PKL Electrochemical Cell and the Peukert's Law

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Abstract

At lower temperature (0^0C) the electrolyte of the PKL becomes freeze. So it is not possible to use this cell, where, ambient temperatures become 0^0C and below 0^0C. At upper temperature (above 100^0C) the organic properties of PKL juice will destroy. So it will not possible to use this cell in higher temperature (above 100^0C). Here, ideal temperature for this system is room temperature and it may be from 20^0C to 40^0C. But it is also usable at a temperature range from 5^0C to 60^0C as well as other cells. The effective capacity of a cell is reduced if the cell is discharged at very high rates. This is called the capacity offset and the effect is common to most cell chemistries. Manufacturers rate the capacity of a battery with reference to a discharge time. For example, a battery might be rated at 200 AH when discharged at a rate that will fully discharge the battery in 20 hours. In this example, the discharge current would be 10 amperes. If the battery is discharged in a shorter time, with a higher current, the delivered capacity is less. This exponential relationship between the discharge current and delivered capacity is explained by Peukert's law.

Keywords: *Peukert's Law, Electrochemical Cell, PKL, Discharge Characteristics*

1. Introduction

The power delivered by cells with a sloping discharge curve falls progressively throughout the discharge cycle. This could give rise to problems for high power applications towards the end of the cycle. For low power applications which need a stable supply voltage, it may be necessary to incorporate a voltage regulator if the slope is too steep. Like other cells PKL cell also lose its power with time. Though it is not quantify yet and at this stage it is not needed so much therefore it is not done. But it shows a very interesting characteristic with time. If we keep it unused for some time its capacity regains. Therefore, it shows better result on intermittent use with some time gap. And in this way it can be used for longer time than continuous use[1-14]. In 1897 the German scientist W. Peukert expresses the capacity of a lead–acid battery in terms of the rate at which it is discharged. As the rate increases, the battery's available capacity decreases. Peukert's law can be written as:

$$t = H\left(\frac{C}{IH}\right)^k$$

Where, H = the rated discharge time (in hours).
C = the rated capacity at that discharge rate (in Ampere-hours).
I = the actual discharge current (in Amps).
K = the Peukert’s constant (dimensionless) [K normally lies between 1.1 and 1.3.].
t = the actual time to discharge the battery/Cell (in hours).
Using the above example (200AH battery with a discharge rate 20H), if the battery has a Peukert constant of 1.2 and it is discharged at a rate of 15 amperes, its rating will be

$$t = 20\left(\frac{200}{15X\,20}\right)^{1.2}$$

= 12.29 H

It would therefore dispense only 12.29 X 15 = 184 AH rather than 200.
The formula also can be rewritten as:

$$It = C\left(\frac{C}{IH}\right)^{k-1}$$

Where, *It* is the effective capacity at the discharge rate.
This formula directly provides the effective capacity in ampere hours (AH) as shown below:

$$It = 200\left(\frac{200}{15X\,20}\right)^{(1.2-1)}$$

= 184 AH

The nominal voltage of a galvanic cell is fixed by the electrochemical characteristics of the active chemicals used in the cell. The actual voltage appearing at the cell terminals at any particular time depends on the load current and the internal impedance of the cell and this also varies with the temperature, the state of charge and with the age of the cell. The fig.1 shows typical discharge curves for cells using a range of cell chemistries. The X axis shows the cell characteristics as a percentage of cell capacity. Each cell of chemistry has its own characteristic nominal voltage and discharge curve. Some chemistry such as Lithium ion have a fairly flat discharge curve while others such as Lead acid have a pronounced slope [3,15-21].

2. Pulse performance

In many cases it is required to know the ability to deliver high current pulses of batteries [6, 22-30]. The current carrying capacity of a cell depends on the effective surface area of the electrodes. The current limit is however set by the rate at which the chemical reactions occur within the cell. The chemical reaction takes place on the surface of the electrodes and the initial rate can be quite high as the chemicals close to the electrodes are transformed. Once this has occurred however, the reaction rate becomes limited by the rate at which the active chemicals on the electrode surface can be replenished by diffusion through the electrolyte. The pulse current can therefore be substantially higher than the specified rate. Pulse Performance of PKL Cell: In case of PKL cell it is also found that the cell can supply substantially higher current pulse.

3. Life cycle and deep discharge

This is one of the key cell performance parameters and gives an indication of the expected working lifetime of the cell. The cycle life is defined as the number of cycles a cell can perform before its capacity drops to 80% of its initial specified capacity. Note that the cell does not die suddenly at the end of the specified cycle life but continues its slow deterioration so that it continues to function normally except that its capacity will be significantly less than it was when it was new [8, 31-34]. Cycle life decreases with increased Depth of Discharge and many cell chemistries will not tolerate deep discharge and cells may be permanently damaged if fully discharged. Special cell constructions and chemical mixes are required to maximize the potential Depth of Discharge of deep cycle batteries [1,35-40].

4. Temperature characteristics

Cell performance of a battery or cell changes dramatically with temperature. At the lower extreme temperature the electrolyte itself may freeze setting a lower limit on the operating temperature. At the upper extreme temperature the active chemicals of cell may break down destroying the battery. In between these limits the cell performance generally improves with temperature [6, 41-43]. The effect of temperature on cell is basically the effect of temperature on electrolyte. In PKL cell electrolyte is the juice of PKL. Therefore at lower temperature (0^0C) it will freeze. So it is not possible to use this cell, where, ambient temperatures become 0^0C and below 0^0C. At upper temperature (above 100^0C) the organic properties of PKL juice will destroy. So it will not possible to use this cell in higher temperature (above 100^0C). Here, ideal temperature for this system is room temperature and it may be from 20^0C to 40^0C. But it is also usable at a temperature range from 5^0C to 60^0C as well as other cells.

5. Capacity and discharge time

Battery discharge performance depends on the load the battery has to supply. If the discharge takes place over a long period of several hours the effective capacity of the battery can be increased than the specified capacity. On the other hand if the discharge times less than one hour the effective capacity falls off dramatically [3].

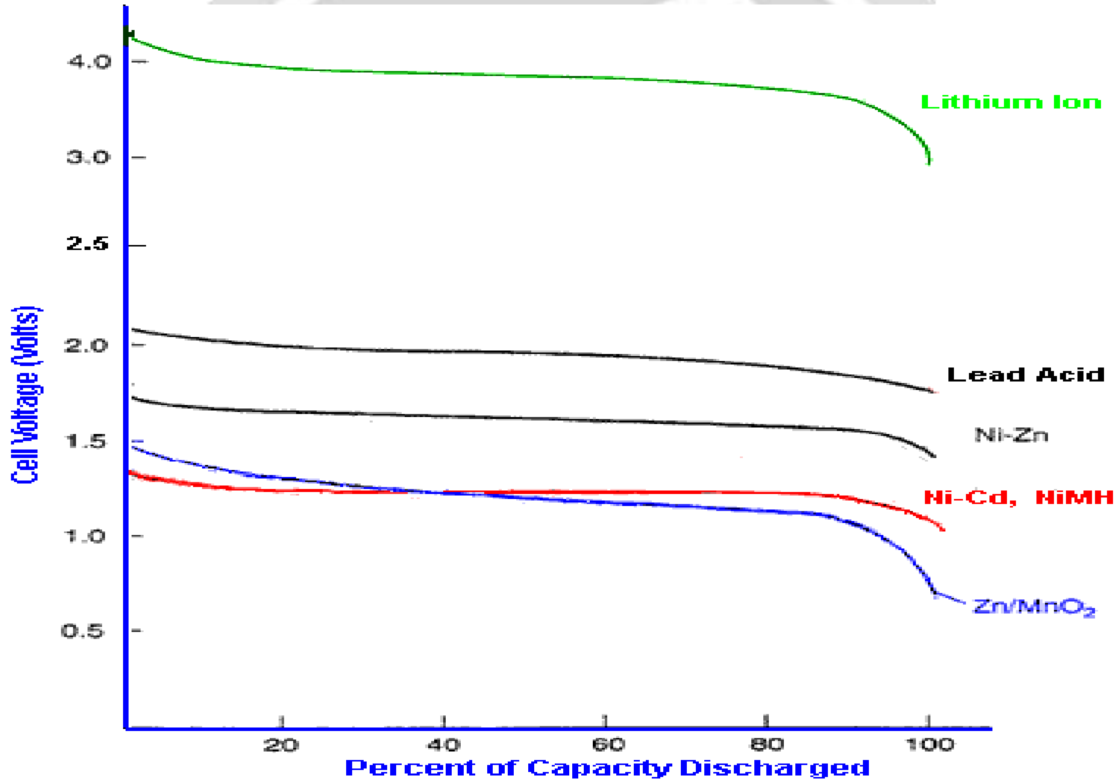

Fig.1: Typical discharge curves for cells.

The power delivered by cells with a sloping discharge curve falls progressively throughout the discharge cycle. This could give rise to problems for high power applications towards the end of the cycle. For low power applications which need a stable supply voltage, it may be necessary to incorporate a voltage regulator if the slope is too steep. A flat discharge curve simplifies the design of the application in which the battery is used since the supply voltage stays reasonably constant throughout the discharge cycle.
Capacity and Discharge Time of PKL Cell: In case of PKL cell it is also found that if we discharge the cell with a light load (50% of the source) it runs for a longer period. But for higher rate (100% of the source and above) of discharge its capacity falls dramatically.

6. Self discharge characteristics of an Electrochemical Cell

The self discharge rate is a measure of how quickly a cell will lose its energy while sitting on the shelf due to unwanted chemical actions within the cell. The rate depends on the cell chemistry and the temperature [4]. The equilibrium of the electrode reactions are normally in the discharge direction since, thermodynamically, the discharged state is more stable. The rate of self-discharge (loss of capacity [charge] when no external load is applied) of the lead acid cell is fairly rapid, but it can be reduced significantly by incorporating certain design features [3].

The following [5] shows the typical shelf life for some primary cells:

1. Zinc Carbon (Leclanché) 2 to 3 years
2. Alkaline 5 years
3. Lithium 10 years or more

Typical self discharge rates for common rechargeable cells are as follows: [5]

1. Lead Acid 4% to 6% per month
2. Nickel Cadmium 10% per month
3. Nickel Metal Hydride 30% per month
4. Lithium 5% to 10% per month
5. NiMH batteries 1.25% per month

The fig.2 below shows typical self discharge rates for a Lithium Ion battery [2]:

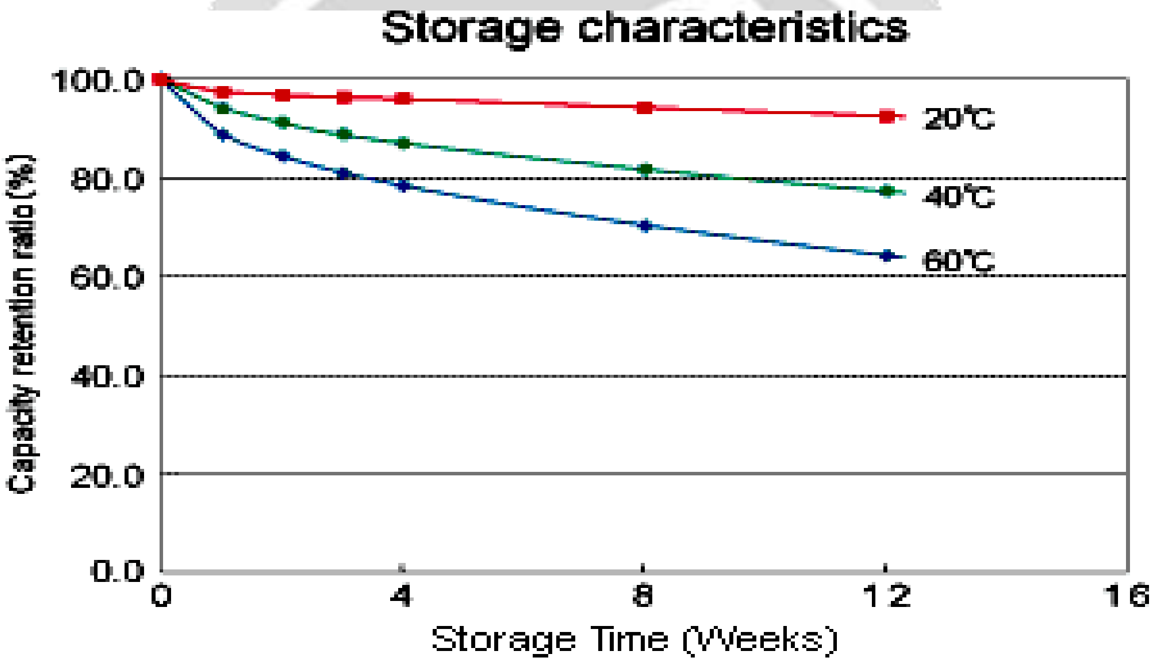

Fig.2: Typical self discharge rates for a Lithium Ion battery.

7. Self Discharge Characteristics of PKL Cell:

Like other cells PKL cell also lose its power with time. Though it is not quantify yet and at this stage it is not needed so much therefore it is not done. But it shows a very interesting characteristic with time. If we keep it unused for some time its capacity regains. Therefore, it shows better result on intermittent use with some time gap. And in this way it can be used for longer time than continuous use.

8. Discharge characteristics of PKL cell

To measure the discharge characteristics of PKL cell a module of PKL was taken. It considered as 6 volts PKL system. We connected a constant incandescent lamp load of 6 volts. The arrangement of measuring is shown in fig.3. For simplicity we show the PKL system as a unit cell.

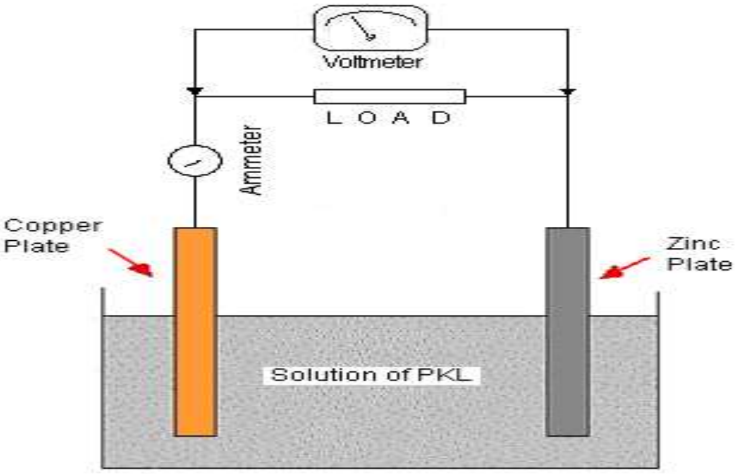

Fig.3: Arrangement of measuring discharge characteristics.

We observed the voltage and current as listed below in table1. We continue the taking the load test 120 minutes i.e. 3 hours from beginning. It may be pointed out here that initially when we connected the load a substantial voltage drop occurs and this drop is 0.48 Volts which is around 8% of system voltage. We also show a column for power drawn by the load in the table multiplying voltage and current.

9. Results and discussion

It is described here, the current voltage relationship of the PKL power system.

Table 1: Voltage and Current of PKL module under load condition.

Time t (minutes)	Load Voltage V (Volt)	Load Current I (Ampere)	Power W (Watt)
0	5.52	0.76	4.2
5	5.51	0.75	4.1
10	5.51	0.74	4.1
15	5.50	0.73	4.0
20	5.50	0.72	4.0
25	5.50	0.71	3.9
30	5.49	0.70	3.8
35	5.49	0.69	3.8
40	5.48	0.68	3.7
45	5.46	0.67	3.7
50	5.45	0.66	3.6
55	5.45	0.65	3.5
60	5.44	0.64	3.5
65	5.43	0.63	3.4
70	5.41	0.62	3.4
75	5.39	0.61	3.3
80	5.37	0.60	3.2
85	5.35	0.58	3.1
90	5.32	0.56	3.0

95	5.30	0.54	2.9
100	5.27	0.52	2.7
105	5.25	0.48	2.5
110	5.23	0.48	2.5
115	5.20	0.46	2.4
120	5.18	0.44	2.3

Based on the observed result we plot three characteristics of PKL cell. These are for voltage, current and power graph for the load. All these are on same time frame. These graphical representation show how voltage, current and power changes with time.
Fig. 4 shows the Variation of voltage with the variation of time

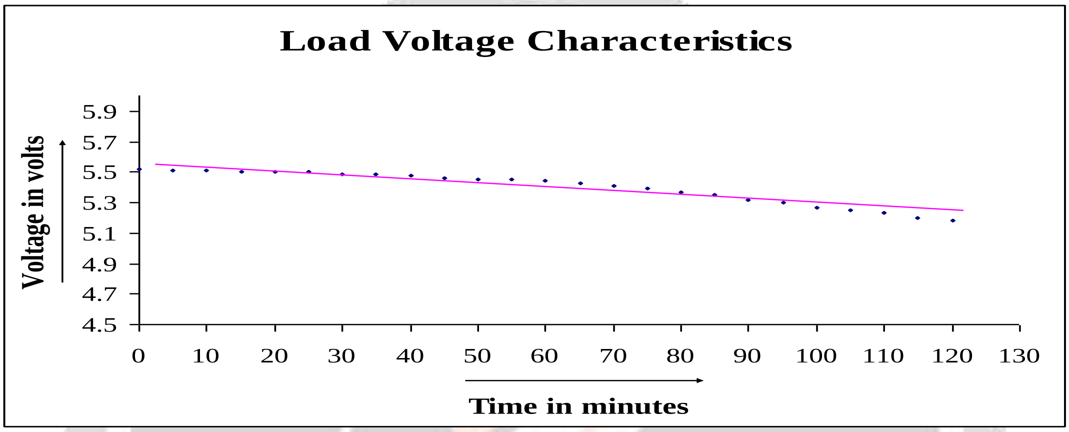

Fig.4: Variation of voltage with the variation of time

As per this graph it is seen that the voltage is reducing gradually as time passes. If we compare it with other cells we find this change is relatively rapid. Fig. 5 shows the current versus time graph for the same system.

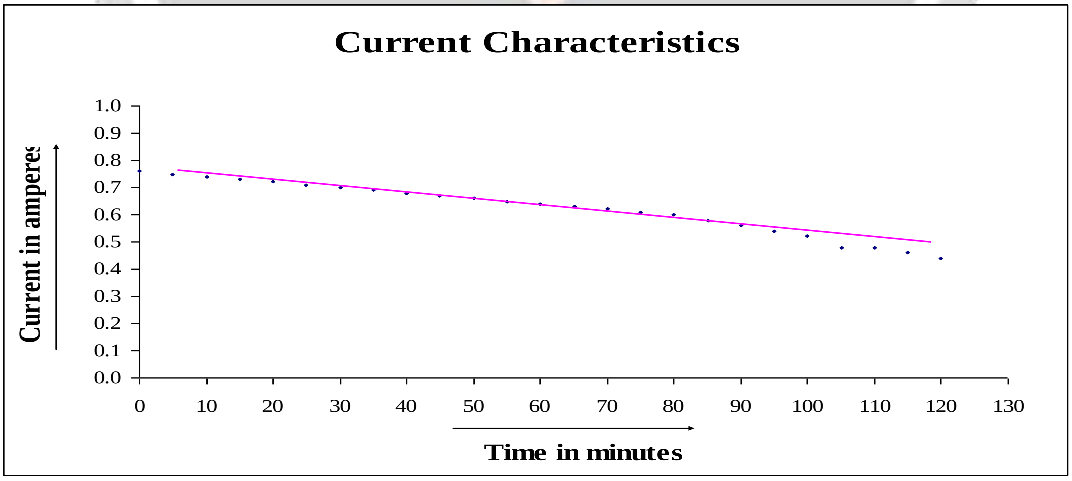

Fig. 5: Variation of current with the variation of time

As per this graph it is seen that the load current is reducing gradually as time passes. If we compare it with other cells we find this change is relatively rapid. Fig.6 shows the power versus time graph for the same system.

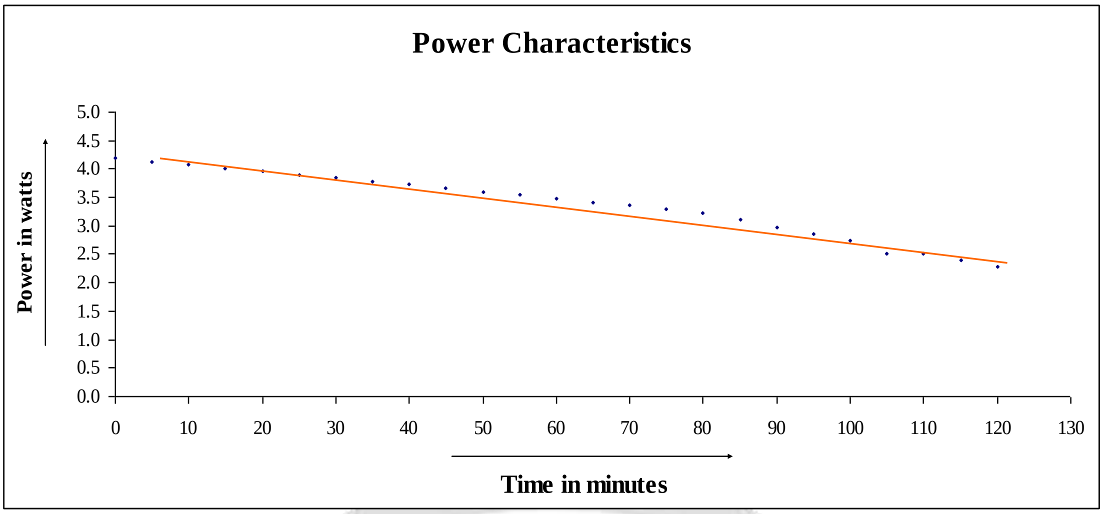

Fig. 6: Variation of power with the variation of time

We know power is the product of voltage and current. i.e. Power, P = V × I Watts, Where, V = Voltage (in volts), I = Current (in Ampere).Since voltage and current are reducing with time therefore as per this graph it is seen that the load power is also reducing gradually as time passes. For a sustainable system this going down process shall be lower.

10. Conclusions

It has been shown that, the Cycle Life and Deep Discharge Characteristics of PKL Cell: PKL cell is a very simple cell. Here there is no complex construction. Just a zinc plate and a copper plate are sunk in PKL juice. It is zinc-copper based cell and completely a renewable source. It is not subjected to charge. So there is nothing to think the charging of this cell. The PKL cell is based on Voltaic or Galvanic Cell. That is why it can be called so called Voltaic or Galvanic Cell or Quasi Voltaic or Galvanic Cell. We can regain the capacity of the cell by the following ways: (1) By adding the PKL extract or juice after some regular time interval (2) By changing the PKL juice after some regular time interval (3) By cleaning the plates after some regular time interval. When we do these activities the cell gets back its full life again. Every time we can get the PKL juice from our field and the plates are usable unless it is completely dissolved (only Zinc plate) or become unusable. So this is a very important characteristic of the PKL cell which will make it useable for the poor people.

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