TechPaper

Emergency lighting batteries

Main battery types for use in self-contained emergency lighting

TRIDONIC

Content

Introduction

When the general artificial lighting fails, orientation must still be ensured in buildings for staff and visitors alike. Accordingly, there are legal provisions governing the equipment and dimensioning of emergency lighting installations that will be activated when there is a mains voltage failure. Various systems are suitable to supply emergency lighting installations with electricity in event of a power failure: self-contained, group battery, central battery, power generators or high-security mains.

Self-contained emergency luminaires have a battery built in as a power source. If the mains voltage fails, the emergency luminaire automatically switches to the battery supply.
Different types of batteries are available for use in a self-contained emergency luminaire.
The most commonly used batteries are NiCd, NiMH and $LiFePO_4$ and all of them have specific characteristics. The following chapters explain the differences in the battery types utilised in the Tridonic product portfolio.

Main battery types

NiCd, NiMH and $LiFePO_4$ batteries

NiCd batteries

NiCd battery technology has been used for a long time in self-contained emergency lighting. NiCd batteries use nickel oxide hydroxide and cadmium as electrodes. Due to the toxicity and the hazardous nature of cadmium, NiCd batteries have a negative impact on the environment. They are banned from use in most applications, excluding medicine, military and emergency installations, having mostly been replaced by NiMH batteries. Even though they are banned in such a broad spectrum of applications, there are no signs that the European Union (EU) will restrict their use in emergency lighting. The key benefit of NiCd batteries is that they are very robust and, when compared to NiMH batteries, they are able to withstand higher temperatures and are more durable in harsh environments.

The biggest design challenge when using NiCd batteries is their low energy density which makes the battery larger in size for a given energy in comparison with the other technologies mentioned below. This means that they are not suitable for small luminaire designs. Alternatively the battery can be placed outside the luminare in a suitable enclosed housing.

Characteristics:
- Very robust: Suited for high temperatures (up to 55 °C)
- Design life: 4 years
- Storage time: up to 12 months from production date
- Critical to the environment due to Cadmium content
- Larger dimensions compared to the other battery types

NiMH batteries

The NiMH battery has a ~30 % higher energy density than NiCd batteries, offering the possibility of smaller luminaire designs. Compared to NiCd batteries, NiMH batteries are not as durable in harsh environmental conditions and need a different, microcontroller controlled charging method (e.g. multilevel charge or intermittent charge) to achieve higher temperature ratings.

Characteristics:
- Suited for high temperatures (up to 55 °C) depending on the used charge algorithm
- Design life: 4 years
- Storage time: up to 12 months from production date
- Non-critical to the environment – no heavy metal content
- Higher energy density compared to NiCd batteries

$LiFePO_4$ batteries

In the whole battery market, from big energy storage for photovoltaic systems to small handheld devices, there is a movement from well-known technologies, which were used for decades, to the relatively new lithium based technologies.

The main benefits of lithium based technologies are a very high energy density, and a long lifetime up to twice that of the NiCd or NiMH batteries.

When using lithium batteries there are some points that have to be considered. There have been reports about possible risks of the lithium technology, which are mostly caused by the chemical reactivity of some lithium technologies.

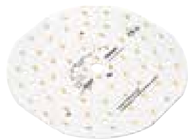
To ensure safety in operation, Tridonic have been testing several lithium batteries of different chemical compositions since 2013, with regard to performance over lifetime and possible safety issues in terms of high temperature, flames and mechanical damage.

The 18650 $LiFePO_4$ cell which is used in the Tridonic batteries stood out due to its good performance and safety in all of the performed tests. This battery was recently introduced into the product range and will be extended to most of Tridonic's emergency LED driver portfolio.

Characteristics:
- Suited for high temperature operation (up to 55 °C)
- Design life: 4 years at 55 °C
  8 years at 35 °C
- Storage time: up to 12 months from production date
- Higher energy density than NiCd and NiMH batteries
- Non-critical to the environment – no heavy metal content

Main battery types
Comparison for a typical application

The following table shows an emergency solution with the three different Battery types for the same LED driver and LED module combination.

	NiCd batteries	NiMH batteries	$LiFePO_4$ batteries
LED driver		 LC 17W 250-700mA flexC C EXC (28000693)	
LED module		 CLE G3 160mm 3000lm 840 ADV (89602857)	
Emergency LED driver	 EM converterLED BASIC 202 NiCd/ NiMH 50V (89800558)		 EM converterLED BASIC 202 MH/LiFePO4 50V (89800575)
Battery	 Accu-NiCd 2A 55 (89800092)	 Accu-NiMH 4Ah 2A CON (28002316)	 Accu-LiFePO4 2A CON (28002318)
Cell voltage	1.2 V	1.2 V	3.2 V
Cell capacity	4 Ah	4 Ah	1.5 Ah
Cell count	2	2	2
Wiring of cells	Series	Series	Parallel
Cell dimensions	32.5 x 60.5 mm	18.3 x 90 mm	18 x 65 mm
Battery energy	9.6 Wh	9.6 Wh	9.6 Wh
Case temperature range to ensure 4 years design life	+5 … +55 °C	+5 … +45 °C	+5 … +55 °C
Case temperature range to ensure 8 years design life	not available	not available	+5 … +35 °C
Energy consumption per year	19,3 kWh	19,3 kWh	12,5 kWh
Light output in emergency mode	~ 290 lm	~ 290 lm	~ 290 lm

Battery charging methods
Comparision of CC, MLCC, IC and VDCC

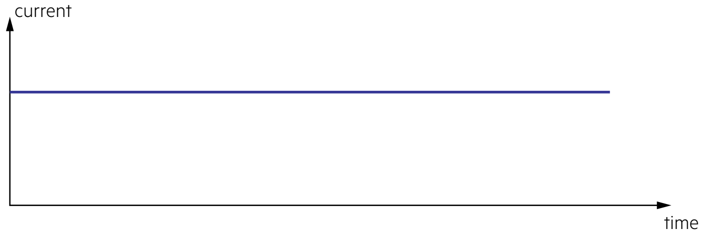
To ensure the reliable operation of emergency lighting in the case of a power failure, the batteries must be charged and ready to use at any given point in time and different charging methods are available to serve this need. Tridonic emergency control gears use one of the following battery charging methods:

- Constant current charging (CC)
- Multi-level constant current charging (MLCC)
- Intermittent charging (IC)
- Voltage dependent charging (VDCC)

NiCd and NiMH batteries can be charged with CC and MLCC. With MLCC, the batteries can be used with a higher temperature in operation. IC can be used if it is necessary to increase the temperature further on NiMH batteries. All of these charging methods are time based. To use $LiFePO_4$ batteries, a constant measurement of the voltage is required. This is done only with the VC, which was introduced specifically for the use with $LiFePO_4$ batteries.

Constant current charging (CC)

Constant current charging (CC) is the easiest way to charge a battery. It is suitable for NiCd and lower temperature NiMH applications. Constant current charging means that the battery will be constantly charged with the same current. Within 24 hours the battery is charged to 100 %. Afterwards the battery remains being charged with the same current to ensure permanent 100 % state of charge. The result of using this method is that the wasted energy from the constant charging heats up the battery.



Battery chemistry	Cell capacity	Case Temperature range
NiCd	4.2 / 4.5 Ah	+5 ... +55 °C
NiMH	2.2 Ah	+5 ... +50 °C
	4 Ah	+5 ... +40 °C

Multi-level constant current charging (MLCC)

Multi-level constant current charging (MLCC) is designed to reduce the recharge time and reduce the self-heating when the battery is fully charged. MLCC is suitable for NiCd and medium temperature NiMH applications.
In general MLCC has three different charging states:

- Initial Charge:
  The Initial Charge mode is automatically activated by the emergency unit when a new battery is connected to the unit. In this mode the battery is charged to 100 %. When the battery is fully charged the emergency unit switches automatically into the Trickle Charge mode.

- Fast Charge:
  The Fast Charge mode is automatically activated when the battery is discharged or partly discharged. The exact time depends on the charging state of the battery after the discharge. When the battery is fully charged, the emergency unit switches automatically into Trickle Charge mode.

- Trickle Charge:
  In the Trickle Charge mode, the battery is charged with a low current. It is designed to keep the battery fully charged without overcharging it to a high extent. The advantage of the lower Trickle Charge current is that the self-heating of the battery is reduced, making it possible to use the battery in higher environment temperatures when compared to the constant current charging.

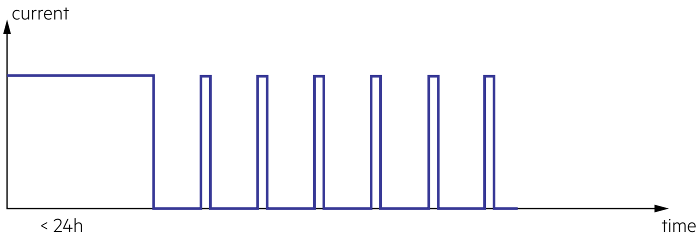
Battery chemistry	Cell capacity	Case Temperature range
NiCd	4.2 / 4.5 Ah	+5 ... +55 °C
NiMH	2.2 Ah	+5 ... +50 °C
	4 Ah	+5 ... +45 °C

Intermittent charging (IC)

With intermittent charging (IC) it is possible to allow higher battery temperatures with NiMH batteries. Similar to the multi-level constant current charging, there are three different charging modes:

- Initial charge:
  The initial charge mode is automatically activated by the emergency unit when a new battery is connected to the unit. In this mode the battery is charged to 100 %. When the battery is fully charged the emergency unit switches automatically into the trickle charge mode.

- Fast charge:
  The fast charge mode is automatically activated when the battery is discharged or partly discharged. The exact time depends on the charging state of the battery after the discharge.



When the battery is fully charged, the emergency unit switches automatically into trickle charge mode.

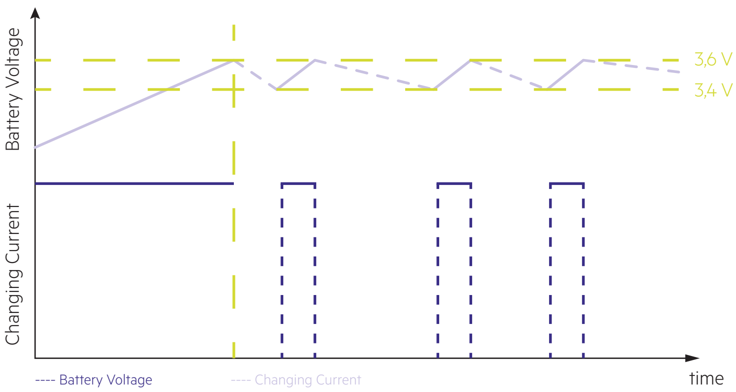
- Trickle charge:
  In the trickle charge mode of IC, the battery is charged with a pulsed current which is designed to keep the battery fully charged without overcharging it at a high extent. The advantage of the pulsed trickle charge current is that the self-heating of the NiMH battery is further reduced. Due to this lower self heating it is possible to use the battery in higher temperature environments compared to the constant current and multi-level constant current charging.

Tridonic emergency control gears use the IC charging method to charge the battery in trickle charge state for 4 minutes with a constant current, followed by a 16 minute pause.

Battery chemistry	Cell capacity	Case Temperature range
NiMH	2.2 Ah	+5 … +55 °C
	4 Ah	+5 … +50 °C

Voltage dependent constant current charging (VDCC)

Voltage dependent constant current charging monitors the voltage level and switches the charging on and off depending on the battery voltage. With this, the charging time can be minimised which makes voltage dependent constant current charging the most energy efficient charging method.



Unlike MLCC and IC there are no different charging modes. The two possible states are charging and not charging.
When the battery is connected for the first time, it is charged until the nominal voltage of 3.6 V is reached. At this voltage the charging stops. Because of self-discharge, batteries will slowly lose energy if they are not charged. If the voltage falls beneath
3.4 V, the charging starts again. This process repeats itself.
Voltage dependent charging is only suitable for $LiFePO_4$ batteries. $LiFePO_4$ batteries from Tridonic have an inbuilt protection against overcharging to ensure safe operation.

Battery chemistry	Cell capacity	Case Temperature range	Design life
$LiFePO_4$	1.5 Ah	+5 … +35 °C	8
		+5 … +40 °C	7
		+5 … +45 °C	6
		+5 … +50 °C	5
		+5 … +55 °C	4

Charging methods of Tridonic emergency LED drivers

Tridonic offers emergency control gear that uses all four charging methods. Information on which charging method is used for a specific emergency control gear can be found in the respective data sheet.

Please note that all batteries and the associated charging methods mentioned here refer to those used by Tridonic products and are only applicable to them.

Testing of emergency lighting batteries

Quality and testing at Tridonic

Emergency lighting is a safety-relevant issue and, because of this, there are strict standards to adhere to, of which the most relevant are the luminaire standard IEC 60598-2-22 and the component standard for self-contained emergency lighting IEC 61347-2-7. Differences in the performance of batteries are not only due to different battery chemistries, but stem from differences in the quality of each individual cell.
To ensure that all batteries meet the requirements applicable to them, Tridonic does not only rely on the manufacturer's assurances, but conduct extensive tests on batteries before adding them to the product portfolio. These tests are carried out by Tridonic and also by external, independent and certified test houses that specialise in battery testing.

The results of these tests define which batteries have the high quality required for inclusion in the Tridonic portfolio.
The high standard of these battery tests are reflected in the fact that less than 5 % of all tested batteries do, in the end, survive all test phases. Only these batteries qualify for the Tridonic emergency battery portfolio and many that, according to the manufacturers also meet all requirements, are rejected.

This rigorous selection process ensures that Tridonic batteries offer the highest level of safety and reliability. The following diagram shows the selection process for batteries in more detail.

Qualification

Search criteria:

- ICEL 1010 E50 & other life test data or certificates
- Signed battery certificates
  IEC 62133
  IEC 61951-1 / -2
- BASF licensing agreement

Testing

Metallurgy and chemical breakdown:

- Detailed cell analysis
- Screening analysis
- Anode reserve
- CT scan analysis
- Chemical analysis
- Cross section
- Breakdown analysis
- Calorimetry testing

Approval

Application test:

Tridonic internal qualification tests against compatible control gears

- Battery certificates
- Supplier audit
- Ongoing monitoring
- Cell design report

When a battery is selected, a Declaration of Design (DoD) is created in conjunction with the supplier before the product is added to Tridonic's portfolio. The Declaration of Design includes the specification of usage, which mainly consists of the lifetime determining parameters temperature, charge cycles, deep discharge and storage time.

Transportation of emergency lighting batteries

Safety regulations for the transportation of $LiFePO_4$ batteries

The UN Model Regulations define any cells and batteries, cells and batteries contained in equipment, or cells and batteries packed with equipment, containing lithium in any form as Class 9 Dangerous Goods (miscellaneous dangerous substances and articles) and are assigned under UN Nos. 3090, 3091, 3480, or 3481 as appropriate. Therefore any $LiFePO_4$ batteries or luminaires containing $LiFePO_4$ batteries are subject to the transport regulations set out by the Model Regulations and more specifically:

- Road transport – ADR (The European Agreement concerning the International Carriage of Dangerous Goods by Road)
- Sea transport – IMDG (International Maritime Dangerous Goods Code)
- Air transport – IATA DGR (International Air Transport Association Dangerous Goods Regulations)

Another important document is the UN Manual of Tests and Criteria, more specifically Part III sub-section 38.3 "Lithium metal and lithium ion batteries". This document sets out criteria, test methods, and procedures to be used for classification of dangerous goods. All lithium cells and batteries must be of the type proved to meet the requirements of each test specified in this document. This is more commonly referred to as a "UN 38.3 Certificate".

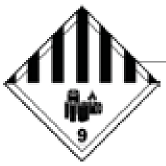
For $LiFePO_4$ batteries you will need to consider the following UN numbers:

- UN 3480 – Lithium Ion Batteries
  This will typically be used when transporting batteries by themselves, for example to be used as spares/replacement or when being delivered to yourself from Tridonic.
- UN 3481 – Lithium Ion Batteries Contained In Equipment
  This will typically be used when transporting luminaires where the battery is installed inside of the luminaire itself.
- UN 3481 – Lithium Ion Batteries Packed With Equipment
  This will typically be used if the battery being transported is not installed inside the luminaire however they are contained inside the same package, for example the EM ready2apply.

Transportation at Tridonic

By default, Tridonic transports batteries by road and sea freight. The biggest advantage of this type of shipment is the higher charge level of the batteries that is permitted (air freight limits UN3480 to 30 % state of charge). The higher charge level allows batteries to be stored longer before being used for the first time. The regulations for the transportation of luminaires with Tridonic emergency drivers and $LiFePO_4$ batteries have to be checked individually.

Explanation of packaging labels



Class 9 Lithium Battery Label

Lithium Battery Mark

Cargo Aircraft Only label

Storage of emergency lighting batteries

Guidelines for the storage of batteries

When batteries are stored they need to be in an open circuit state, which means that they are not connected to any load and also not being charged. In this state they tend to lose any previously applied charge and therefore discharge themselves. The exact rate of self-discharge depends largely on the battery type and environmental conditions such as temperature and humidity. For all batteries from Tridonic, the following rules for storage apply:

- Storage time: <6 months resp. <12 months depending on the storage temperature
- Avoid atmosphere with corrosive gas
- Disconnect batteries before storage or delivery
- Avoid the storage of discharged batteries
- Store batteries within the required humidity and temperature ranges

Long-term storage in open circuit conditions leads to battery self discharge and deactivation of the chemical components. That is why for NiCd and NiMH batteries it could be necessary to charge and discharge the batteries a few times to recover the initial performance.

There are no universal regulations for the storage of batteries although individual insurance companies can require certain measures to be observed so, to ensure that all of the required measures are taken, please get in contact with your insurance company.

Naming of emergency lighting batteries

Explanation of abbreviations

Tridonic product names follow a predefined scheme. Knowing and understanding the logic behind it, helps to read important information about the product from the name.
This chapter explains the naming of Tridonic emergency lighting batteries.

Scheme of naming

The naming of Tridonic emergency lighting batteries, for example ACCU-LiFePO4 3.6Ah 2A 2S1P CON, is divided into a total of six blocks. Spaces or hyphens serve as separation between the blocks. Each of these blocks conveys information about one specific aspect. These individual aspects are core naming, battery technology, capacity, number of cells, cell wiring and additional information.

The following illustration gives an overview of the naming blocks.

For each EM battery naming max. 40 digits are allowed

	Naming					Battery technology							Capacity					Number of cells		Cell wiring				Additional information									
Number of digits	A	A	A	A	A	B	B	B	B	B	B	B	C	C	C	C	C	D	D	E	E	E	E	F	F	F	F	F	F	F	F	F	F
	Max. 5					Max. 7							Max. 5					Max. 2		Max. 4				Max. 10									
Accu NiCd	A	C	C	U	-	N	i	C	d									2	A					5	5								
Accupack NiCd	P	A	C	K		N	i	C	d									3	D					C	O	N							
Accu NiMH	A	C	C	U		N	i	M	H				4			A	h	5	C					C	O	N							
Accupack NiMH	P	A	C	K		N	i	M	H				2	.	2	A	h	4						C	O	N							
Accu LiFePO4	A	C	C	U		L	i	F	e	P	O	4	9			A	h	5	A														
Accu LiFePO4	A	C	C	U		L	i	F	e	P	O	4	3	.	6	A	h	6	A	2	S	2	P	C	O	N							
Accupack LiFePO4	P	A	C	K		L	i	F	e	P	O	4	1	.	5	A	h			3	S	2	P	C	O	N		R	2	A		S	M

Naming of emergency lighting batteries

Explanation of abbreviations

The following tables explain the meaning of the individual naming block codes.

Naming

Indicator	Name					Explanation
A	A	C	C	U	-	Simple battery
A	P	A	C	K		Battery in housing

Battery technology

Indicator	Name	Explanation
B	NiCd	Nickel-Cadmium
B	NiMH	Nickel-Metalhydrid
B	$LiFePO_4$	Lithium-Ironphosphat

Capacity

Indicator	Name	Explanation
C	Capacity	Unit = Ah

Number of cells

Indicator	Name	Explanation
D	Numer of cells	Number of cells

Cell wiring

Indicator	Name	Explanation
E	Cell wiring	Serial and parallel wiring

Abbreviations such as "2S1P", "2S2P" or "3S2P" stand for the type of circuitry of cells.
The numerical value in front of "S" indicates how many cells are connected in series
The numerical value in front of "P" indicates how many cells are connected in parallel

Additional information

Indicator	Name	Explanation
F	50	High temperature operation up to 50 °C possible
F	55	High temperature operation up to 55 °C possible
F	CON	With plug connector
F	R2A	ready2apply specific
F	R2A SM	ready2apply SM specific (SM = "Surface Mount")

NiCd and NiMh cells are connected in series.
$LiFePO_4$ are either connected in parallel or combined in parallel and series

Naming of emergency lighting batteries
Calculation of voltage and capacity

1.5 Ah cells (18650) are all connected in parallel, resulting in a constant voltage of 3.2 V.
The capacity is 1.5 Ah per cell and increases with the number of cells.
Example: 1.5 Ah (per cell) x 6 cells = 9.0 Ah (total capacity)

With 3.6 Ah cells (26650), the capacity and the voltage depend on the type of connection.
This is indicated in the naming. The capacitance and voltage can be calculated as follows:

Article no	Name	Explanation
28003814	ACCU-LiFePO4 3.6Ah 2A 2S1P CON	2 cells in series (2S), one piece in array in parallel (1P). Voltage: 2 cells at 3.2 V in series = 2 x 3.2 V = 6.4 V Capacity: constant capacity (3.6 Ah)
28003815	ACCU-LiFePO4 7.2Ah 4A 2S2P CON	2 cells in series (2S), two pieces in parallel arrangement (2P). 2 cells of 3.2 V each in series = 2 x 3.2 V = 6.4 V Capacity: 2 pieces arranged in parallel: 2 x 3.6 Ah (per cell) = 7.2 Ah
28003816	ACCU-LiFePO4 7.2Ah 6A 3S2P CON	3 cells in series (3S), two pieces in parallel arrangement (2P). 3 cells at 3.2 V in series: 3 x 3.2 V = 9.6 V Capacity: 2 pieces arranged in parallel: 2 x 3.6 Ah (per cell) = 7.2 Ah

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