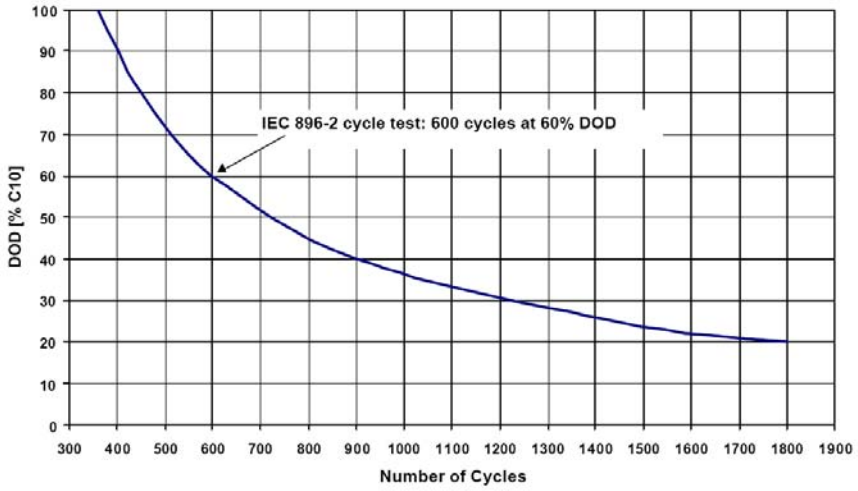
Cycle life

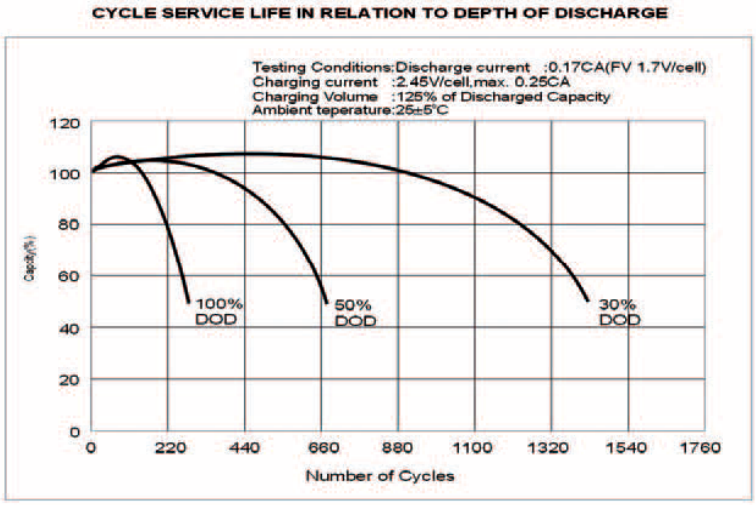
Typical VRLA Battery Cycling Ability vs. Depth of Discharge*

	Typical Life Cycles	
Capacity Withdrawn	**Gel**	**AGM**
100%	450	150
80%	600	200
50%	1000	370
25%	2100	925
10%	5700	3100

Gel:

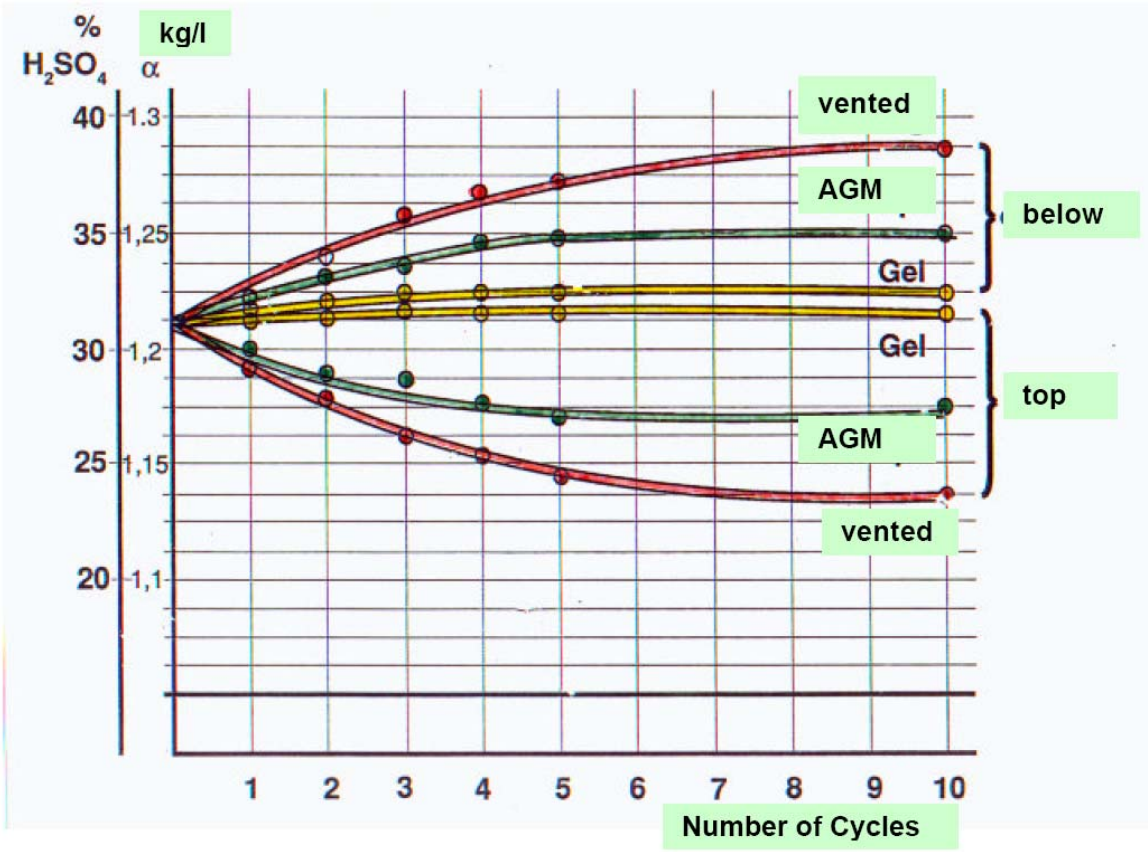


AGM:



Gel-batteries withstand deep discharges much better than AGM-batteries due to
- surplus of electrolyte (1.5 to 1.7-times more electrolyte in Gel-cells)
- micro-porous separator used
Due to less void volume in the separator/electrolyte less heat evolution occurs in Gel-batteries compared to AGM-batteries by oxygen recombination. The heat dissipation in Gel-batteries is quite on the same level as in vented batteries and much better than in AGM, due to the surplus of electrolyte.

Acid stratification can occur especially during cyclical applications. It causes shorter battery life due to increased corrosion and sulphation. AGM show higher levels of stratifications than gels.



Recharging

Gel charge voltage settings for three step battery chargers
Float: 2.23V/cell @ 20ºC / 68ºF
Absorption: 2.40V/cell @ 20ºC / 68ºF (max 5 hrs)
Temperature compensation: -5mV/ºC/cell or -2.8mV/ºF/cell

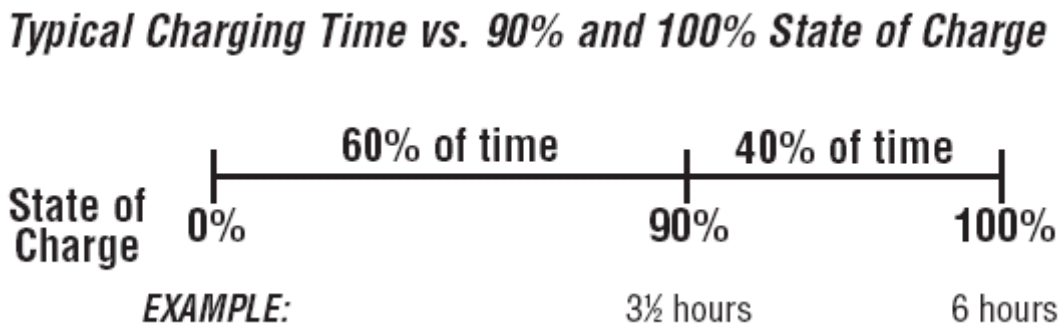
Gel Charge and Float Voltages at Various Temperature Ranges

Temp. °F	Charge		Float		Temp. °C
	Optimum	Maximum	Optimum	Maximum	
≥ 120	13.00	13.30	12.80	13.00	≥ 49
110 – 120	13.20	13.50	12.90	13.20	44 – 48
100 – 109	13.30	13.60	13.00	13.30	38 – 43
90 – 99	13.40	13.70	13.10	13.40	32 – 37
80 – 89	13.50	13.80	13.20	13.50	27 – 31
70 – 79	13.70	14.00	13.40	13.70	21 – 26
60 – 69	13.85	14.15	13.55	13.85	16 – 20
50 – 59	14.00	14.30	13.70	14.00	10 – 15
40 – 49	14.20	14.50	13.90	14.20	5 – 9
≤ 39	14.50	14.80	14.20	14.50	≤ 4

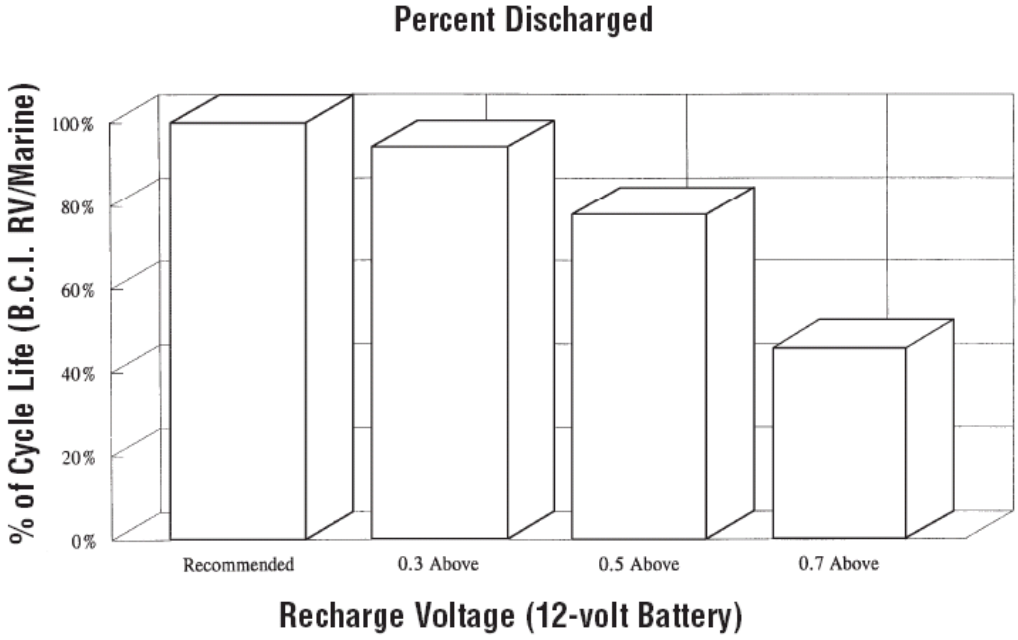
AGM Charge and Float Voltages at Various Temperature Ranges

Temp. °F	Charge		Float		Temp. °C
	Optimum	Maximum	Optimum	Maximum	
≥ 120	13.60	13.90	12.80	13.00	≥ 49
110 – 120	13.80	14.10	12.90	13.20	43 – 49
100 – 110	13.90	14.20	13.00	13.30	38 – 43
90 – 100	14.00	14.30	13.10	13.40	32 – 38
80 – 90	14.10	14.40	13.20	13.50	27 – 32
70 – 80	14.30	14.60	13.40	13.70	21 – 27
60 – 70	14.45	14.75	13.55	13.85	16 – 21
50 – 60	14.60	14.90	13.70	14.00	10 – 16
40 – 50	14.80	15.10	13.90	14.20	4 – 10
≤ 40	15.10	15.40	14.20	14.50	≤ 4

Overall, a re-charging process is expressed by a charge coefficients (also called “charge factor”). The following values represent charge coefficients after a 10h-discharge:
- 1.04 to 1.06, typically 1.05, for Gel-batteries,
- 1.05 to 1.12, typically 1.08, for AGM-batteries and
- 1.15 to 1.30, typically 1.20, for vented batteries.



Gel Percent Cycle Life vs. Recharge Voltage
This chart (below) shows the effect on life of overcharging a gel battery. (e.g.: Consistently charging at 0.7 volts above the recommended level reduces life by almost 60%!)



How can you tell if a battery has been damaged by under- or overcharging?
For all battery types, the only way is with a load test:
a. Recharge if the open circuit voltage is below 75%.
b. If adjustable, set the load at 1⁄2 the CCA rating or three times the 20 hour rate.
c. Apply the load for 15 seconds. The voltage should stabilize above 9.6 volts while on load.
d. If below 9.6 volts, recharge and repeat test.
e. If below 9.6 volts a second time, replace the battery.

OPEN CIRCUIT VOLTAGE VERSUS REMAINING CAPACITY

MasterVolt:

Capacity	0%	20%	40%	60%	80%	100%
Gel voltage*	11.54V	11.88V	12.18V	12.48V	12.78V	13.02V
AGM voltage*	11.64V	11.88V	12.09V	12.30V	12.51V	12.72V

*Open circuit voltage is measured after the battery was disconnected from any load or power source for at least 24hrs.

East Penn:

Open Circuit Voltage vs. State of Charge Comparison*

% Charge	Open Circuit Voltage Flooded	Gel	AGM
100	12.60 or higher	12.85 or higher	12.80 or higher
75	12.40	12.65	12.60
50	12.20	12.35	12.30
25	12.00	12.00	12.00
0	11.80	11.80	11.80

NOTE: Divide values in half for 6-volt batteries.

** The "true" O.C.V. of a battery can only be determined after the battery has been removed from the load (charge or discharge) for 24 hours.*

The open circuit voltage (OCV) of individual cells must not vary from each other by more than 0.02 V.

Battery Storage

Gel: The rate of self discharge is approximately 2% per month @ 20ºC/68°F.
AGM: The rate of self discharge is approximately 3% per month @ 20ºC.

Storage temperature	Gel Charging interval	AGM Charging interval
< 20ºC / < 68 ºF	Every 24 months	Every 9 months
20 to 30 ºC / 68 to 86 ºF	Every 12 months	Every 6 months
30 to 40 ºC / 86 to 104 ºF	Every 6 months	Every 3 months
40 to 50 ºC / 104 to 122 ºF	Every 3 months	Every 1.5 months

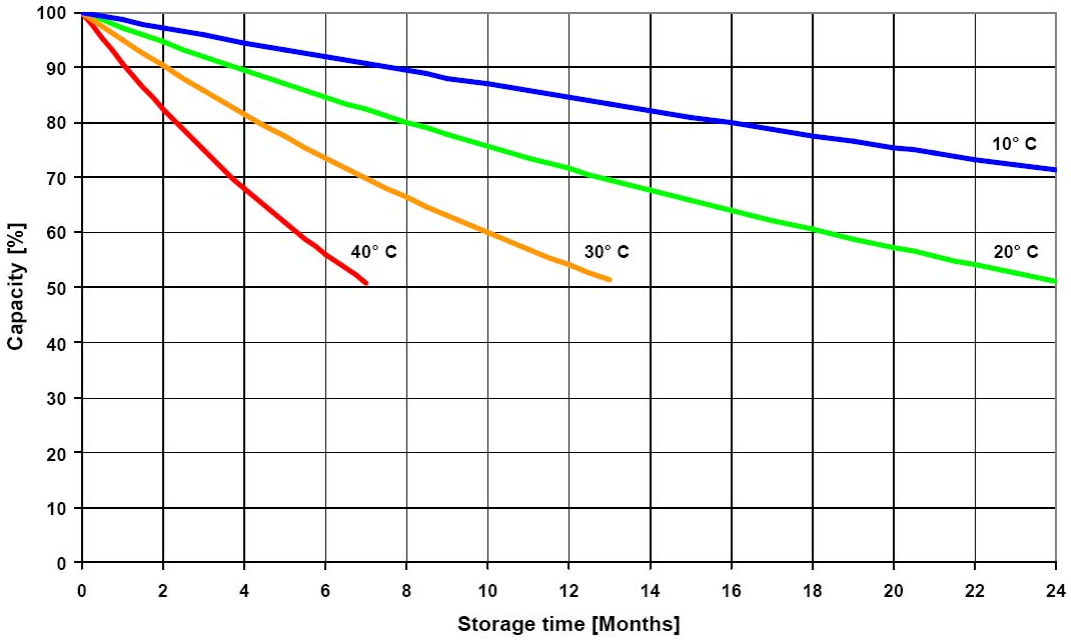


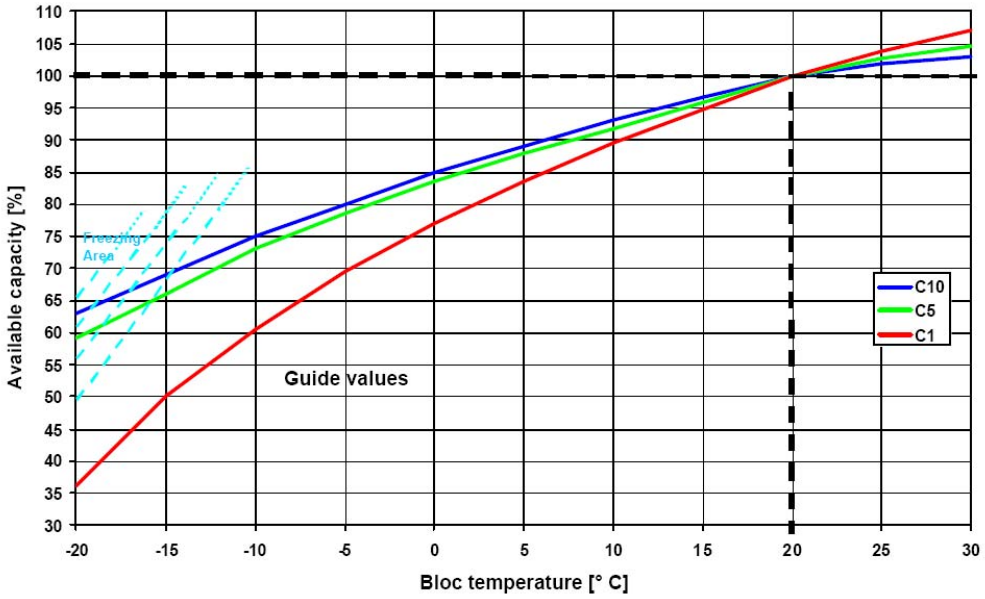
Fig. 1: Self-Discharge vs. Temperature (standard Gel-batteries)

Capacity

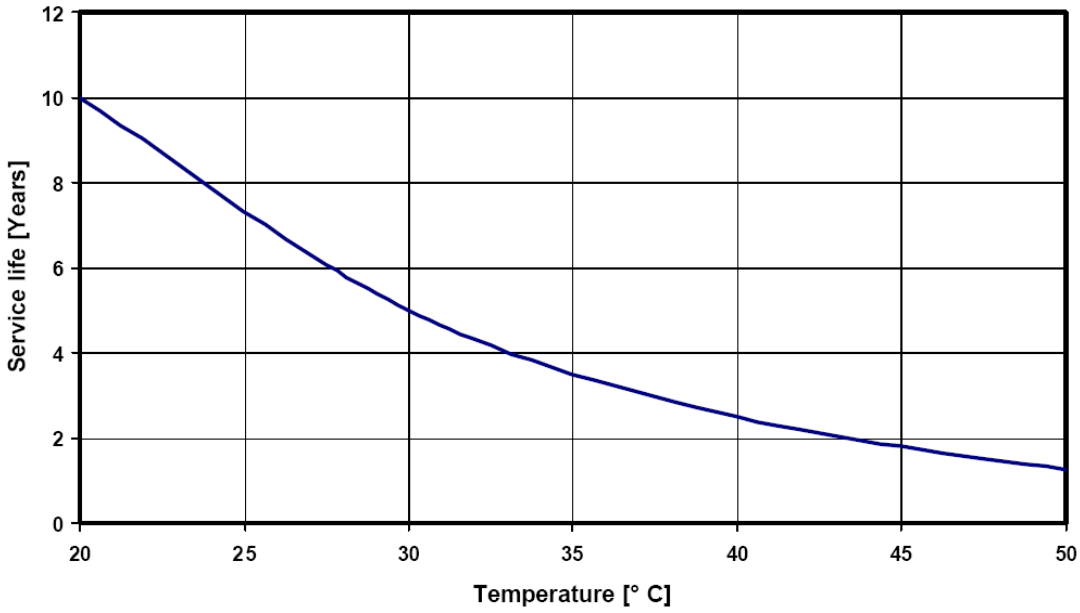
For both Gel & AGM: Allowed operating temperature: –20 to 45ºC / –4 to 113ºF; Nominal operating temperature: 10 to 30ºC / 50 to 86ºF. Recommended at 20ºC/ 68ºF. The battery life is halved for every 10ºC of rise in temperature. Lower temperatures will reduce the available capacity

Temperature	Gel & AGM Capacity*
0C (32F)	86%
20C (68F)	97%
25C (77F)	100%
40C (104F)	103%

* percent of rated capacity at 25C

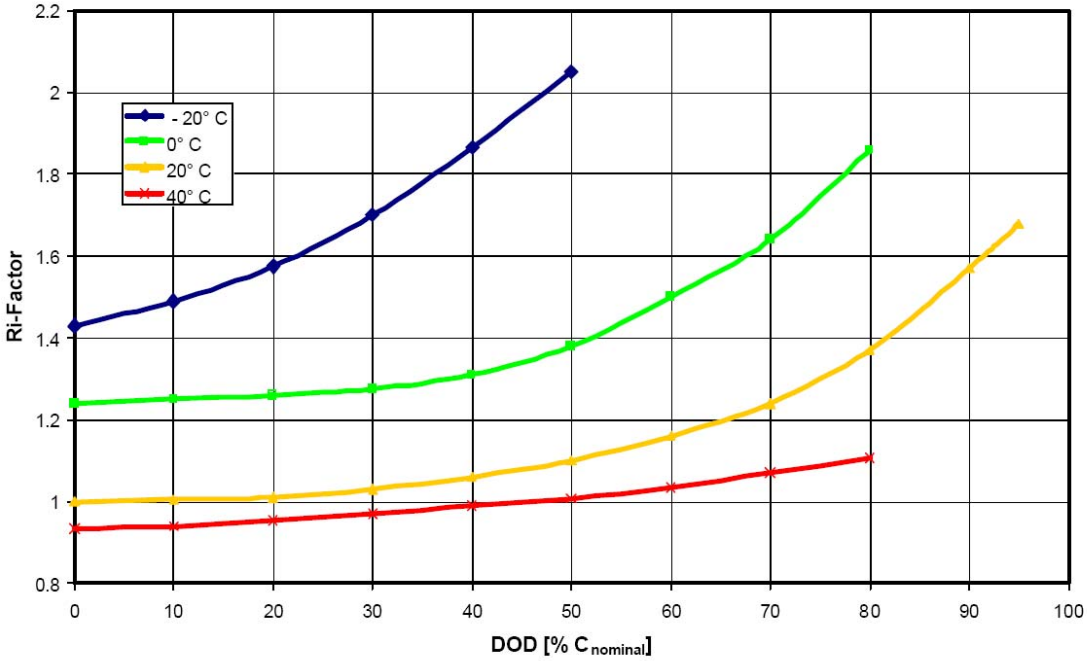


Service Life in Years vs Temperature



Internal Resistance R_i

The internal resistance Ri is an important parameter when computing the size of batteries. The internal resistance Ri varies with depth of discharge (DOD) as well temperature, as shown in fig. 18 below. Hereby, the Ri-value at 0% DOD (fully charged) and 20° C, respectively, is the base line (Ri-factor = 1).



Installing Batteries in Parallel

Most battery manufacturers, standards and guidelines recommend a maximum of 4 strings in parallel. It is possible to have more strings in parallel without reducing the life of the battery or getting problems with the battery.
Preconditions and features for 2 up to 10 strings in parallel:
General: The same voltage drops must be realized from each string to the end connector regardless if a string consists of one unit (single cell / monobloc) or several units. This can be achieved by proper choice of cable lengths, cable diameters and arrangement (for instance, by crosswise configuration).
The connector cables for positive and negative terminals of each battery string must have the same length.
The minimum cable size for the end connectors of a string is 25 mm^2/100 Ah string capacity.
The end-connector cables must be placed on a copper bar with at least 100 mm^2/100 Ah string capacity with the lowest possible distance.
It is a must to have a circuit breaker for each string or every two strings.
The strings must have all the same number of cells and temperature
If these requirements are fulfilled paralleling of up to 10 strings is possible.
All battery performance data have to be applied to the end terminal of each string. By using the parallel strings the reliability of the system is increased due to the redundancy. Neither the lifetime nor the reliability will be reduced.
Also, the type of lead-acid batteries may differ as long as the requested charging voltage (Vpc) per string is fulfilled.
Always connect the individual series strings first and check that the different strings are at the same potential before connecting them together.