

## Testing of the traction batteries in electric vehicles and their further use

K. Friedrischková, D. Vala, B. Horák

*VŠB – Technical University of Ostrava, Faculty of electrical Engineering and Computer Science,  
Department of Cybernetic and Biomedical Engineering,  
17.listopadu 15, 708 33 Ostrava, Czech Republic  
(e-mail: kristyna.friedrischkova@vsb.cz).*

**Abstract:** In view to an expanding number of electric vehicles on the roads is also increasing demand for high quality batteries. These batteries suitable for the automotive industry (Lithium Iron Phosphate) offer great potential. In this article I will deal with properties that shorten the lifetime of these cells. And while their secondary use when installed in electric vehicles.

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**Keywords:** Traction battery, electric vehicle, testing, measurement.

### 1. INTRODUCTION

History of Lithium Iron Phosphate (LiFePO<sub>4</sub>) cells dates back to 1996, when a scientist from the University of Texas, Goodenough, patented these chemical batteries. Wikipedia (2015).

Phosphate based technology possesses superior thermal and chemical stability which provides better safety characteristics than those of Lithium-ion technology made with other cathode materials. Lithium phosphate cells are incombustible in the event of mishandling during charge or discharge, they are more stable under overcharge or short circuit conditions and they can withstand high temperatures without decomposing. When abuse does occur, the phosphate based cathode material will not burn and is not prone to thermal runaway. Phosphate chemistry also offers a longer lifecycle.

Phosphates significantly reduce the drawbacks of the Cobalt chemistry, particularly the cost, safety and environmental characteristics. Once more the trade off is a reduction of 14% in energy density, but higher energy variants are being explored.

Due to the superior safety characteristics of phosphates over current Lithium-ion Cobalt cells, batteries may be designed using larger cells and potentially with a reduced reliance upon additional safety devices.

The performance of Lithium Ion cells is dependent on both the temperature and the operating voltage. If thresholds are exceeded may be partially or permanent damage to the cells or even their destruction.

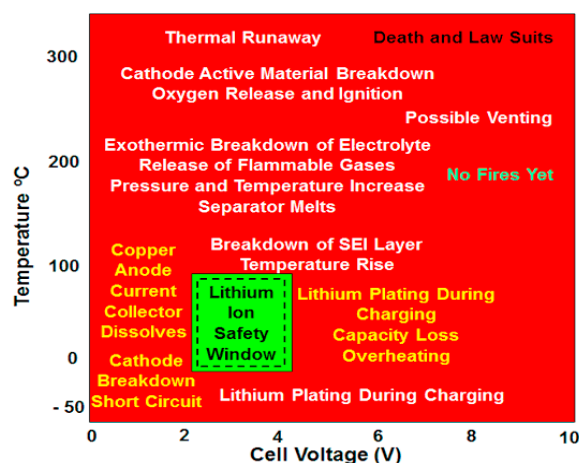


Fig. 1. Operating window Lithium Ion cell.

Exceeding the limits or failures use can cause voltage defects:

- Over-Voltage
- Under-voltage / Over-discharge

#### 1.1 Over-Voltage

If the charging voltage is increased beyond the recommended upper cell voltage, typically 4.2 Volts, excessive current flows giving rise to two problems.

- Lithium Plating
- Overheating

#### 1.2 Under-voltage / Over-discharge

Rechargeable Lithium cells suffer from under-voltage as well as over-voltage. Allowing the cell voltage to fall below about 2 Volts by over-discharging or storage for extended periods results in progressive breakdown of the electrode materials.

### 1.3 State of Charge

The voltage restrictions necessary to avoid the problems outlined above can be translated into recommendations for the operating range of the State of Charge of the battery is in the Fig. 2.

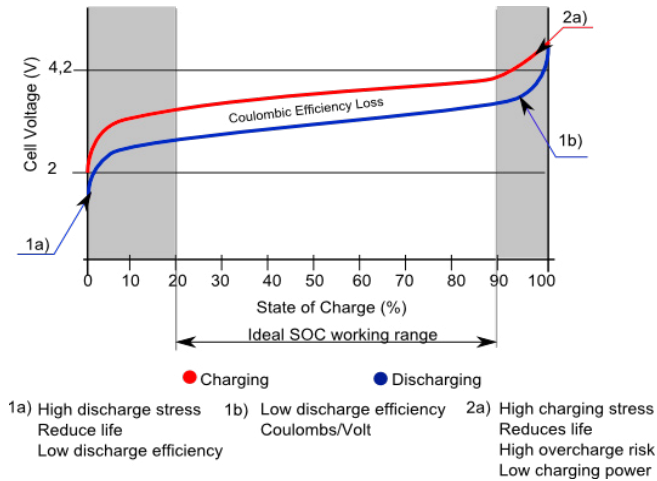


Fig. 2. SOC operating window.

Operating outside of these limits will adversely affect the life of the battery.

### 1.4 Temperature Effects

Heat is a major battery killer, either excess of it or lack of it, and Lithium secondary cells need careful temperature control.

- Low temperature operation
- High temperature operation
- Thermal runaway

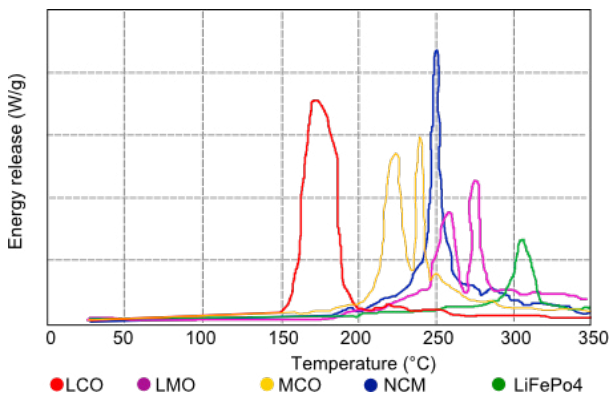


Fig. 3. Properties decomposition of selected cathode material.

The graph (Fig. 3) above shows that Lithium Iron Phosphate cathodes do not break down with the release of oxygen until much higher temperatures and when they do, much less energy is released. The reason is that the Oxygen molecules in the Phosphate material have a much stronger valence bond to the Phosphorus and thus it is more difficult to break. The other cathode chemistries are based on Lithium metal oxides

which have much weaker valence bonds binding the Oxygen to the metal and these are more easily broken to release the Oxygen.

## 2 LIFECYCLE

That batteries have a definite life is due to occurrence of the unwanted chemical or physical changes to, or the loss of, the active materials of which they are made. Otherwise they would last indefinitely. These changes are usually irreversible and they affect the electrical performance of the cell. This page describes the factors influencing battery life.

Battery life can usually only be extended by preventing or reducing the cause of the unwanted parasitic chemical effects which occur in the cells. Ways of improving battery life and hence reliability are also mentioned below.

### 2.1 Calendar Life and Cycle Life

Battery performance deteriorates over time whether the battery is used or not. This is known as "calendar fade". Performance also deteriorates with usage and this is known as "cycle fade".

Battery Calendar Life is the elapsed time before a battery becomes unusable whether it is in active use or inactive. There are two key factors influencing calendar life, namely temperature and time, and empirical evidence shows that these effects can be represented by two relatively simple mathematical dependencies. A rule of thumb derived from the Arrhenius Law describes how the rate at which a chemical reaction proceeds, doubles for every 10 degrees rise in temperature, in this case it applies to the rate at which the slow deterioration of the active chemicals increases. Similarly the  $t^{1/2}$  (or  $\sqrt{t}$ ) relationship represents how the battery internal resistance also increases with time  $t$ . The graph below illustrates these effects.

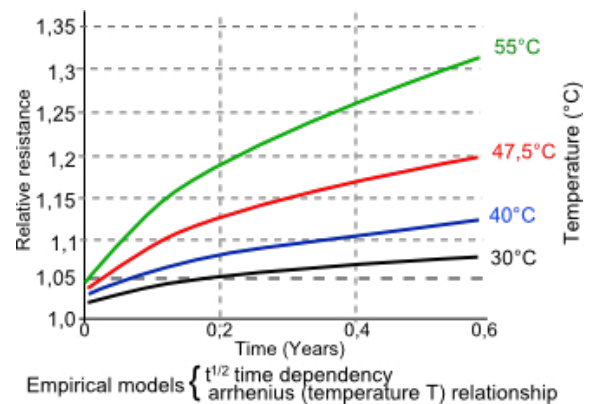


Fig. 4. Increasing Internal Resistance with Time and Temperature.

Battery Shelf Life like calendar life is the time an inactive battery can be stored before it becomes unusable, usually considered as having only 80% of its initial capacity.

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