

# The battery as power source

There are different kinds of rechargeable batteries. The most common and on ships the most used type is the lead acid battery. A less familiar one is the nickel-cadmium (NiCad) battery, which can still often be found in old emergency power systems. Due to the complex charge method required by a NiCad battery, and the fact that they are environmentally unfriendly, these batteries are not suitable for use onboard a boat.

## The principle of the lead acid battery

A battery is a device that converts electric power into chemical energy. This energy can be converted into electric power for DC consumers such as lighting and starter engines. A battery consists of several cells with a voltage of 2 Volt each. For a 12 Volt battery, six cells are connected in series and fitted inside a single casing. To achieve 24 Volt, two 12 Volt batteries are connected in series. Each cell has positive oxidised lead plates and negative lead metal plates, and an electrolyte consisting of water and sulphuric acid. Together they create a galvanic element of 2 Volt.

During discharge, the lead oxide on the lead plates is converted into lead sulphate. The acid level decreases because sulphuric acid is required for this process. To recharge the battery, an external power source - such as a battery charger, alternator or solar panel - with a voltage of around 2.38 Volt per cell must be connected. The lead sulphate will then be converted back into lead and lead oxide, and the sulphuric acid content will rise. There are limits set for the charge voltage to prevent the release of an excessive amount of hydrogen. A charge voltage of more than 2.4 Volt per cell, for instance, releases a lot of hydrogen gas, which forms the highly explosive oxyhydrogen when it comes into contact with oxygen in the air. The upper limit on charge voltage for a 12 Volt battery is 14.25 Volt, and the corresponding value for a 24 Volt battery is 28.5 Volt, both at 25 °C. The relationship between how full a battery is and the specific gravity of the water/sulphuric acid mixture is as follows:



percentage charged	battery voltage	specific gravity	percentage discharged
0%	11,64 Volt	1,100	100%
20%	11,88 Volt	1,140	80%
40%	12,09 Volt	1,175	60%
60%	12,30 Volt	1,210	40%
80%	12,51 Volt	1,245	20%
100%	12,72 Volt	1,280	0%

Different types of battery - in terms of the thickness and number of plates per cell - correspond to different applications. The maximum current that can be delivered is determined by the total plate surface. The number of times that a battery can be discharged and recharged - the number of cycles - depends on the thickness of the plates. A battery casing of the same size and the same weight can be filled up with either many thin plates or a few thick ones.

#### The starter battery

A starter battery has many thin plates per cell, leading to a large total plate surface. This type of battery is, therefore, suitable for delivering a high level of current over a short period of time. The number of times that a starter battery can be heavily discharged is limited to around 50. However, as starting the engine uses only a small part of the energy stored (around 0.01%), the battery lasts a number of years. This type of battery is unsuitable for cyclic use as a service battery.

#### The semi-traction battery

A semi-traction battery has fewer but thicker plates in each cell. These batteries supply a relatively lower starter current, but can be discharged more often and to a greater extent (200 to 500 full cycles). This kind of battery is highly appropriate for the combined function of starter/service battery.





### The traction battery

This type of battery has even fewer, but very thick, flat or cylindrical plates. It can therefore be discharged many times and fairly completely (1000 full cycles). This is why traction batteries are often used in forklifts and small electrical equipment such as industrial-grade cleaning machines.



Traction batteries require a special charging method. Their tall size makes them sensitive to the accumulation of sulphuric acid at the bottom of the battery container. This phenomenon is called stratification and occurs because sulphuric acid is denser than water. Acid content increases in the lower part of the battery, intensifying local plate corrosion, and decreases in the upper part, reducing capacity. The battery is discharged unevenly, significantly reducing its lifespan. In order to spread the acid out evenly, the battery has to be purposefully overloaded using excessive voltage. This generates a large amount of hydrogen gas, which can form the dangerous oxyhydrogen once mixed with oxygen in the air. The voltage required to recharge these batteries is around 2.7 Volt per cell, or 16.2 Volt for a 12 V system and 32.4 Volt for a 24 V system. These high levels of voltage are very dangerous for the connected equipment and the large amount of gas generated makes these batteries unsuitable for use onboard boats.

### The Lithium Ion battery

Until now Lithium Ion batteries were mainly available as chargeable batteries with a small capacity, which made them popular for use in mobile phones and laptops. Now Mastervolt offers Lithium Ion batteries with large capacities. Our Lithium Ion batteries have a high energy density and are perfect for cyclic applications. Compared to traditional lead acid batteries, Lithium Ion batteries offer savings of up to 70% in volume and weight, while the number of charging cycles is three times higher. An added benefit is that Lithium Ion batteries can supply a constant capacity, regardless of the connected load. The available capacity of a lead acid battery is reduced in case of larger discharge currents. Lithium Ion batteries can be discharged to 80% without affecting their lifespan, whereas lead acid batteries are more affected by deep discharge and can only be discharged to 50% of the available capacity.



### **Lasts longer**

Lithium Ion batteries also offer major benefits compared to nickel-cadmium batteries, such as a much larger power density and a longer lifespan. And because lithium is the lightest metal, Lithium Ion batteries are also more lightweight. They can also be charged at any time, while nickel-cadmium batteries require complete discharge for an optimal performance and to prevent memory effect. Furthermore, Lithium Ion batteries can be charged with a very high current, up to 100% of the capacity, resulting in a very short charging time and no memory effect.

### **Cell Management System**

Lithium Ion batteries can be charged many times over, but not infinitely. A disadvantage of Lithium Ion batteries is the natural imbalance between stronger and weaker cells. In the charging process, one or more cells will reach their maximum charge level faster due to this imbalance, while others do not get fully charged. The latter cells will be discharged faster, causing the battery to switch sooner due to under-voltage and reducing the lifespan of the battery. To prevent this, Mastervolt Lithium Ion batteries are equipped with a Cell Management System that automatically compensates for the imbalance between the cells and increases the lifespan.





# Frequently asked questions about batteries

## **How long will it take before my battery is discharged?**

This depends on its capacity and the amount of power consumed by the connected equipment. As a rule, the faster a battery is discharged, the less power it supplies. This also works the other way around: The longer it takes before a battery discharges, the more energy you can get from it. A 100 Ah battery supplies a current of 5 amps for 20 hours, during which time the voltage does not drop below 10.5 Volt. This amounts to 100 Ah. If a 100 amp consumer is connected to the same battery, however, the battery will be able to power it for only 45 minutes. After this time the battery voltage will fall to 10.5 Volt and the battery will be empty, having supplied no more than 75 Ah. Connecting a load of 1.2 amps to the same battery will allow it to run for 100 hours before the battery voltage drops to 10.5 Volt. It will then have supplied 120 Ah.

## **How long will my battery last?**

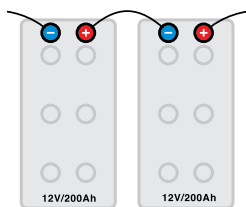
The lifespan of a battery is related to how often and to what extent it is discharged, with proper charging with the right charger also being crucial. At a normal frequency of use for holidays and weekends, a lifespan of between five and seven years is quite common for gel and AGM batteries. When batteries are frequently discharged you will need to adjust the capacity. There is also an option to use 2 Volt cells. A lifespan of 15 years is not exceptional for this type of battery as long as they have the right capacity. Lithium Ion batteries are top of the bill. You can discharge and recharge them super fast and they last up to three times longer than other types of batteries.

## **What is series connection and parallel connection?**

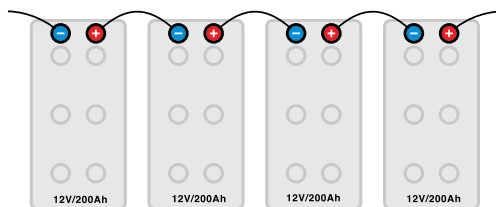
A series connection is used to increase voltage, while keeping capacity at the same level. Two serially connected 12 V/100 Ah batteries make a combined battery set of 24 V/100 Ah. In a series connection, the positive pole of one battery is connected to the negative pole of the other, with the poles that remain at the ends being connected to the system. Batteries with different capacities should never be linked in series.

The examples below apply to the use of normal 12 V batteries. Mastervolt also supplies 2 V, 6 V and 24 V batteries; the principle of series and parallel connecting remains the same.

### Series connection

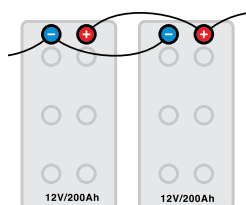


Series connection 24 V/200 Ah.



Series connection 48 V/200 Ah.

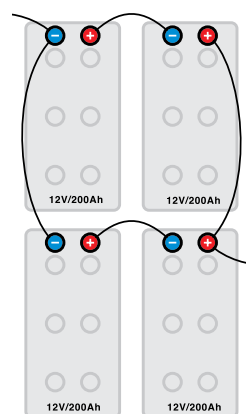
### Parallel connection



Parallel connection 12 V/400 Ah.

Parallel connection is used when you need to increase your capacity. The positive leads are connected together, as are the negative leads. The cabling from the battery to the system should be: Positive from battery 1 and negative from battery 2 (or the last in the parallel connection).

### Series/parallel connection



Series/parallel connection 24 V/400 Ah.

Make sure there is sufficient space between the batteries when installing multiple batteries: There should be a 'finger' of space between them to allow the heat to be diverted.



### Can I leave the batteries onboard during winter?

This is fine for gel, AGM and Lithium Ion batteries as the lower temperature will actually prolong their lifespan. Remember to charge the batteries completely and to ensure that no consumers are left connected. Voltmeters, timers and car radio memory are some of the stealthy consumers to look out for in this respect. Wet batteries have to be regularly topped up and charged to avoid freezing. It is advisable to connect the boat's shore power once every two to three weeks so the batteries can be fully recharged.

### How should I maintain gel, AGM and Lithium Ion batteries?

Gel, AGM and Lithium Ion batteries do not need maintenance, which means they can be installed anywhere on a boat. However, we recommend checking all the connections once a year to make sure that they are properly attached, and to clean the top surfaces with a slightly moist cloth. The batteries also need to be completely charged every time for a maximum lifespan, although this is less important for Lithium Ion batteries.

### What are maintenance-free batteries?

Various types of batteries are used in the maritime sector, each with its own specific characteristics. Here is a summary:

#### Lead-calcium battery

Lead-calcium batteries are often used in the car industry as starter batteries. These are normal lead acid batteries with a liquid electrolyte of sulphuric acid and water, but with calcium added to the lead in order to minimise hydrogen gas production and, therefore, water consumption. Extra electrolyte is also added in order to compensate for the natural evaporation of the water. This type of battery is only suitable for small boats of around six to eight metres, and solely as a starter battery as its structure precludes use as a light or service battery. The lead acid battery is not entirely closed. Hydrogen gas may be released during charging and is drained through a small opening, usually on the side of the battery. As acid may leak from the opening in certain circumstances, ventilation is needed.

#### AGM battery

A different type of lead acid battery is the AGM (Absorbed Glass Mat) battery. In this model, the electrolyte (water and sulphuric acid) is absorbed into an extremely delicate glass fibre mat. Just like with any other battery, charging generates hydrogen gas and oxygen, which are transported through the capillary tubes of the glass fibre mat. Once the two gases are recombined, water is once again obtained and subsequently reabsorbed into the glass fibre mat. The recombination process is then complete. The glass fibre mat also serves as insulation between the plates, allowing the plates to be close together and leading to very low internal resistance. This means that a high discharge current is no problem. The charge current could be a little lower than with gel batteries (approx. 30%) because the glass fibre mat is also an efficient heat insulator, and heat generated by charging is gradually conducted to the outside of the case. This requires the charge current to be somewhat restricted and results in a slightly longer charging time. AGM batteries are highly suitable for applications requiring a high discharge current, such as a bowthruuster or winches and for medium cycle use. The AGM battery is entirely closed and therefore maintenance free. If the AGM battery is heavily overcharged, for instance due to the use of a (cheap) unregulated battery charger, a small amount of hydrogen gas is formed. This gas escapes through a special vent in the battery casing that is designed to prevent oxygen from entering the battery. Incorrect charging will reduce the battery's lifespan.





### The gel battery

With wet lead acid batteries that use a liquid electrolyte of water and sulphuric acid, the water is broken down into hydrogen and oxygen during charging, mostly at the end of the charging cycle. These gases subsequently escape through the filler cap. This means water gets used up and must be regularly replenished with distilled (battery) water.

The electrolyte in a gel battery is a gel that binds the water with the acid. While the batteries are being filled, the gel heats up and liquefies. After the battery has been filled with the liquefied gel, the gel cools and solidifies. This process results in tiny hairline cracks in the gel between the plates. During the charging process, oxygen  $O_2$  is generated on the positive plate and hydrogen  $H_2$  on the negative plate. The cracks in the gel let the gases combine to create water. The gel then absorbs the water so that no water disappears from the system and no gases are produced.

Gel batteries are not a new technology and have been in use since the 1950s. The most important applications are in emergency power systems, telecommunications systems, power supply and, for the last 10 to 15 years, as service batteries in maritime systems. Gel batteries come in two different versions. The 12 Volt design is appropriate for regular use and available in capacities up to 200 Ah. The second design is a 2 Volt traction battery, available in capacities up to 2700 Ah and highly suitable for systems with frequent and significant discharging where a long lifespan is needed. For a battery of 12 or 24 Volt, six or twelve gel batteries need to be connected in series to provide the required voltage. Major benefits of gel batteries include very limited self-discharging, the possibility of a short charging time, and the lack of gas production under normal circumstances. All of this makes gel batteries very suitable for nautical applications. They are also ideal for heavy cyclical applications.





### The Lithium Ion battery

Mastervolt's Lithium Ion batteries are based on Lithium Ion ferric phosphate, which has an energy density three times higher than that of lead acid batteries. Although there are materials with an even higher energy density, these are generally considered less safe. Mastervolt's Lithium Ion batteries are the safest batteries of their kind. A unique feature is their built-in Bidirectional Active Cell Management, or BAC. The system controls voltage, current and temperature, and guarantees optimal safety. Lithium Ion batteries are MasterBus compatible and up to 15% more efficient than lead acid batteries. This gives you:

- Shorter charging times.
- Less generator use for charging.
- More power than from a traditional battery of the same dimensions.
- A lead acid battery, for example, has a DOD (depth of discharge) of 50%. This means that you can only use up to 200 Ah from a 400 Ah battery. A Mastervolt Lithium Ion has a DOD of 80%, almost 60% more usable battery capacity. With this percentage, a battery of 400 Ah supplies 320 Ah, or 120 Ah more.
- Lithium Ion batteries are also ideal for electric and hybrid sailing. Mastervolt Lithium Ion batteries can be infinitely parallel connected.
- Another benefit is that Lithium Ion batteries weigh less, require less space and are surprisingly easy to install.

### What not to do with batteries, especially gel and AGM

- Incorrect charge voltage. Too low a voltage means that the battery cannot charge to 100% - the sulphate then hardens on the plates and the battery loses some of its capacity. Excessive voltage causes the batteries to generate gas, leading to water loss and drying out.
- Excessive discharging. Discharging a battery further than its capacity greatly shortens its lifespan.
- Too large ripple on the charge voltage. Cheap and old-fashioned chargers and alternators often have a significant voltage ripple (voltage variation) in the output voltage.
- The use of an alternator without a 3-step regulator, a very high ambient temperature or charging without temperature compensation.

### Conclusions and recommendations

- The low internal resistance of AGM batteries makes them highly suitable for powering winches, windlasses and bowthrusters, for starting engines, and for limited cyclic use.
- Gel batteries are very suitable as service batteries due to the fact that they can be quickly charged and have a long lifespan, even with many charge/discharge cycles
- For a service battery you can choose for either a 6 Volt, 12 Volt or 24 Volt version or the 2 Volt model.
- Mastervolt batteries are completely maintenance free and in normal circumstances do not release acid or generate dangerous gas during charging. They are simple to install anywhere onboard, such as next to the bilge or in the engine room (reduced lifespan due to higher temperatures). Special battery cases or external ventilation is usually unnecessary as natural ventilation will suffice.
- Lithium Ion batteries are definitely the best. They save up to 70% in space and weight, last three times longer and can be recharged and discharged very quickly. A minimum of 2000 charge cycles is no exception. Mastervolt Lithium Ion batteries are now available in two versions: 24 V/160 Ah and 12 V/320 Ah.



# Determining lifespan

The average lifespan of a 12 Volt gel or AGM battery is six years if the battery remains unused and is kept in a charged state. After five or six years of float voltage at an average ambient temperature of 25 °C, the battery still retains 80% of its original capacity. Higher average temperatures will shorten the lifespan of the battery; lower may increase the lifespan. The number of charge and discharge cycles of a 12 Volt battery is strongly correlated to its structure and quality. Mastervolt's 12 Volt gel or AGM batteries can take around 300 full cycles of being discharged down to 20% and charged back to full capacity.

Most manufacturers consider batteries to be spent at a remaining capacity of 80%. This does not, however, mean that the battery has to be replaced immediately. For example, the battery can still be used if only 50% of the battery capacity is actually required. It is therefore not necessary to replace the battery after six years or 300 full cycles. An average use of seven years is perfectly normal for gel and AGM batteries.

## 2 Volt traction gel batteries

The lifespan for 2 Volt traction gel cells is around 10 to 15 years and the maximum number of full cycles is 900 to 1000. When discharging to 50 or 75% of capacity, the number of cycles is 2000 and 4000, respectively. These batteries are therefore highly suitable for larger systems that require intensive use and a very long lifespan.



## Lithium Ion batteries

Mastervolt Lithium Ion batteries have a lifespan of more than 2000 cycles, which is three times longer than lead acid batteries. This can be attributed to a wide range of features including cell management, the negligible self discharge, the absence of 'memory effect' (lazy battery effect) and a DOD of 80%.



## Which battery suits you best?

	AGM 12 V semi-traction	AGM 6 V semi-traction	MVG 12 V semi-traction	MVSV 2 V traction	MLI Lithium Ion	traditional open batteries	
						semi-traction	traction
Maintenance free	++++	++++	++++	++++	++++	-	-
Gas formation during charging	+++	+++	+++	+++	+++++	+	-
Self-discharging while inactive	+++	+++	++++	++++	+++	-	-
Lifespan with full discharging	++	++	+++	++++	+++++	+	+++
Lifespan with limited discharging	+++	+++	++++	++++	+++++	++	+++
High charge current resistance	++	++	+++	++++	+++++	++	++
Suitable for making high capacity battery set	++	+++	+++	++++	++++	+	+++
Starting engines	++++	+++	+++	++	++++	++	-
Shock-resistance	++++	++++	++++	++++	++++	+	+
Number of charge/discharge cycles	++	+++	+++	++++	+++++	+	+++
Temperature-resistance	++	++	++++	++++	++++	+	++
Installation/angle of inclination	++++	++++	++++	++++	++++	-	-
Return on investment with limited use	+++	+++	+++	++++	+++	+	++
Return on investment with intensive use	++	++	+++	++++	+++++	+	+
Suitable for electric sailing	++	++++	+++	++++	+++++	+	++
Product warranty	2 years	2 years	2 years	7 years	2 years	approx. 1 year	approx. 1 year
Worldwide onboard service	++++	++++	++++	++++	++++	+	-

+++++ = excellent    ++++ = very good    +++ = good    ++ = reasonable    + = not very good    - = insufficient

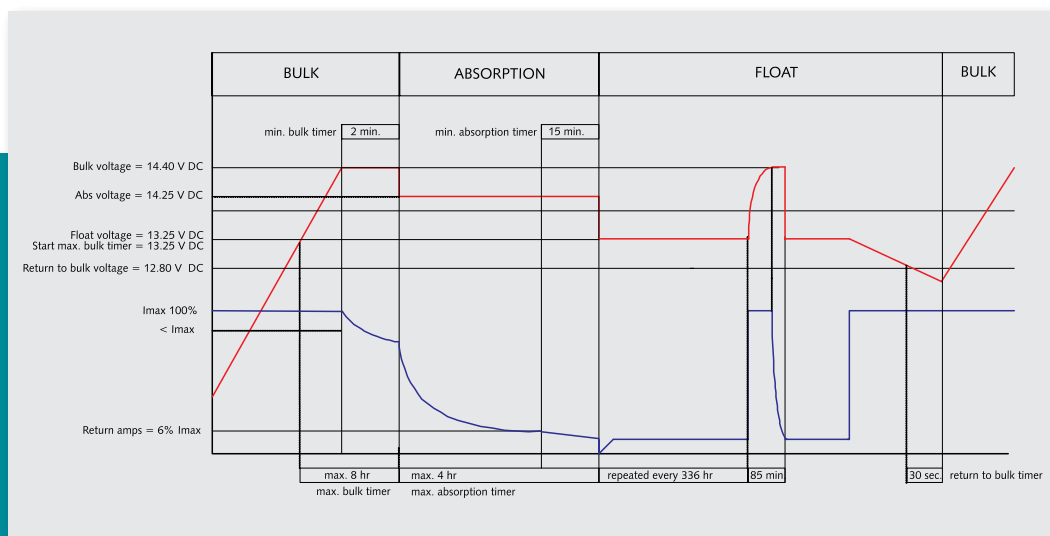


## 3-Step<sup>+</sup> charging

This modern charging technology allows a battery to be quickly and safely charged in three phases (steps). The first step is the bulk phase, in which the battery is charged quickly. The output current of the battery charger is at maximum (100%) during this phase and the battery voltage depends on the charging degree of the battery. The duration of this phase depends on the ratio of battery to charger capacity, and on the degree to which the batteries were discharged to begin with. The bulk phase is followed by the absorption phase, which begins once a battery has been charged to 80% (90% for gel and AGM batteries), and ends when the battery is completely full. Battery voltage remains constant throughout this stage, and the charging current depends on the degree to which the battery was initially discharged, the battery type, the ambient temperature, and so on. With a wet battery this phase lasts some four hours, with gel and AGM batteries around three.

This does not apply to Lithium Ion batteries as these are charged to 100% with full current. Once the battery is 100% charged, the Mastervolt charger automatically switches to the float phase.

In this step, the batteries are kept in optimal condition and the connected users are supplied with power. If power consumption is higher than can be supplied by the battery charger, the remaining power is supplied by the battery. The battery is then (partly) discharged and the charger automatically switches back to the bulk phase. If consumption is reduced, the charger will start charging the battery again via 3-step<sup>+</sup> charging. A battery charger with 3-step<sup>+</sup> charging can remain connected to the battery, even in winter, and ensures a long lifespan for your batteries as well as being safe for the connected equipment.



3-Step<sup>⊕</sup> charging characteristic (IUoUo).

### Absorption time

The duration of the second phase in the charging of a battery. The battery will, in general, be charged from 80 to 100% during this phase, which lasts around four hours with a wet lead battery, and two to three hours with gel and AGM batteries. With Lithium Ion batteries the absorption time is very short as they can be charged to 100% with full current. This phase is automatically set for Mastervolt battery chargers.

### Charge factor

The charge factor indicates the efficiency of a battery. The efficiency of the average wet battery is approximately 80%, which means it must be recharged 1.2 times the eventual capacity in Ah to get the same capacity. This translates into a charge factor of 1.2. The lower the charge factor or the higher the battery efficiency, the better the quality. Mastervolt's gel and AGM batteries have a low charge factor of 1.1 to 1.15 and thus offer the very best quality.

### Discharge factor

This is also known as Peukert's Law, and allows you to determine how long a battery can be used at a given load before it needs recharging.

### Cycle

A battery only lasts a certain number of cycles, depending on its type and quality. One charge/discharge cycle is the process of discharging a battery to 0% of capacity and recharging it back to 100%. Twice recharging after discharging to 50% is also one cycle, as is four times discharging to 75% and recharging. A starter battery, for instance, can take around 50 to 80 cycles, which may seem little but is in practice more than sufficient: While the current used for starting an engine is high, it only lasts a short time and represents 0.001 of a cycle. In other words, an engine can be started 80,000 times before a battery is worn out. A high-quality semi-traction battery lasts for around 250 to 300 cycles.

If the battery is only discharged to 50% of capacity, 600 cycles are available. Assuming 25 weekends of sailing (50 days) plus 20 days of holiday and discharging only to 50%, the battery will go through 70 half cycles or 35 full cycles. This means that in theory it will last eight years, which is fairly accurate in the case of gel and AGM batteries.

# Charging batteries

## Charge voltage

Gel (12 and 2 Volt) and AGM (6 and 12 Volt) batteries need to be charged with a voltage of 2.38 Volt per cell at a temperature of 25 °C. For a 12 Volt battery set, this corresponds to 14.25 Volt, and for a 24 Volt battery set to 28.5 V. The maximum time that a battery can be charged at this voltage is four hours, after which the voltage has to be reduced to 2.2 Volt per cell, or 13.25 and 26.5 Volt, respectively. Lithium Ion batteries need to be charged with a voltage of 29.2 Volt for a 24 Volt system and 14.6 Volt for a 12 Volt system. The float voltage is 26.5 and 13.25 respectively.

With emergency power systems, where gel batteries can be in float condition for long periods of times (years), the float voltage needs to be slightly increased to 13.8 and 27.6 respectively at a temperature of 25 °C. As there is always equipment on boats such as refrigerators that draw power from a battery even when it is being charged, a maximum charge voltage has been set to protect the connected appliances. This maximum is 14.55 Volt for a 12 Volt system and 29.1 Volt for a 24 Volt system, which is also the charge voltage applicable at an ambient temperature of 15 °C. Mastervolt has DC-DC converters that regulate the onboard voltage to a lower level (13.8 or 27.6 Volt) thus ensuring that (halogen) lamps do not fail during charging. Mastervolt's modern battery chargers come with a temperature sensor for attaching to the battery, which allows the charger to automatically regulate the charge voltage in accordance with battery temperature. Adjusting voltage to high or low temperatures is not necessary with Lithium Ion batteries.

## The charge current

A rule of thumb for gel and AGM batteries states that the minimum charge current should be 15 to 20% of capacity. Connected equipment usually also needs to be powered during charging, so include the power used for that purpose



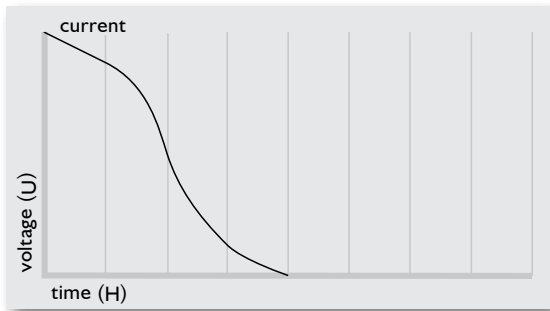
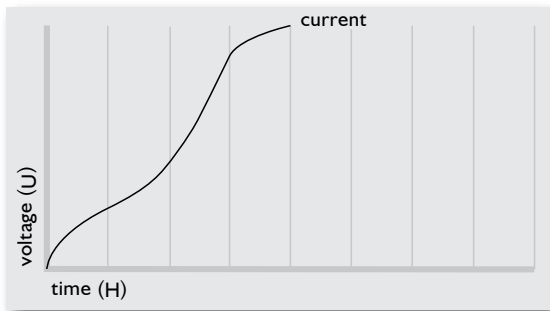
in the abovementioned figure. This means that, with a battery set of 400 Ah and a connected load of 10 amps, battery charger capacity has to be between 70 and 90 amps in order to charge the battery in reasonable time. The maximum charge current is 50% for a gel battery and 30% for an AGM battery. For a Lithium Ion battery the charge current can be the same as the capacity. A 100 Ah Lithium Ion battery, for example, can be recharged with 100 amps.

## The charge system

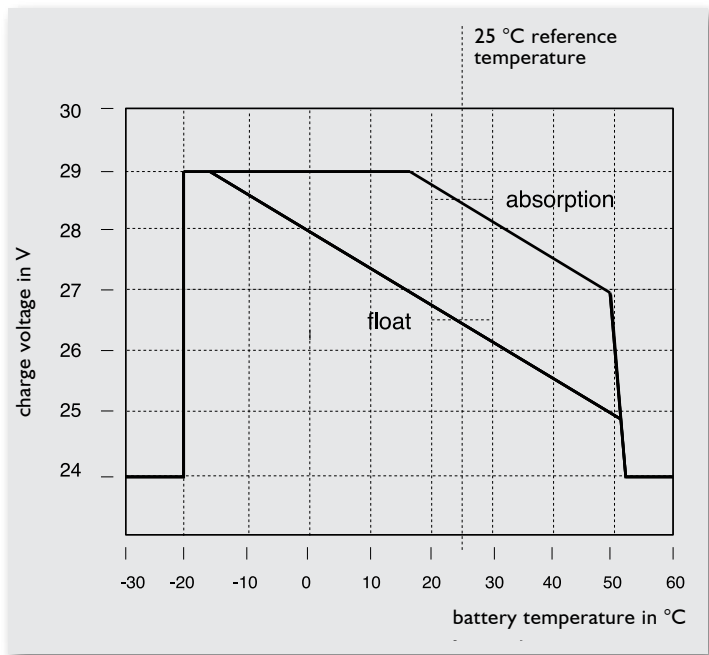
Ensuring the longest possible lifespan for gel, AGM and Lithium Ion batteries requires a modern battery charger with 3-step<sup>®</sup> charging and a sensor for measuring battery temperature. These battery chargers will constantly regulate charge voltage and charge current and adapt the charge voltage to the battery temperature. In order to prevent premature failure of the battery, the ripple voltage of the battery charger has to stay below 5%. If the battery also powers navigation or communication equipment such as GPS or VHF, the ripple voltage must be no more than 100 mV (0.1 Volt) or problems may occur with the equipment. Another advantage of a low ripple voltage is that onboard power systems will not be damaged if a battery pole is corroded or incorrectly attached. A low ripple voltage even allows the charger to power the system without being connected to a battery.



Mastervolt chargers are, of course, all equipped with good voltage regulation that keeps ripple voltage below 100 mV. For GMDSS (Global Maritime Distress Safety System) systems onboard larger ocean-going vessels, the battery charger also has to be equipped with an amp and voltmeter plus an alarm contact. The alarm contact is connected to the ship's alarm system so that any interruptions to the operation of the charger – due to a cut in the 230 Volt supply, for instance – are detected on time. The optional Mass Charger Interface makes Mass chargers very suitable as GMDSS chargers.



Resistive charge: The WA charge curve.



Temperature compensation curve.

**Calculating charging time**

Various factors have to be taken into account when calculating the charging time for a battery. The first consideration is battery output. With a standard wet battery, output is about 80%. This means that 120 Ah has to be charged into the battery in order to be able to draw 100 Ah later. With gel, AGM and Lithium Ion batteries the output is higher - 85 to 90% - so there is less waste and charging time is shorter compared to wet batteries. Another issue that has to be considered when calculating charging time is the fact that the last 20% of the charging process takes four hours (this does not apply to Lithium Ion batteries). In the second stage, also known as the absorption phase, the battery decides how much power it needs to absorb independently of the output of the battery charger. The amount of power depends on the type of battery (wet, AGM, gel or Lithium Ion) and other factors such as the extent to which it was charged to begin with, temperature, lifespan and the ambient temperature.

**The following formula can be used to calculate the charging time of a battery:**

$$Lt = \frac{Co \times eff}{AI - Ab} + 4h$$

- Lt** = charging time
- Co** = capacity drawn from the battery
- eff** = efficiency  
1.1 for a gel battery, 1.15 for a AGM battery and 1.2 for a wet battery
- AI** = battery charger current
- Ab** = consumption of the connected equipment during the charging process

Taking a battery that is discharged to 50% and applying the previous example of a 400 Ah gel battery and an 80 amps charger, charging up to 100% will take:

$$Lt = \frac{200 \times 1.1}{80 - 10} + 4h \approx 7h$$

**Checking the remaining capacity of a sealed AGM or gel battery**

The simplest way to check the remaining capacity or the condition of a battery is with an Ah meter, such as Mastervolt's MasterShunt battery consumption meter. In addition to charge and discharge current, this monitor also tracks battery voltage, the number of amp-hours consumed and how much longer the battery has before it needs recharging. The device also provides data on how often the battery has been discharged and to what extent, with both the average and highest discharge level shown. It is easy to connect to the MasterBus network and, with its integrated system clock combined with command-based events, you can program the system to your preference.

A different but very imprecise method of checking your battery is to measure the voltage, which can only be done when the battery has not been used (discharged) or charged for at least 24 hours. While measuring voltage provides a rough estimation of how discharged a battery is, small variations in voltage make an accurate digital voltmeter essential.

remaining battery capacity	battery voltage
25%	between 11.7 and 12.3 Volt
50%	between 12.0 and 12.6 Volt
75%	between 12.1 and 13.0 Volt
100%	between 12.6 and 13.35 Volt

The above-mentioned method is only 15-20% accurate and gives but a rough indication of the power remaining in the battery.

## Ventilation

Under normal conditions, gel and AGM batteries produce little or no dangerous oxyhydrogen. The little gas that escapes is negligible. However, just like with all other batteries, heat is generated during charging. To ensure the longest possible lifespan, it is important for this heat to be dissipated as quickly as possible. The following formula can be used to calculate the ventilation required for Mastervolt chargers.

$$Q = 0.05 \times I \times f1 \times f2 \times n$$

Q = required ventilation in m<sup>3</sup>/h

I = maximum charge current of the battery charger

f1 = 0.5 reduction for gel batteries

f2 = 0.5 reduction for closed batteries

n = number of cells used (a 12 Volt battery has six cells of 2 Volt each)

Returning to the previous example of a 12 V/400 Ah battery set and an 80 amps charger, the minimum ventilation necessary will be:  $Q = 0.05 \times 80 \times 0.5 \times 0.5 \times 6 = 6 \text{ m}^3/\text{h}$

This air current is so small that natural ventilation will suffice. If the batteries are installed in a closed casing, two openings will be needed: One on the top and one underneath. The dimensions of the ventilation opening can be calculated using the following formula:

$$A = 28 \times Q$$

A = opening in cm<sup>2</sup>

Q = ventilation in m<sup>3</sup>

In our case, this amounts to  $28 \times 6 = 168 \text{ cm}^2$  (around 10 x 17 cm) for each opening.

Lithium Ion batteries do not produce any oxyhydrogen and are therefore safer to use. When batteries are charged quickly there is some degree of gas formation, in which case the above formula can be used to divert the heat. Contact your installer for larger systems with multiple battery chargers.



### Transporting gel, AGM and Lithium Ion batteries

These types of batteries are completely closed and can be easily shipped as sea freight or air cargo. For sea and rail transportation, batteries are considered as harmless goods. The IATA/DGR (International Air Transport Association's Dangerous Goods Register) also classifies batteries as non-hazardous goods for air transport so they can be sent to any destination in the world quickly and relatively cheaply.

### Peukert's Law

On the surface it seems easy to calculate how much longer a battery will continue to supply sufficient power. One of the most common methods is to divide battery capacity by discharge current. In practice, however, such calculations often turn out to be wrong. Most battery manufacturers specify battery capacity assuming a discharge time of 20 hours. A 100 Ah battery, for instance, is supposed to deliver 5 amps per hour for 20 hours, during which time voltage should not drop below 10.5 Volt (1.75 Volt/cell). Unfortunately, when discharged at a current level of 100 amps, a 100 Ah battery will only deliver 45 Ah, meaning that it can only be used for less than 30 minutes. This phenomenon is described in a formula – Peukert's Law - devised more than a century ago by the battery pioneers Peukert (1897) and Schroder (1894).

Peukert's Law describes the effect of different discharge values on the capacity of a battery, i.e. that battery capacity is reduced at higher discharge rates. All Mastervolt battery monitors take this equation into account so you will always know the correct status of your batteries.



