

Prismatic Li-Ion Cell for Unmanned Aircraft

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ABSTRACT

Saft is working on advanced 28V Li-ion batteries for use in NAVY unmanned aircraft applications. This battery employs seven (7) prismatic state-of-the art Li-ion cells connected in series. The battery needs to be less than 40lbs in weight and 600 in³ in volume. This paper presents the performance results of the new prismatic cell. This development is pioneering new technological territories for SAFT since the PL55E cell is the first prismatic cell developed and delivered by SAFT America [1]. The experience gained will be useful and the PL55E cell will be followed by more prismatic cells added to the SAFT Li-ion portfolio. The presentation will give an overall status update of the technology as well as a brief overview of the complete 28V battery.

INTRODUCTION

In the last couple of years SAFT has been developing a prismatic cell (PL55E) to be used in 28V batteries for unmanned aerial vehicles. The new cell employs standard SAFT chemistry based on a doped nickel oxide positive electrode, graphitic anode and low temperature electrolyte. SAFT has optimized the cell electrodes for the specific needs of this aircraft application. Key requirements driving this effort include energy and power available at low temperature, overall battery energy content and peak power, cycle life as well as chemistry stability after exposures at elevated temperature. All these features are strengths of the Ni based chemistry, which Saft has been using in its Li-ion batteries for over 10 years [2, 3].

TABLE 1

Parameter	Requirement	Actual
Capacity at 4.0V	> 55Ah	58Ah
Capacity at 4.1V	Not req.	64Ah
Weight	Not spec.	1.51Kg
Gravimetric Energy Density	>110Wh/Kg	134Wh/Kg
AC Impedance	Not spec.	0.65mΩ
Impedance (2 sec)	Not spec.	0.81mΩ

As Table 1 shows the cell delivers 58Ah at beginning of life (the specification requires 55Ah at end of life). It is capable of 500A continuous discharge and over 1500A in pulse current. The cell has stacked electrodes with bussing tailored to handle large currents as well as mechanical loads. The electrodes are enclosed in hermetically laser welded 304 stainless steel hardware, which employs a novel terminal feed through design. The PL55E cell is 5.44 in x 5.71 in x 1.36 in, Figure 1. The cell also includes a vent for safety. PL55E cells have been tested under the UN Transportation Vibration profile as well as under the UN external short circuit test and passed.



Figure 1: PL55E cell and the 28V battery.

Development goals for the electrochemical performance included meeting capacity and power requirements for the aircraft application and extending both storage and operational temperature range with little impact on performance and life. More specifically meeting power requirements at -40°C is combined with improving high temperature stability of up to 72°C (with a desired long term goal of 85°C). These are mutually exclusive requirements which are difficult to meet. Additionally achieving a low self-discharge for the new cell was critical in order to meet storage and low maintenance requirement of the application.

LOW TEMPERATURE PERFORMANCE

An important aspect of performance requirements for this aircraft battery is power delivery at low temperature. In order to evaluate the progress in this effort Saft used its standard electrode design as the baseline. Preliminary testing was conducted in cylindrical cells containing both the baseline as well as the modified chemistry. After developing the electrodes with improved chemistry a more comprehensive comparison was performed in the prismatic cell format.

Low temperature power is mostly a function of the positive electrode although the negative electrode and the electrolyte also have certain contributions. Several major changes were implemented to the electrodes.

- 1) The positive electrode for the PL55E cell was tailored for low temperature performance by modifying the morphology of the electrode design. This meant optimizing the conductive network of the electrode, revisiting the binder type and content, refining the electrode manufacturing process parameters, etc.
- 2) In addition, the loading of both electrodes was increased significantly in order to meet the capacity requirements. It might seem that this change is countering the impact of the first change; however, the ultimate design goal was meeting both capacity and low temperature requirement. Without this change, the baseline design would have met low temperature specifications but not provided the capacity needed by the applications.
- 3) Lastly the PL55E electrodes were matched to 4.1V. This means that the cell can be also used in any application requiring End of Charge (EOC) Voltage of 4.1V. Figure 2 shows the capacity of PL55E at the C rate when discharged from 4.0V and from 4.1V, respectively. Going to the higher EOC voltage produces about 9% more capacity.

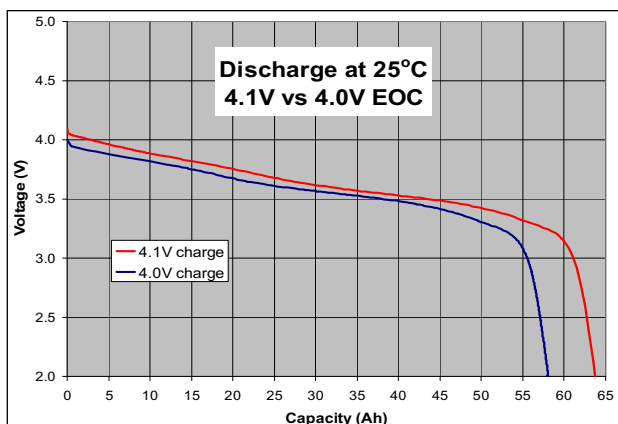


Figure 2: Capacity at 4.1V vs. capacity at 4.0V end of charge voltage

Saft conducted testing in the prismatic cell format to study the effect of the modifications to the electrode. Figure 3 compares the performance of the improved electrochemistry with the baseline. Capacity verification was performed at several rates; C/2 rate (30A), C-rate (60A), and 2C rate (130A). Capacities in Ah are the solid lines and cell temperatures in degrees Celsius are the dotted lines. Initial testing was done at 25°C. The capacity of the improved electrode design is measured to be about 20% more, however, since 9% is attributed to EOC voltage increase, the benefit really is about 11%.

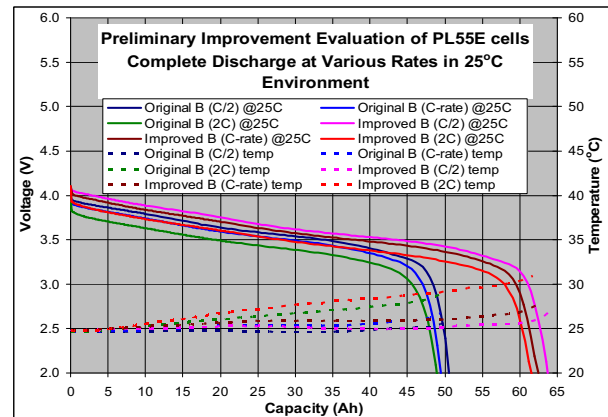


Figure 3: Continuous Discharges @25°C

The same testing was performed at low temperatures. Figures 4 and 5 show the voltage profiles and capacity of the PL55E cells at -20°C and at -40°C, respectively. At the lower temperatures the initial voltage drop for both baseline and improved electrodes is very similar. In this case, the improvement for low temperature (Change 1) is countered by the heavier loading in the new design. Thick electrodes by default have higher impedance due to diffusion limitations. However, as expected, the discharge capacity measured at all of the rates is higher for the improved cells (circled in red) over the baseline (circled in blue) cells.

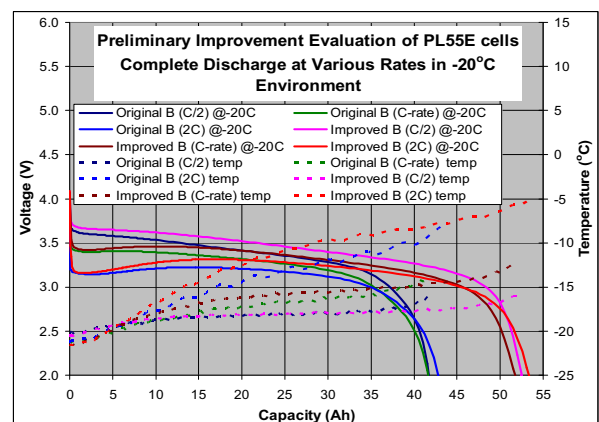


Figure 4: Continuous Discharges @ -20°C