Batteries used on rolling stock are either Lead Acid, Nickel Cadmium or Nickel Metal Hydride. Schaffler have the algorithms for all three types of batteries. Batteries on diesel driven cars (DMUs) are used to start the engines and supply power for the switch gear and air conditioning on the car. On electric trains, batteries are used to power the pantograph gear to connect the train to the overhead wires and can also act as a backup power supply.

How long should batteries last on a train?

If batteries need to be replaced within two years or less, then it is most likely that they are being charged with a power supply and not an intelligent battery charger. Schaffler expect the life to exceed 8 years and have already experienced 12 years of life using their intelligent battery chargers. Float charging is a fixed charging voltage set higher than the open circuit voltage but slightly lower than the gassing voltage. This is not a satisfactory method of charging but regrettably frequently used. This method will shorten the effective life of the batteries.

Train batteries are typically large and expensive and require special care when charging so they last longer. Consequently, charging these batteries is more complex than may be expected.

Optimum Battery Charging Algorithm

The optimum battery charging algorithm is summarised below. The system is known as IUIU. That means Constant Current – Constant Voltage – Constant Current –Constant Voltage (followed by the trickle charge at the float voltage). Keeping to this algorithm will extend the life of the batteries to the maximum possible. This applies to batteries in constant use as well as those kept in storage.
1. **Constant Current Charging (I)**

   During the first period of charging the batteries are charged at a constant current of 20% of their amp-hour rating. The battery voltage increases. This mode ends when the batteries reach their float voltage. (typically 2.3 volts per cell for lead acid).

2. **Constant Voltage Charging (U)**

   The second period of charging remains at the constant float voltage and the charge current drops away exponentially. This mode ends when the charge current drops away to 10% of the ampere hour rating.

3. **Constant Current Charging (I)**

   The current is held constant at 10% of the Ampere Hour rating until the voltage increases to the gassing level and this mode ends. (equalising)

4. **Constant Voltage Charging (U)**

   This equalising voltage is held constant until the charging current drops to 5% of the Ampere Hour rating which signifies the end of this mode and the IUIU algorithm.

5. **End of Charge**

   At the end of the IUIU algorithm the voltage returns to the float voltage and the battery retains its charge. The battery continues to receive trickle current while being held at float voltage.

   **Battery Discharge.** When the batteries are discharged this algorithm is automatically re-engaged.

**Battery Equalising**

Over time, depending on how the battery is used, sulphate crystals can accumulate within the battery and harden to form insulation. This is called Sulfation. Such sulphur accumulation reduces the effective surface area of the cell plates and thus reduces battery charge capacity and battery life. Another condition known as stratification is where different concentrations of acid form layers within the battery liquid leading to uneven charging and reduced battery life. Battery equalising is a method of charging a battery at a higher voltage, producing gassing, but at a limited current. This function dissolves much of the accumulated sulphur and mixes the battery solution thus extending battery life. Gel type batteries do not require equalising.

**Temperature Considerations**

The temperature of a battery has an effect on the amount of charge a battery accepts and the rate at which it will accept the charge. The advanced battery charging systems measure the battery temperature and adjust charging voltage and current accordingly. Schaffler battery charger monitor the temperature of up to two battery compartments. The algorithm reduces charging when the highest compartment reaches 40°C and stops charging when the temperature is 60°C or more.

Temperature as well as dv/dt can also be used to signify the end of charge for Nickel Metal Hydride and NiCad batteries.

**SCHAFFLER Battery Chargers**

Schaffler Battery chargers are designed taking into account the specific circumstances effecting battery charging in combination with the rugged requirements of railways. These factors include:

- Type of battery
- Ampere hour rating of the batteries
- Number of cells in series
- Typical and peak battery usage
- Voltage, current and Power constraints
- EMI and audible noise
- Shock and vibration
- Fault protection and redundancy
## Protective Features

- I x t overload protection, 10 to 100%
- Instantaneous over-current protection 15 to 150%
- Output short circuit
- Earth Fault
- External trip circuit
- Hardware fault coding
- Over voltage
- Under voltage
- Over temperature heat sink
- Over temperature ambient
- Thermistor input facility

## Intelli-battery Charger HBC 8000

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage Options</td>
<td>415 volts 3-phase 50/80 Hz</td>
</tr>
<tr>
<td></td>
<td>240 Vac 30 Hz to 525 Vac 80 Hz 3-phase</td>
</tr>
<tr>
<td></td>
<td>376 to 700 Vdc</td>
</tr>
<tr>
<td></td>
<td>750 Vdc 3rd rail supply</td>
</tr>
<tr>
<td>Nominal battery voltage</td>
<td>24 Vdc, 72 Vdc, 110 Vdc, 280 Vdc</td>
</tr>
<tr>
<td>Charging battery voltage</td>
<td>Adjustable in software to suit number of cells, ampere hour rating and battery type</td>
</tr>
<tr>
<td>Battery charger output</td>
<td>Two outputs provided: one for the batteries</td>
</tr>
<tr>
<td></td>
<td>One for the standing load</td>
</tr>
<tr>
<td></td>
<td>Battery output is separate to the standing load output</td>
</tr>
<tr>
<td>Output currents available</td>
<td>100 amps to 500 amps at 24 VdC</td>
</tr>
<tr>
<td></td>
<td>100 amps to 200 amps at 72 VdC</td>
</tr>
<tr>
<td></td>
<td>100 amps to 200 amps at 110 VdC</td>
</tr>
<tr>
<td>Equalising Charge</td>
<td>Battery charger includes USB port and software for a laptop computer for selecting Equalising and for interrogating the history and status</td>
</tr>
<tr>
<td>Temperature (Optional)</td>
<td>Battery charging is reduced when battery temperature rises above 40°C and stops at 60°C. Two temperature probes for the battery enclosures are provided</td>
</tr>
<tr>
<td>Efficiency</td>
<td>92.1% at 100% load</td>
</tr>
<tr>
<td>Power factor</td>
<td>0.94 at full load</td>
</tr>
<tr>
<td>Isolation</td>
<td>Secondary galvanically isolated from input supply. Hi-pot tested at 2100 volts</td>
</tr>
<tr>
<td>Ripple voltage maximum</td>
<td>&lt; 0.5 volts RMS at 6 kHz</td>
</tr>
<tr>
<td></td>
<td>Output DC filter will be provided</td>
</tr>
<tr>
<td>Active circuit</td>
<td>No connection to earth</td>
</tr>
<tr>
<td>Start up load Overload</td>
<td>Equal to steady state load</td>
</tr>
<tr>
<td></td>
<td>Current limited to full load amps</td>
</tr>
<tr>
<td></td>
<td><strong>Note:</strong> there is no over current allowed on a battery charger</td>
</tr>
<tr>
<td>Signal outputs at control plug</td>
<td>Normally open contacts rated at 5 amps at 110 VDC</td>
</tr>
<tr>
<td></td>
<td>intended for the train management system</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>-25 to 60 ° C (within the locker)</td>
</tr>
<tr>
<td>Protection</td>
<td>IP65 self-ventilated for underframe mounting</td>
</tr>
<tr>
<td></td>
<td>Forced ventilated through heatsink only for in-car mounting</td>
</tr>
<tr>
<td>External connections</td>
<td>Three military style plugs including mating cable plugs.</td>
</tr>
<tr>
<td></td>
<td>3-phase 415 supply input</td>
</tr>
<tr>
<td></td>
<td>74 VDC output</td>
</tr>
<tr>
<td></td>
<td>Communication</td>
</tr>
<tr>
<td>Voltage surges; lightning</td>
<td>Differential mode 2.6 kVp</td>
</tr>
<tr>
<td></td>
<td>Common mode 1.3 kVp for 100 µsec</td>
</tr>
<tr>
<td></td>
<td>Waveform 1.2/50 µsec</td>
</tr>
</tbody>
</table>
Manufacturing standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 50155</td>
<td>Electronic equipment used on rolling stock equipment</td>
</tr>
<tr>
<td>IEC 1287-1</td>
<td>Power converters installed on board rolling stock</td>
</tr>
<tr>
<td>EN50121-3-2</td>
<td>Electromagnetic Compatibility</td>
</tr>
<tr>
<td>IEC 61000-4-3</td>
<td>EMC standard</td>
</tr>
<tr>
<td>IEC61373</td>
<td>Railway application rolling stock equipment Shock &amp; Vibration testing</td>
</tr>
<tr>
<td>BRB/RIA-12</td>
<td>British Rail Standard for transients and surges</td>
</tr>
<tr>
<td>AS 3000</td>
<td>Wiring regulations</td>
</tr>
</tbody>
</table>

100 amp 72 Vdc Battery Charger IP65 self-ventilated

220 amp 24 Vdc Battery Charger Forced ventilated through heatsink only

11 kW Battery Charger for 110 Vdc Nickel Metal Hydride batteries. Enclosure IP67 self-ventilated

Schaeffler have supplied battery chargers to Australia, USA, UK, China, South Africa, Thailand and other South East Asian counties. They are operating on Diesel Locomotives, DMUs, EMUs and Monorail. Schaeffler welcome technical discussion related to battery charging and extending the life of batteries on rolling stock.