Research Paper

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Effect of Temperature on Battery Life and Performance in Electric Vehicle

Engineering

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ABSTRACT

The performance of an electric vehicle (EV) strongly depends on the performance of its high-voltage battery pack, which is influenced by temperature. The temperature of battery systems for electrical-drive vehicles directly affects vehicle dynamic performance, long-term durability and cost of the battery systems. In cold temperatures, batteries perform poorly because of high internal resistance; The vehicle may start slowly. And at high temperature increase the rate of corrosive reaction so limiting the battery life. With reduce the temperature battery life increases and battery performance reduces gradually. The temperature variation within a cell lead to non uniform rates of battery discharge meaning that the available energy cannot be readily accessed there by reducing the driving range. So uniform temperature distribution must require in battery pack otherwise uneven temperature distribution affect the charging and discharging behaviour. In this paper, describe that how the temperature affect the charging and discharging rate, battery life and battery capacity. Here also discuss some solutions for maintain the temperature uniformity in battery pack of electric vehicle.

Introduction:

Battery temperature influences the availability of energy, discharge power (for startup and acceleration) , and charge acceptance during energy recovery from regenerative braking. Temperature also affects the life of the battery and its replacement frequency. Therefore, batteries should operate within a temperature range that is optimum for performance and life.

Chemical reactions internal to the battery are driven either by voltage or temperature. The hotter the battery, the faster chemical reactions will occur. High temperatures can thus provide increased performance, but at the same time the rate of the unwanted chemical reactions will increase resulting in a corresponding loss of battery life. Batteries function best at room temperature, and any deviation towards hot and cold changes the performance and/or longevity. Operating a battery at elevated temperatures momentarily improves performance by lowering the internal resistance and speeding up the chemical metabolism, but such a condition shortens service life if allowed to continue for a long period of time.

The shelf life and charge retention depend on the self discharge rate and self discharge is the result of an unwanted chemical reaction in the cell. Similarly adverse chemical reactions such as passivation of the electrodes, corrosion and gassing are common causes of reduced cycle life. Temperature therefore affects both the shelf life and the cycle life as well as charge retention since they are all due to chemical reactions.

When ambient temperature changes occur the electrons within the battery is affected. When an increase in temperature occurs the electrons are excited. A decrease in temperature inhibits electrons. This is a natural reaction on electrons in most systems. Furthermore, the combination of a rapid temperature change and high humidity can cause condensation to form and a potential hazard for your battery and device for that matter.

Effect of a temperature on battery:

Temperature has a direct effect on the life of a battery. The design life of the battery is based on an average annual temperature of 77-degrees F(25°C). As the temperature increases above 77-degrees F, the ability of the battery to hold greater current is increased, but, the life of the battery decreases.

For example, if a battery's design life is 10 years at 77-degrees F, but the annual average battery temperature is 95-degrees F, the life of the battery will be only 5-years, a 50% decrease.

MAXIMUM ANNUAL AVERAGE BATTERY TEMPERATURE (degrees F)	PERCENT REDUCTION IN BATTERY LIFE
77	0%
86	30%
95	50%
104	66%
113	75%
122	83%

The lead acid battery is an electrochemical device. Heat accelerates chemical activity; cold slows it down. Normal battery operating temperature is considered to be 77°F (25°C).

Higher-than-normal temperature has the following effects on a lead acid battery:

- Increases performance
- increases internal discharge
- Lowers cell voltage for a given charge current
- Raises charging current for a charge voltage
- Shortens life
- Increases water usage
- Increases maintenance requirements

Lower than normal temperatures have the opposite effects. In general, at recommended float voltage, a battery in a cool location will last longer and require less maintenance than one in a warm location.

The Arrhenius Equation:

The Arrhenius equation defines the relationship between temperature and the rate at which a chemical action proceeds in battery. It shows that the rate increases exponentially as temperature rises.

Below equation is known as Arrhenius equation.

$$k = Ae^{-\frac{E_a}{RT}} \quad or \quad ln\ k = -\frac{E_a}{RT} + ln\ A$$

Where:

- k = Chemical Reaction Rate
- A = Pre-exponential Factor
- E_a = Activation Energy
- R = Gas Constant
- T = Temperature in Kelvin

As a rule of thumb, for every 10 °C increase in temperature the reaction rate doubles.

Thus, an hour at 35 °C is equivalent in battery life to two hours at 25 °C. Heat is the enemy of the battery and as Arrhenius shows, even small increases in temperature will have a major influence on battery performance affecting both the desired and undesired chemical reactions.

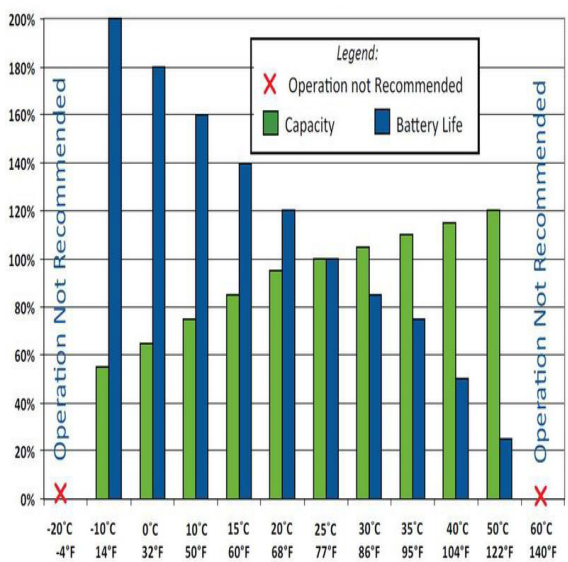
Relation between Temperature and different parameters of battery:
Different temperatures affect the internal chemical reaction rates, and internal resistance and efficiency of all types of batteries.

Charge times will vary as temperatures change:

Batteries are significantly less efficient when being charged at lower temperatures.

- Increasing as the temperature drops below 25 ˚C / 77˚ F
- Decreasing as the temperature rises above 25˚C / 77˚ F
- Battery life will vary when operated at different temperatures:
- Continued operation at higher temperatures will shorten battery life.
- Increasing as the temperature drops below 25 ˚C / 77˚ F
- Decreasing as the temperature rises above 25˚C / 77˚ F

Battery Capacity & Battery Life Compared at Different Temperatures

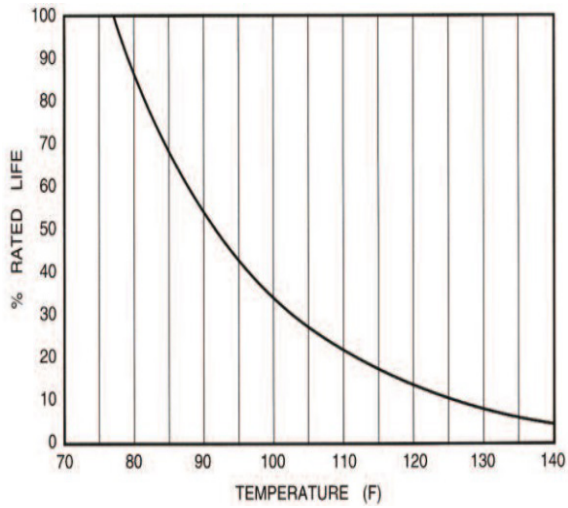


Run times will vary as temperatures change:

Batteries are significantly less efficient under heavy discharges at lower temperatures.

- Increasing as the temperature rises above 25 ˚C / 77˚ F
- Decreasing as the temperature drops below 25˚C / 77˚ F

Calculating the actual battery life at elevated temperature:
From below graph (temp. Vs. %battery life) determine the actual life of the VRLA battery operated at a constant elevated temperature.



When battery operated at a constant non temperature compensated voltage and in a n uncontrolled environment, for example the ambient temperature varies with the seasons, the actual life can be calculated considering the cumulative effect of each of the average operating temperatures and the time for which it exist during the year.

For example, a battery with a 4 years design life () operating at a 90°F would have an actual life () of 2.16 years.

(2.16 yrs = 54% × 4 yrs)

$$L_A(\text{years}) = \frac{L_D(\text{months})}{\frac{\text{Time @ T1}}{DT_1} + \frac{\text{Time @ T2}}{DT_2} + \frac{\text{Time @ T3}}{DT_3} + \frac{\text{Time @ T4}}{DT_4}}$$

Where,

. = Actual Life (years)

. = Design life (months)

Time@T1 = months at define temp.

DT1 = % rated life (from graph)

Research and development need:
The temperature is main factor that affect the battery life and performance.

For reduce this problem, there is need of research in direction of "how to maintain the temperature at optimum level"

For maintain the optimum temperature, required Battery Thermal Management System (BTMS) and also need to develop The Air Cooling arrangement in conventional electric vehicle battery pack.

Conclusion:
In this paper, gives some explanation about effect of temperature on life of battery and performance.

Here conclude that battery life is increase with decrease in battery pack temperature and performance is decrease with decrease in temperature. When temperature of battery pack is maintain between 20°C to 25°C, it's largely affect the battery life improvement. The production electric vehicles require a proper Battery Thermal Management System (BTMS) and proper air cooling arrangement to allow them operate at hot climate.

The little information is available to help a user to predict the actual service life of a battery when it is not kept at a stable temperature.

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