let the neutralizing solution enter the cell.
7. Keep the battery at the recommended charge voltage (see chapter 4 "Charging").
8. The room in which the battery is installed should be well ventilated and its temperature as close as possible to 20°C.

8.2 Cleaning

When necessary, batteries could be cleaned using a soft dry antistatic cloth or water-moistened soft antistatic cloth paying attention not to cause any ground faults.

No detergent nor solvent-based cleaning agents nor abrasive cleaners should be used as they may cause a permanent damage to the battery plastic container and lid.

8.3 Voltage checks

All voltage measurements should be made when the whole battery has stabilized on floating, at least 7 days after battery installation or after a discharge cycle. To facilitate voltage reading in the correspondence of each block terminal protection covers are designed with a safe and proper hole. Measure and record individual block voltages on float once a year. It is normal to have a spread of block voltages up to $2,23^{+0,1}_{-0,1}$ V particularly in the first year of operation. In the following time the tolerance of the voltage of each cell could be in the narrower range of $2,23^{+0,1}_{-0,05}$ V. No corrective action is required in this case; for higher differences a boost charge is suggested. Maintaining a correct battery charging voltage is extremely important for the reliability and life of the battery. So, it is advisable to carry out a periodical checking of the overall float voltage to verify any possible defect of charger or connections.

8.4 Specific gravity reading

When taking specific gravity readings, care must be taken to make sure that the electrolyte level in the cell to be measured is at the "MAX" line and that any distilled water added recently has been properly mixed in.

The specific gravity of the electrolyte varies with temperature; consequently, hydrometer readings should be corrected as indicated in chapter 10 "Electrolyte".

The specific gravity may range $\pm 0,01$ points within a cell at the nominal values of 20°C; during the first year of operation a wider range could be noted.

NEVER ADD ACID TO INCREASE SPECIFIC GRAVITY READINGS.

8.5 Cell Appearance

Healthy cells, when fully charged, show a marked contrast between the dark brown positive and the light grey negative plates. For cells in transparent jars (LM, LM/S, SD, SDH, SGL, SGH), it is extremely useful to inspect the appearance of each cell in the battery at regular intervals.

Any cells not showing a healthy plate coloration or having a specific gravity or voltage noticeably lower than the other cells, or in which the plates bubble unevenly or not at all, should be regarded as suspect. Such cells should be carefully examined for internal short-circuits, such as may be caused by small pieces of scale bridging across the plates.

8.6 Pilot Cell

For regular monitoring of the battery condition, select one or more battery cells as a "pilot" cell(s); for batteries comprising more than 60 cells, select one pilot cell for every 60 cells. The electrolyte specific gravity of the pilot cell(s) will be indicative of the state of charge of the whole battery.

8.7 Periodic Inspections

Written records must be kept of battery maintenance, so that long-term changes in battery condition may be monitored. The following inspection procedures are recommended:

EVERY THREE MONTHS:

- Visual inspection on cells/racks (appearance, cracks or corrosion signs, electrolyte leakage....).
- Check and record the overall float voltage at the battery terminals (not at the charger!).
- Measure and record the pilot cell(s) voltage.
- Measure and record the pilot cell(s) electrolyte specific gravity.
- Measure and record the pilot cell(s) electrolyte temperature
- Electrolyte level.
- Room ventilation.

YEARLY:

- All the controls indicated at three months.
- Check and record the voltage of all cells.
- Measure and record electrolyte specific gravity and temperature of all cells.
- In case of frequent high discharge current please consider checking the bolt torque every year (especially for SGL – SGH range).
- Clean the cells.
- In case coat the connection with no-oxide grease.

YEARLY SUGGESTED:

- Discharge test followed by boost charge.

9. BATTERY TEST

As prescribed by EN 60896-21/22, any discharge test must be conducted with a battery in a fully charged condition.

To achieve this condition it might be necessary to perform a boost charge (2,40 V per cell at 20 °C, blocking it when the charging current reaches 0,001 C₁₀ or 24 hours after the start of charging, whichever occurs first).

In order to take temperature readings of a battery, one pilot cell or block shall be chosen. The surface temperature of the container wall centre of each pilot cell or block shall be measured immediately prior to the discharge test.

The individual readings shall be between 15°C and 30°C. The temperature of the selected block shall be considered as representative of the average temperature of the battery. It is desirable that the average cell surface temperature and the ambient temperature fall as nearer to the reference temperature of 20°C or 25°C as possible.

In the case of batteries having a capacity lower than 80% of the nominal rating it is advisable to replace them within 12 months.

Here below some precautions to be taken:

- Discharge must be stopped at the final discharge voltage.
- Deeper discharges must not be carried out unless specifically agreed with FIAMM.
- Recharge immediately the battery after each (full or partial) discharge test.

9.1 Service/ Functional test

This is a test of the battery's ability, to satisfy the design requirements of the system. It means to discharge the battery directly to the load (in this case take precautions to ensure that a battery failure does not jeopardize other equipment) or dummy load to simulate a main failure.

1. Record the floating voltage of each cell, as well as the total system voltage.
2. Check the actual load (A or W), as well as the minimum admissible voltage of the system.
3. On FIAMM discharge tables you can approx. determine the discharge rate (minutes of discharge). **Please note that battery performances decrease with battery age.** After switching off the rectifier, discharge the battery for a time of 20% of that calculated discharge rate.
4. During the discharge, record at regular intervals, cell/block voltage, battery temperature, discharge current, total battery voltage.
5. For safety reasons, during the test assure that the total battery voltage remains above the minimum depending on discharging rate in order to avoid any failure to the system (please note that approaching to the final voltage, the voltage curve decreases rapidly).
6. Wait at least 48 hours between two consecutive discharge tests (in the event of a full discharge).
7. For particular comments on test data, please refer to FIAMM technical offices.

9.2 Capacity test

Please carry out this test only when complete information on the quantity of energy inside the battery is requested.

Take precautions because after this test battery SHOULD NOT BE ABLE TO SUPPLY ENERGY IN CASE OF MAIN FAILURE.

Dummy load is usually necessary to provide the request discharge current. Test is usually carried out to verify the battery capacity to a specific end voltage and discharge rate (usually 1, 3 or 10 hours).

Test must be conducted in accordance with EN 60896-11. Please refer to the prescription indicated in the above standard.

Record at regular intervals cell/block voltage, battery temperature on pilot cell, discharge current, total battery voltage (readings have to be made at least at 25%, 50% and 80% of the discharge time and then at suitable time intervals which permits the detection of the transition to the final discharge voltage).

According to IEC60896-11 the discharge shall be terminated when one of the following values t_{disch} , whichever comes first, has been recorded:

1. t_{disch} = the elapsed time of discharge of the string, with n cells, to a voltage of $n \times U_{final}$ (V)
2. t_{disch} = the elapsed time when a cell or monoblock in the string reached a voltage of

$$U = U_{final} - \left(\sqrt{\frac{\text{Cell voltage}}{2}} \right) \times 0,2$$

At the end of discharging test, batteries have to be recharged immediately (according to paragraph 4.2 "Boost charge").

The following formula determinates the battery capacity:

$$C = \text{discharge current} \times t_{disch}$$

(where t_{disch} is indicated in hours)

For temperatures different from the nominal (20°C) and discharge rates between 3 to 10 hours, the battery capacity shall be corrected as follows:

$$C_{20^\circ C} = \frac{C}{1 + \lambda(\theta - 20)}$$

Where:
 θ = initial pilot cell temperature (°C)
 λ = 0,006 for tests > 1 hour
 λ = 0,01 for tests ≤ 1 hour

A new battery shall supply at least:

C_a =0,95 Nominal capacity at the first cycle
 C_a = Nominal capacity at the fifth cycle

Trending battery capacity during years will provide information in predicting when the battery will no longer meet design requirements.

10. ELECTROLYTE

High quality electrolyte for Stationary Standby Batteries (which is a solution of pure sulfuric acid diluted with distiller water to the correct specific gravity) is required for filling dry charged cells.

10.1 Specific Gravity Values

The following table gives specific gravity (Sp.Gr.) data at 20°C for fully charged cells with the electrolyte at the maximum level and for electrolyte filling:

Nominal Sp. Gr. [kg/L] @20°C	Sp. Gr. Range for filled cells [kg/L] @20°C	Sp.Gr. for Filling Dry Charged Cells [kg/L] @20°C	Cell Type
1,27	1,26 - 1,28	1,26	SD - SDH
1,24	1,23 - 1,25	1,23	LM - LM/S
1,22	1,21 - 1,23	1,21	SGL - SGH

NEVER ADD ACID TO INCREASE SPECIFIC GRAVITY of electrolyte.

10.2 Impurities Limits

Here below please find the max impurities for new electrolyte and refilling water.

Impurities		Unit	Max Value IEC 62877-1
Iron	(Fe ²⁺)	mg/L	30
Copper	(Cu ²⁺)	mg/L	0,5
Antimony	(Sb ³⁺)	mg/L	1,0
Arsenic	(As ³⁺)	mg/L	1,0
Bismuth	(Bi ³⁺)	mg/L	1,0
Tin	(Sn ²⁺)	mg/L	1,0
Chromium	(Cr ³⁺)	mg/L	0,2
Nichel	(Ni ²⁺)	mg/L	0,2
Ammonium Ions	(NH ₄ ⁺)	mg/L	50
Nitrate Ions	(NO ₃ ⁻)	mg/L	10
Chlorine Ions	(Cl ⁻)	mg/L	5
Organic Substances	(O ₂)	mg/L	30
Other Impurities		mg/L	250

10.3 Temperature Correction of Specific Gravity

Electrolyte specific gravity varies with temperature. For an accurate measurement, the reading must be corrected to the nominal electrolyte temperature (usually 20 °C). The correction formula is given below:

$$SG_{corrected} = SG_T + 0,0007 \times (T - 20)$$

Where SG_T = specific gravity at "T" temperature.

Electrolyte Temperature Specific Gravity at full charge

[°C]	[°F]	[kg/L]
-20	-4	1,2680
-15	5	1,2645
-10	14	1,2610
-5	23	1,2575
0	32	1,2540
5	41	1,2505
10	50	1,2470
15	59	1,2435
20	68	1,2400
25	77	1,2365
30	86	1,2330
35	95	1,2295
40	104	1,2260
45	113	1,2225
50	122	1,2190
55	131	1,2155
60	140	1,2120

10.4 Electrolyte Volumes – LM Range Batteries

For LM range Flooded batteries, the table shows the electrolyte volume delta (min–max) and the corresponding mass delta, assuming an electrolyte density of 1.24 kg/L.

LM range	Electrolyte min–max [L]	Electrolyte min–max [kg]
LM 100	0,41	0,507
LM 150	0,41	0,507
LM 200	0,41	0,507
LM 250	0,51	0,633
LM 300	0,61	0,760
LM 350	0,71	0,886
LM 420	0,86	1,063
LM 490	1,00	1,240
LM 600	1,22	1,519
LM 700	1,56	1,941
LM 800	1,56	1,941
LM 900	1,97	2,447
LM 1000	1,97	2,447
LM 1200	2,38	2,953
LM 1500	2,85	3,543
LM 1750	3,47	4,314
LM 1875	3,47	4,314
LM 2000	3,47	4,314
LM 2250	4,28	5,314
LM 2500	4,28	5,314
LM 3000	5,14	6,386
LM 3500	5,14	6,386

11. VENTILATION (in accordance with EN 62485-2)

During normal operating conditions, lead acid batteries emit low quantity of gases which can reach an explosive mixture when hydrogen concentration is higher than Lower Explosion Limit (LEL) threshold which is 4% vol.

The purpose of ventilating a battery location or enclosure by natural or forced (artificial) ventilation is to maintain the hydrogen concentration below the above stated limit. Battery locations and enclosures are to be considered as safe from explosions, when the concentration of hydrogen is kept below this safe limit.

The minimum air flow rate for ventilation of a battery location or compartment shall be in accordance with European Standard EN 62485-2 calculated by the following formula:

$$Q = 0,05 \times N \times I_{gas} \times C_{rt} \times 10^{-3}$$

where:

Q = ventilation air flow in m³/h

N = number of cells (each 2 volt)

C_{rt} = capacity C₁₀ [Ah] at 1,80 volt/cell at 20°C

The current I_{gas} [mA/Ah] producing gas as indicated in the table of the above-mentioned standard can be assumed as:

I _{gas} = 5	For batteries on float charge
I _{gas} = 20	For batteries on boost charge

11.1 Determination of openings

The amount of ventilation air flow shall preferably be ensured by natural ventilation, otherwise by forced (artificial) ventilation. Battery rooms or enclosures require an air inlet and an air outlet with a minimum free area of opening calculated by the following formula:

$$A = 28 \times Q$$

with

Q = ventilation flow rate of fresh air [m³/h]

A = free area of opening in air inlet and outlet [cm²]

Note: To this calculation the air velocity is assumed to be 0,1 m/s.

The air inlet and outlet shall be located at the best possible location to create best conditions for exchange of air, i.e.

- Openings on opposite walls.
- Minimum separation distance of 2 m when openings on the same wall.

The following picture gives an indication of the correct opening to assure a complete battery room air exchange.

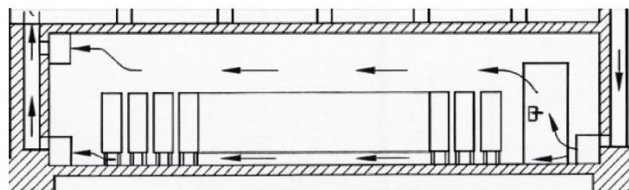


Fig. 8:
Opening on opposite walls.

11.2 Forced ventilation

Where an adequate air flow Q cannot be obtained by natural ventilation and forced ventilation is applied, the charger shall be interlocked with the ventilation system, or an alarm shall be actuated to secure the required air flow for the mode of charging selected. The air extracted from the battery room shall be exhausted to the atmosphere outside the building.

11.3 Close vicinity to the battery

In the close vicinity of the battery the dilution of explosive gases is not always secured. Therefore a safety distance extending through air must be observed within which sparking or glowing devices (max. surface temperature 300 °C) are prohibited. The dispersion of explosive gas depends on the gas release rate and the ventilation close to the source of release. For calculation of the safety distance d from the source of release the following formula applies assuming a hemispherical dispersal of gas. The safety distance "d" is given from the following formula:

$$d = 28,8 \times \sqrt[3]{N} \times \sqrt[3]{I_{gas}} \times \sqrt[3]{C_{rt}}$$

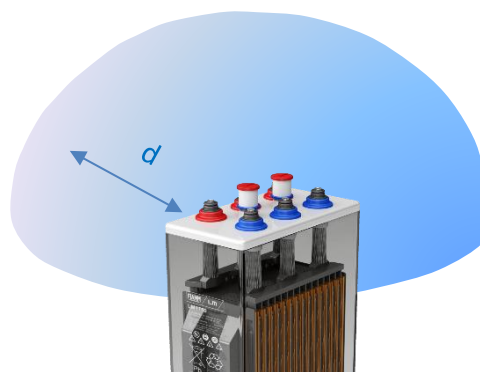


Fig. 9:
Immediate proximity to the battery.

where N depends on the number of cells per monoblock battery (N) or vents openings per cell involved (1/N).

For further information please refer to IEC 62485-2 Standard or contact FIAMM at: info.standby@fiamm.com

Note: A calculation program is available upon request.