Batteries Division

ZVEI: Die Elektroindustrie

ZVEI Information Leaflet No. 32

Issued July 2020 (identical with German version November 2016)

Charging lead starter batteries

1. General

The goal of this information leaflet is to communicate general information on recharging lead starter batteries, choosing the right charging device and describing technical framework conditions relating to the charging of lead starter batteries. Below, the term “starter battery” is to be considered to refer throughout to a lead-acid based starter battery.

For better comprehension, only the 12 V region is covered here. The following applies to 6 V and 24 V batteries:

- The voltages given in this information leaflet are to be halved for 6 V batteries.
- For 24 V batteries, they must be doubled.

Why do starter batteries have to be recharged?

A starter battery installed in a vehicle is charged when the motor is running by the car’s alternator. In certain circumstances, however this charging may not be sufficient.

Causes for this can include:

- “Key off loads” – loads that are active in the vehicle even when the motor is switched off.
- Use over short distances
- Long parking times
- Installed additional loads such as e.g. cooler, auxiliary heating, sound system etc.

In a parked car with the motor off, the battery always supplies a wide variety of electric loads. It is run down because of them. Very long periods spent parked and a large number of so-called “quiescent power consumers” can significantly reduce the state of charge of the battery. It may be that starting up is no longer possible because of this.

Damage to the alternator or connecting cabling can also lead to a “negative charge balance” and thus the discharging of the battery.

This can, in extreme cases, become apparent in a failure to start. The charging of the battery influences the service life of the battery. Incomplete charging or overcharging reduce the service life.

2. Types of starter battery

In the last 15 years, the requirements of starter batteries in vehicles have changed dramatically. This has led, in essence, to three different battery technologies being used. These technologies are categorised as follows:

- Conventional starter batteries. These batteries are usually equipped with liquid electrolytes. They are maintenance-free by design.
- EFB batteries for start-stop applications. These batteries differ from conventional starter batteries thanks to their clearly improved cycle properties.
- AGM batteries for start-stop application with excellent high current and cycle properties. These are a further improvement on EFB batteries. These batteries have a fixed electrolyte and are thus particularly spill-proof.

This information leaflet has been developed by the Industrial Batteries Work Group of the ZVEI – Zentralverband Elektrotechnik- und Elektronikindustrie e. V., Batteries Division

For explanation:

2.1 Conventional starter batteries

Conventional starter batteries are available in “maintenance-free” design and in the “classic” design. The electrolyte is liquid and consists of dilute sulphuric acid. This is why they are referred to as “flooded batteries”.

The battery cover can be one of two different types.
a) Cover without openings
b) Cover with openings that are screwed shut, through which, after unscrewing, demineralised water can be topped up.

2.2 EFB batteries

EFB batteries are a development of flooded batteries. The abbreviation stands for “enhanced flooded battery” and means that the battery has been optimised through targeted measures for use in a start/stop vehicle and has been designed for a higher resistance to early ageing through acid layering under more demanding operating conditions.

These batteries are usually “maintenance-free” by design; that is, under normal operating conditions (temperature, correct charging voltage) no refilling of demineralised water to make up for fluid lost during operation should be necessary over the entire service life of the battery.

Starter batteries with liquid electrolytes are also called “closed batteries”. If the housing is damages, these batteries can leak electrolyte.

2.3 AGM batteries

The abbreviation “AGM” stands for “absorbent glass mat” and indicates a design of “closed battery” or VRLA battery (valve regulated lead acid battery) that is closed with special valve plugs.

The electrolyte is fixed in a glass mat. If the housing is damaged, as a rule, no electrolyte will leak. The valves of such batteries may not be opened, as otherwise they may be damaged.

These batteries are particularly long-life and are very resistant to acid layering during ordinary charging/discharging operation.

3. Safety notices and general recommendations

The following is to be noted for safe handling of lead-acid batteries:

– Sulphuric acid in batteries can cause serious burns
– During operation, and particularly when charging, hydrogen and oxygen gas are produced, which can result in an explosive mixture in certain situations
– From a particular nominal voltage, residual voltage can lead to dangerous currents running through the body when contact is made

Standard EN 50272 contains safety requirements of batteries and battery systems and described the basic measures to be taken to protect against dangers resulting from electrical current, escaping gases and electrolytes.

The symbols on the battery represent safety notices. Incorrect handling and use of batteries can be dangerous. Before carrying out work on the battery, read carefully and completely follow the instructions in this leaflet, on the battery, in the device manual and operating instructions for your vehicle. Starter batteries may only be used for the purpose for which they are designed.

When used, stored and charged, starter batteries develop an explosive hydrogen/oxygen mixture. Every spark, including electrostatic discharge, can ignite these gases. For this reason, only use antistatic cloths and insulated tools when handling and installing.

Batteries must be protected against mechanical damage, as this can cause dangerous chemicals to leak that may lead to burns.

Batteries are heavy. Please be careful when lifting and transporting them. So that no acid can escape, do not tip batteries.

Sulphuric acid is corrosive and destructive to tissue:

- After skin contact, rinse/shower with water, remove splashed clothes and wash them.
- After eye contact, carefully rinse with water for several minutes, remove contact lenses if possible, continue to rinse. Then immediately have the eyes tended to by a doctor.
- After swallowing, immediately drink plenty of water, swallow activated charcoal, do not induce vomiting.

If acid is sprayed on objects, rinse immediately with soapy water or a neutralising substance e.g. a soda solution.

Further safety notices can be found on ZVEI information leaflet No. 1 “Information on the safe handling of lead-acid accumulators (lead batteries)”.

Function of the screw fastenings

When recharging starter batteries, the screw fastenings or sealing plugs should NOT be opened. The battery is ventilated via the sealing plugs and a flashback protector integrated in the plug system, which may not be bypassed!

4. Storage

Batteries are full of acid and should not be tipped. One terminal must always be covered to avoid short circuits. Store batteries fully charged in a dry, frost-free and well ventilated place. Ensure they are protected from direct light (UV). The UV component of daylight leads to perishing in the battery housing. Breakage of the housing and acid leakage can be the result. Use no store where sparks may be generated.

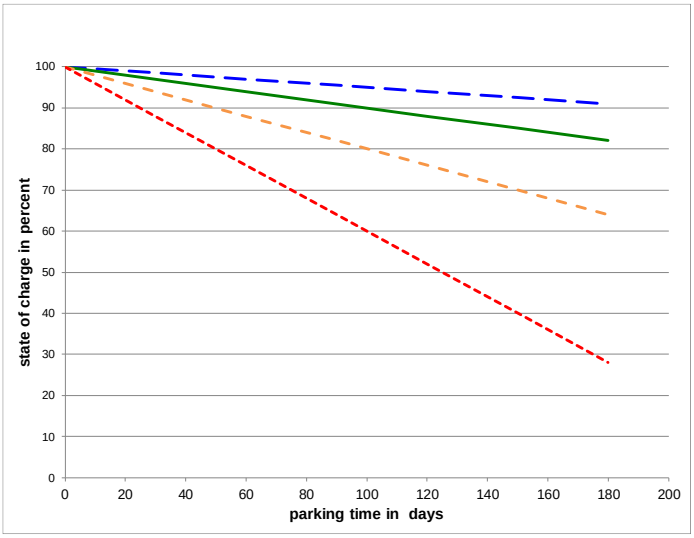
When storing the batteries, use the FiFo principle (first in – first out), that is, use the oldest item first.

Ventilation is a fundamental requirement for battery rooms or cabinets. DIN EN 50272-2 describes in detail which measures are to be taken to ensure sufficient ventilation.

For chemical reasons, every battery is subject to self-discharge. The self-discharge rate depends on the battery technology, state of charge and temperature. This discharge means increased reduction of capacity during storage. To minimise the effect of self-discharge, batteries should be stored cool and dry.

In the following figure, the relationship between self-discharge in the battery and the environmental temperature is represented.

To avoid damage, after 3 months' storage, the quiescent voltage should be tested.



The following charging treatments can be chosen:

- recharging the battery as soon as the voltage has fallen below 12.4 V.
- Trickle charging to maintain full charge status

Batteries with quiescent voltages of < 12.5 V should not be installed in vehicles without prior recharging.

5. Installation and removal of starter batteries for charging

Wherever possible, batteries should always be recharged as installed!

When charging inside the vehicle, additional information is to be noted:

- Switch off all electrical loads and the ignition. Wear protective goggles and suitable protective clothing, including rubber gloves.
- When dismounting, first unplug the negative cable, then the positive one. Avoid short circuits by using tools carefully. Before insertion, clean the battery compartment in the vehicle. Clean the terminals and terminal clips and gently lubricate them with non-acidic grease (Vaseline).
- Before insertion or launch, the battery is to be checked for mechanical damage.
- On insertion, first connect the plus cable, then the minus cable (incorrect, reversed-polarity connection can damage the vehicle's electrics).
- Check the terminal clips are tightly connected.

To ensure functional and safe installation, assemble extensions such as venting tubes, battery holders and terminal covers as necessary and put everything back as it was before the removal of the battery. Leave gas exit openings uncovered, otherwise the battery may burst!

6. Charging devices

Only automatically regulated charging devices with a charging voltage limiter should be used to charge starter batteries.

Regulated charging devices have voltage and current monitoring to the desired values in each case to set the best charging behaviour for the battery. This ensures the optimisation of the charging time, water consumption and amount of energy used.

Non-voltage-limited or unregulated charging devices should only be used in exceptional cases! When using unregulated charging devices, the danger of overcharging is very high. This can cause damage to the battery. If such a charging device is used nevertheless, the charging time must be time-limited. This time limit is to be set so that the battery is charged to a maximum of the nominal capacity of the battery.

The charging device should in any case be protected against polarity reversal. This prevents reverse charging of the battery. The polarity reversal protection prevents the charging of deep-discharged batteries. If the battery voltage is too low (e.g.< 7.5 V), an auxiliary voltage can be used (e.g. a charged battery connected in parallel) to successfully charge the battery nevertheless. Charging devices that recognise sulphated (deep-discharged) batteries, as a rule, do not need an auxiliary voltage.

The charging device's charging current should be selected such that charging duration does not exceed one day. The charging

current should thus not exceed 1/10 of the nominal capacity per second. The voltage of the charging device should be suitable for the nominal voltage of the battery. In charging devices with adjustable nominal voltage, please make sure the voltage is set to the correct setting!

7. Charging starter batteries

The following describes the charging parameters and different types of charging.

The charging parameters are
- Charging voltage
- Charging current
- Charging time
- Charging factor
- Temperature

Types of charging are
- Charging starter batteries
- Recharging after deep discharge/equalising charge
- Charging to retain the charged status of a fully charged battery in pauses of operations or during storage.

Charging voltage:
The charging voltage is determined by the battery design and technology used (grid alloy).

The charging voltage for a 12 V starter battery must be at least 14.8 V. For VRLA (AGM and gel) batteries, the charging voltage should be between a minimum of 14.4 V and a maximum of 14.8 V. An exception to this is the charging of closed, conventional starter batteries after deep discharge. To allow recharging, a charging voltage up to 16 V is proper and permissible. The duration should be limited to a maximum of 4 h.

Charging current:
The charging current should be
- **min. 1/10 of the nominal capacity in amperes and**
- **not exceed half the nominal capacity in amperes.**

Example for standard starter battery:
70 Ah capacity with charging current of 7 A.

Charging currents that are too small extend the charging duration, whereas high currents lead to an increased battery temperature, gas production and an increased potential danger.

Charging time:
The charging time is determined by the charge status of the battery, the charging current and voltage available.

Here it must be noted that, in voltage-regulated charging devices, the charging current sinks as soon as the voltage limit has been reached, leading to an extended charging time. Example:

Charging factor
The charging factor is the factor by which the electrical charge removed during discharge is to be multiplied to determine charge required to reinstate the original charge status of the battery.
More ampere-hours must be charged up than are discharged to reconvert the entire active mass.

A value of 1.2 is a typical charging factor

Too small charging factors cause incomplete charging, sulphation and reduced capacity. Excess factors lead to increased water consumption and increased corrosion.

Influence of temperature
Technical information on the battery is valid for a temperature range of 10°C to 30°C. If a different temperature range is required for charging, charging devices with temperature compensation of the charging voltage are to be used. A voltage compensation of -24 mV/°C is recommended.

During charging, the temperature must remain under 50°C. Never charge damaged or frozen batteries.

Batteries under 0°C can only take on minimal charge; they must first warm up.
High temperature differences in the battery cause irregular functioning in the cells and the early failure of the battery.

In addition, high temperatures lead to reduced service life, while low temperatures reduce the capacity available.

Nominal capacity	Charging status	available capacity	lacking capacity
70 Ah	70 %	49 Ah	21 Ah
	50 %	35 Ah	35 Ah
	30 %	31 Ah	39 Ah
Example	Charging status of 70 % corresponds to lacking capacity of 21 Ah		
	Charging current: 7 A (charging device)		
	21 Ah / 7 h = min. 3 h charging time		

Recharging after deep discharge or equalising charge

An equalising charge is necessary after deep discharge and/or inadequate charging.

If the vehicle is not used for a long period, the start battery will run down. In doing so, lead sulphate will form on the plates, which can damage the battery. These are called sulphated batteries.

During very long down-times, the battery can become deeply discharged, with a highly marked sulphation. This can have the effect that the battery is so damaged that it cannot be charged again without extra measures.

If the actual charging process for a battery after deep discharge cannot be started, it may be necessary to connect a second battery in parallel to create a certain “counter-voltage” and start the charging process.

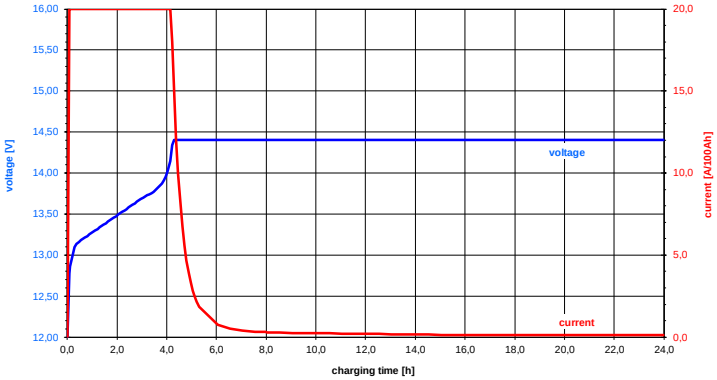
The charging time for deep-discharged batteries is markedly increased. The charging time must be at least 24 h (optimally, 48 h).

Characteristic curve
The functioning of a charging device is described by its “characteristic curve”:

The symbols used here are:
- W: Resistance curve
- U: voltage-regulated (constant voltage)
- I: current-regulated (constant current)
- 0: Switchover point
- a: automatic switch-off

IU or WU characteristic curves are preferred to charge starter batteries.

In the IU characteristic curve, during the first phase, a constant current is used to charge the battery until the starter battery has a defined voltage of e.g. 14.8 V. After this voltage threshold is reached, it



Figure, IU characteristic curve:
Example progress of current and voltage over time.

automatically switches into a constant voltage phase. During this U phase, the charging current drops constantly. At the end of the U phase, the charging current rests at a constant level.

Full charge retention (trickle charging)
During downtime, lead batteries lose capacity through electrochemical processes. This so-called “self-discharging” is both dependent on temperature and battery technology. Seasonal vehicles (motorbikes, caravans etc.) are particularly affected when over-wintering.

In stationary vehicles, alongside this self-discharge, the battery is also run down by the quiescent current of the vehicle.

Trickle charging must be carried out in accordance with an IU characteristic curve.

The recommended trickle charging voltage (at 25°C ±10°C) for a standard

- **Starter battery 13.5 V is**
- **VRLA battery 13.8 V.**

Recharging batteries in the vehicle
Take note of the operating manual or manufacturer instructions on the charging device and the information given in your vehicle manual.

In general, a fully automatic, voltage-regulated charging device (charging voltage max. 14.8 V) is to be considered suitable to charge the batteries contained in the vehicle. Make sure that the ignition and all electrical loads in the vehicle are switched off.

In case of trickle charging/recharging in the vehicle, it is essential to ensure that no charging at a higher voltage than 14.8 V takes place: Danger of destruction of the on-board electrics!

If your charging device nevertheless has an automatic mode with voltages above 14.8 V, the battery must be isolated from the on-board electrics or dismounted from the vehicle. Otherwise, over-voltages may lead to the destruction of the control devices present in the vehicle.

In vehicles with start/stop systems, the battery can always be charged as assembled. However, care must be taken that the minus cable of the charging device is not directly attached to the minus terminal or BDM (battery data module) of the battery. It should be connected to the engine block or a correspondingly labelled location in the engine compartment.
Please take note of the instructions in your vehicle’s operating manual.

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