TOWARDS REDUCED NICKEL-CADMIUM BATTERY COST FOR MICRO SATELLITES

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ABSTRACT

This paper presents the two Nickel-Cadmium technologies offered by Saft for satellites applications : the space-qualified VOS prismatic cells designed for long term LEO and GEO missions, and the VRE cylindrical cell devoted to launcher activities and to short life LEO missions for mini and micro satellites. It also details Saft's effort to minimize the cost for these cells - in strict compliance with customer 's specification and without any changes to the existing product manufacturing process.

BACKGROUND

Saft began its experience in batteries for space in the 1960's with Nickel-Cadmium cells. The low capacity cylindrical cells (VRE) were first qualified for space missions, then the prismatic range (VOS) was developped and qualified in the 1970's.

Saft has equipped in orbit more than 20 mini and micro satellites with VRE cells, and more than 60 spacecraft have flown with VOS cells without any operational failure.

In January 1994 Saft purchased Gates Aerospace Batteries in Florida. Both companies teamed their expertise and extensive knowledge of the space programs. The production of NiCd cells using Gates technology will be discontinued by the end of 1994 : all industrial efforts will be put on the proven Saft VOS cell design.

THE VOS NICD CELL

The Cell Range

Each VOS NiCd prismatic cell consists in a stack of positive and negative electrodes, a non woven felt separator and 31 % KOH electrolyte ; the cell case and the cover are hermetically sealed by TIG welding. The cover is equipped with two terminals fitted with ceramic-to-metal positive and negative seals.

The range in current production comprises cells with a nameplate capacity from 7 to 40 Ah. A 50 Ah cell is being currently evaluated.
There are no development or industrialization costs are necessary when ordering these cells, unless the customer requests specific marking, terminal tabs , tests...

Saft stores its NiCd cells in an impregnated state and has demonstrated up to 10 years of NiCd impregnated storage without a loss of capacity or any impact on life duration. Cells can be stored at customer's facility and reconditionned with only two capacity cycles.

A Rationalized production

Saft has developped a rationalized production tool with two plants. The Bordeaux plant specializes in electrode manufacturing for aerospace activities. The French government issued no cadmium ban regulation for its industries. The Poitiers space facility specializes in the production of cells and batteries.

Repeated investments have enabled a current production capability of more than 1,200 NiCd cells per year. In order to reduce costs, batch campaigns are organized for cells with the same capacity, but in strict respect of each customer's specification.

Manufacturing instructions are regularly updated and improved with the benefits and remarks from the last campaigns.

Saft aims to reduce costs linked to non-quality and attrition by using the AQAP-1 quality system and has undertaken to be compliant with ISO 9001 requirements by the end of 1994.

The cost reduction approach

The typical LEO satellite mission requires five years' lifetime, an electrical constraint to charge the battery in a timespan of 60 to 70 minutes, and a Depth of Discharge range of 20 to 30% of the cell nameplate capacity.

This low DOD leaves a wide margin between the capacity requirement and the actual cell capacity.

This opens room for four possible cost-reduction axes. These options are not implemented today in the standard production process but can be introduced on customer's request :

1- assembling cells from different batches (LEO missions):

To obtain a given number of matched cells to be assembled in batteries, the cell quantities in one batch take attrition rates into account. Usually 10 to 20% of the matched cells are not assembled - even if declared good for flight use. They are stored without a possibility to be assembled for flight battery. Cell prices include a part of the attrition rates. Thus cell cost could be reduced as much as 20% should the customer accept to assemble cells from different manufacturing batches in flight models.

These cells being already manufactured, activated and tested, this option enables a drastic decrease of leadtimes and hardware costs.
Some customers already ordered off-the-shelf cells to be assembled as Engineering Models during the qualification phase.

Moreover, Saft demonstrated that the cells show no performance degradation after long storage periods in an activated state. Two years' LEO cycling performed on cells stored for 10 years gave similar performances to those of " fresh " cells cycled just after their manufacturing.

The risk of available cell capacity divergence is not critical owing to the large margin between the cell actual capacity and the requested capacity for the mission : 70% of excess capacity in average. This can be avoided by selecting only cells presenting the same EOC and EOD voltages before battery assembly.

2- battery assembly with standard components :

A battery cost reduction can be expected by purchasing electrical components according to MIL-STD specifications instead of High-Reliability components, especially for heaters and connectors.

3- lighter electrical testing for LEO missions :

A matching test is performed on each batch of cells before battery assembly. This test includes cycling with LEO or GEO requirements according to the battery mission. The cells are selected within the batch with a maximum capacity range of **Erreur! Signet non défini.** 3 %.

The criteria of the available capacity homogeneity is extremely critical in the cell selection for GEO missions due to the high DOD. For LEO missions, the battery cell capacity dispersion is not critical. A possible cost reduction option is the removal of the capacity matching test for LEO cells.

4- no thermal vacuum on batteries :

Battery electrical performances are identical at atmospheric pressure and in vacuum. Thermal vacuum testing is extremely expensive in terms of manpower and equipment. This cost can be spared during battery acceptance testing by removing the test and replacing it by electrical testing at atmospheric pressure. This option is being currently exercised on European programs.

TOWARDS REDUCED NON-RECURRING COSTS : THE NICD BATTERY CONCEPT

The battery concept

A concept of recurring NiCd battery was developped and qualified for the Spot observation program. The succesful design was adapted to the next Spot spacecraft with minimized development effort and cost. Strong of this experience, Saft proposed the Spot design for other programs.

Altogether more than 100 batteries have been delivered or are to be manufactured with this concept for the following programs : SPOT , ERS, HELIOS and ENVISAT, RADARSAT and GPS.

The NiCd battery concept relies on proven rules for the mechanical and thermal design of the battery.

- The mechanical design consists in two symetrical rows of cells connected in series with tin soldered connections. The cells are held in compression by two rigid endplates secured with two tie-bars. Two rails fasten the collectors and the endplates at their base onto the heat rejection plate with bolts.The cells are electrically insulated from the supporting structure.

- The thermal management of the battery is assured by the use of both thermal collectors and heaters. The thermal collectors are inserted between adjacent cells; they transfer excess of heat generated by the cells to the heat radiator mounted on the spacecarft. The heaters are located on the thermal collectors and are controlled by thermostats or thermistors. Thermistors are glued on the upper part of the thermal collectors.

The Radarsat battery development

The development of the Radarsat battery is a good example of clever cost-reduction without performance-reduction. Ball Aerospace required high quality products but encouraged any cost-saving relevant options from their subcontractors.

For the battery, Ball chose Saft's concept : the design of the 22VOS40 Radarsat battery is identical to that of Spot 4 minus two cells. Ball privileged proven performance to a long and costly development.

When the project began, a matrix identified the compliance of the existing battery design with the Radarsat procurement specification and presented the delta of qualification to be performed. Ball agreed on a volontary reduction of tests and studies but not on risk and performance reduction.

The mechanical and thermal design of the battery were justified by similarity and by modelling. Expected results were extrapolated from the Spot 4 battery development and Saft extensive experience in the manufacturing of Nickel-Cadmium cells and batteries.

Complete electrical, thermal and mechanical tests are performed on Flight Models.

TOWARDS REDUCED CELL COSTS : THE VRE NICD CELLS

Another example of Saft approach towards cost reduction is the offer of a low-cost, high-quality cylindrical cell for short-life LEO applications.

A Low-Cost Commercial Approach

The VRE cell is the ideal candidate cell for low-cost LEO space applications : cylindrical cells usually cost about eight times less than prismatic cells.

This range also offers short procurement lead times : standard cells can be delivered within 6 months and standard batteries within nine months.

Cell Design

Each VRE cylindrical cell consists of one negative and positive wound electrode; the cell case and cover are hermetically sealed by TIG welding. The cells are equipped with one ceramic positive terminal. The positive terminal is equipped with tabs to allow the welding of cells in series.

During their development in the 1960's the cells sustained qualification levels for missile and launcher applications with a high shock and vibration spectrum.

Differences with Commercial Cells

The VRE cells have been designed to sustain the launch phase and operate in a space environment. Major improvements introduced in their design have led to excellent mechanical properties :

- the cells are hermetically sealed with a TIG-welded ceramic cover to sustain operations in vacuum.

- the electrode spool is blocked by insulating and blocking rings to sustain high acceleration and vibration level during the launch phase.

The VRE manufacturing process also considers the requirements of a space mission.

- the cells are electically tested and selected to be matched into batteries. They are also acceptance tested as per the NASA voltage recovery specification. For battery assembly, the cells undergo a careful selection to ensure compatible capacity and voltage performance : the maximum allowed capacity divergeance is ± 5 % within one battery.

- the cylindrical cells VRE production benefits from the same environment as the prismatic VOS : dedicated teams used to space environment specificity, stringent quality requirements, configuration management, product assurance and project management support.

A Rationalized production

Saft has developped a rationalized production tool with two plants. The Nersac plant specializes in electrode manufacturing for portble NiCd activities. The Poitiers space facility specializes in the production of cells and batteries with these plates.

The current production capability is more than 10,000 NiCd VRE cells per year. This potential can be increased without major investments or delays.

In order to reduce costs, batch campaigns are organized for cells with the same capacity, but in strict respect of each customer's specification. One manufacturing batch can total up to 300 cells.

Flight Experience

The VRE cylindrical cell traditionally was Saft's space cell before prismatic VOS was developed and qualified. These cells have equipped more than 20 mini and micro satellites which have flown without any failure.

More than 65 Ariane rockets have been launched without any operational failure. Ariane 5, which first launch is scheduled in 1995, will also rely on these cells. The X-Sar satellite, launched in April 1994 aboard the Space Shuttle, is powered with Saft 1.6 Ah- VRE batteries.

Mission requirements

The range in current production comprises cells with a nameplate capacity from 1 to 6 AH. It answer to the requirements of mini or micro satellites for LEO missions up to 2 years ; the usual Depth of Discharge is comprised between 20 % and 30 %.

A life test cycling with VRE cells carried out in Saft laboratory has demonstrated more than 11,000 cycles : Ten 6 Ah-cells are being currently cycled at 15% DOD and ten 3.5 Ah-cells with a 26 % DOD; see Fig. 2. This cycling is still running without any failure or significant capacity decrease.

The battery offer

Saft also proposes batteries with VRE cells with minor recurring costs. The existing design consists in cells connected in series mounted between flanges and maintained by four tie-rods.

The designs currently available are 24, 25 and 26-cell packs. Other epoxy batteries have been also designed for missile applications with 12, 22, 23 and 24-cell packs.

CONCLUSION

This paper has described the rationale and efforts performed by Saft in an attempt to reduce costs implied by the development and manufacturing of NiCd cells and batteries. This effort proved very succesful in the case of the Radarsat battery development with prismatic VOS cells. For mini and microsatellite applications, the VRE cylindrical cell offers the ideal balance between price, performance and mission duration.

ACKNOWLEDGEMENTS

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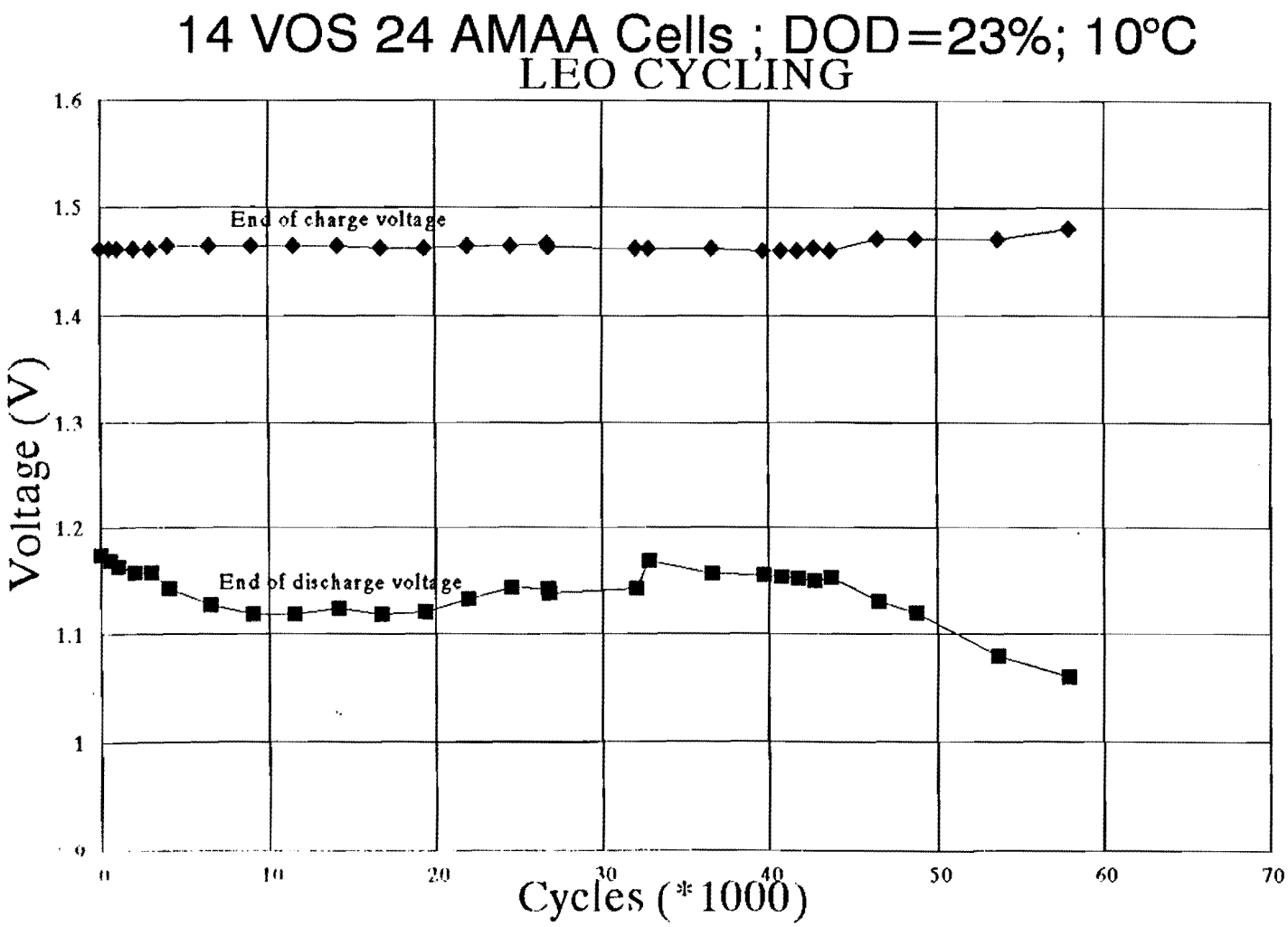
FIGURE 1: VOS CELL PERFORMANCE

SAFT		SPACE ACTIVITIES
NICD CELLS	ESA X80	LOW EARTH ORBIT CYCLING



SAFT TEST N°50

Discharge:
35mn at 5.5A

Charge:
current tapering

Noreconditioning

As per June 93

No cell removed
Cycling still
running

FIGURE 3: VRE CELL PERFORMANCE CAPACITY VS. TEMPERATURE

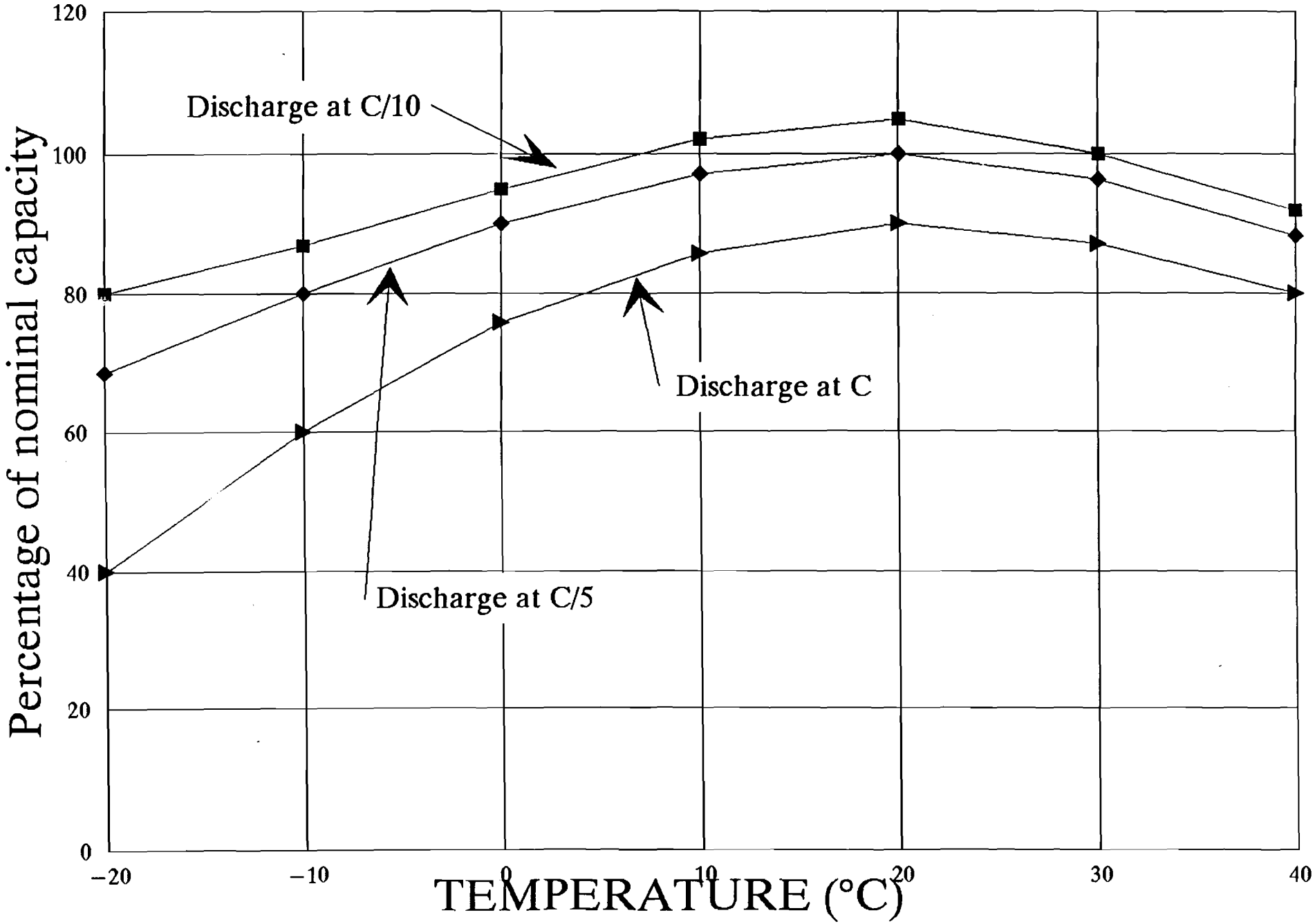
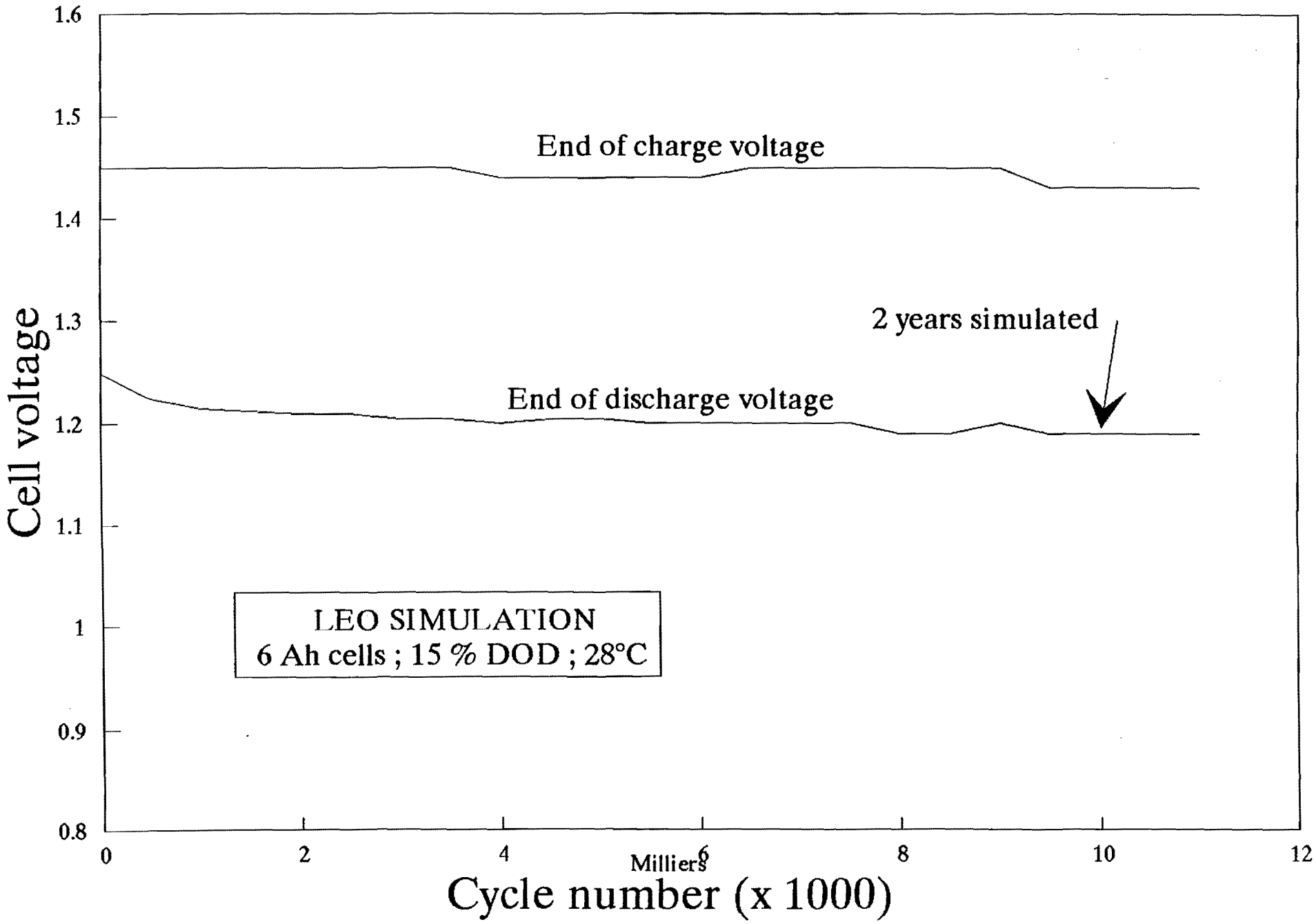



FIGURE 2: VRE CELL CYCLING END OF DISCHARGE VOLTAGE VS. LIFE