

## Comparison of Positive Grid Alloys for Standby Lead Acid Batteries

Allan J. Williamson  
Manager Product Test Laboratory

John H. Kim  
Senior Technical Account Manager

C&D Technologies, Inc. Blue Bell, PA

### **Abstract:**

There are two families of alloys generally employed in the manufacture of industrial lead-acid batteries. This paper discusses the significant performance and maintenance characteristics and life implications of each alloy.

### **Introduction:**

Alloys currently used in the lead-acid battery industry fall into two main classifications: antimony and calcium. For the purposes of this paper the following alloy types were tested: 5% lead antimony (PbSb), 1.6% lead antimony selenium (PbSbSe), and 0.03% lead calcium (PbCa).

Use of antimony in the positive grid, in the range of 2 to 5 %, dates back to 1881 and was originally added to the positive grid melt to achieve rigidity (1) despite concerns about dissolved antimony in the form of  $Sb_2O_3$ , being re-deposited at the negative plate thus increasing local action (2). Concentrations as high as 11% have been observed in tubular batteries used in Standby applications. It was also recognized that antimony had a lower hydrogen overvoltage than lead, which would promote increased gassing and water loss in service (3). Typical applications now utilize between 4 – 12 % antimony (4) with a growing trend toward low antimony, <3%, alloys. Cycle testing has shown a beneficial effect of antimony because of its cohesive influence on the structure of the positive active material. Presently, the antimony alloys are primarily used in folk lift and car batteries.

Low antimony selenium alloys, marketed as “lead-selenium battery”, are considered a subset of the antimonial group. This alloy came into usage in the early 1980’s and has achieved popularity in Europe. Product offerings typically include either 2.8% or 1.6 % antimony. Binary low antimony alloys are difficult to cast and produce a large grain structure with resultant cracking and increased corrosion hence the addition of 0.02% selenium to act as a grain refiner. Ostensible benefits include lower self-discharge and float currents than antimony alloys while maintaining the ability to cycle.

The need for improved maintenance characteristics promoted the development of the lead calcium alloy by Haring and Thomas in 1935 (5). The lead-calcium alloy cell types first saw operation in the Bell system in the early 1950’s. These alloys feature a low self-discharge rate, low float currents, low gassing rate and longer life than lead-antimony and lead-selenium alloys. The lead-calcium alloys dominate the “standby power market” because of these reasons. As a side note, the low float current and low gassing rate characteristics of lead-calcium alloys led to the use in VRLA products. Presently, all of VRLA batteries use lead-calcium alloys for these reasons. The drawback is passivation at the active material to grid interface in binary calcium alloys may result in premature capacity loss (PCL) when used in cyclic operations such as folk lift and engine start applications.

### **Experimental:**

The test routine consists of the following variables: open circuit stand loss testing, tafel testing and accelerated life testing

#### **Open Circuit Stand Test:**

An open circuit stand test to determine the rate of stand loss on open circuit of the PbCa, PbSb and PbSbSe cells was performed. Following the recharge from a baseline measured capacity discharge; the cells are brought to a full state of charge and placed on open circuit. After a suitable period without any charge return, the measured capacity discharge is then

repeated with the difference in capacity attributed to self-discharge. The self-discharge is then calculated from the capacity loss and time on stand and expressed as self-discharge rate/month.

**Tafel Testing:**

A Tafel line from the as built condition was run on the PbCa, PbSb and PbSbSe cells. The Tafel line will be repeated at the conclusion of accelerated life testing to denote any change in the float characteristics.

**Accelerated Life Testing:**

Following baseline capacity testing four cells each of PbCa, PbSb and PbSbSe, were placed on float charge per the manufacturer’s recommendations and life tested at 140° F (60°C). During the aging procedure cell voltage and float current are collected on a daily basis. The cells are removed from the hotroom at 84 day intervals, or approximately every 3 years at ambient per Telcordia acceleration factors, and the measured capacity discharge is repeated. Discharge testing methodology follows IEEE-450-2002 guidelines.

**Results and Discussion:**

The main prerequisites and generally accepted requirements of modern industrial standby batteries are:

- Self discharge characteristics
- Stable float characteristics
- Longevity - the ability to deliver design life and capacity retention

**Self-Discharge:**

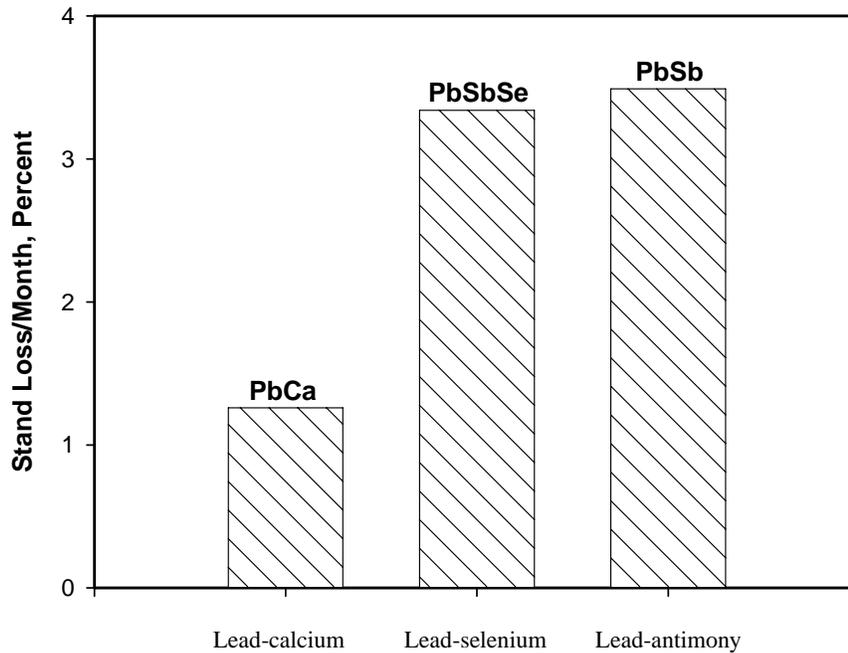
Self-discharge is defined as the ability of a cell to retain some portion of its capacity under specified conditions of temperature, usually 77°F, after it has been stored for a period of time without being charged (normally expressed as a percentage of rated capacity). This is important since it determines how long the batteries can be stored without suffering permanent damages. The quicker batteries self discharge, the user must pay more attention to these batteries by providing them with freshening charge sooner and often. It is generally stated that lead-calcium products can be stored at 77F on open circuit up to 6 months where as lead-antimonial alloy’s storage time is 3 months. On new batteries it is usually ascribed to the local action occurring at the plates, between the active material and grid metal. Table 1 shows the results of the fully charged capacity tests, capacity after stand loss testing, time on test and the rate of self-discharge per month. The self-discharge rate is graphically displayed in Figure 1.

The tested stand loss rate for the lead-calcium cells was 1.26%, which is in good agreement with the commonly accepted rate of 1% self-discharge rate per month. The results for the antimonial alloys (lead-antimony and lead-selenium) are nearly identical. This showed that lead-selenium alloys behave similar to lead-antimony alloys when it came to self discharge characteristics.

<b>Table 1</b>			
	<b>PbCa</b>	<b>PbSbSe</b>	<b>PbSb</b>
Initial Capacity	108.9%	110.6%	104.3%
Capacity after Stand Test	104.7%	95.9%	97.9%
Percent Difference	4.2%	14.7%	6.4%
Days on Test	100	132	55
Self-discharge Rate/Month	1.26%	3.34%	3.49%

The entire open circuit stand test will be repeated at the conclusion of accelerated life testing to determine stand losses as a function of battery age and to ascertain the effect of antimony transfer.

**Figure 1: As Built Self-Discharge Rate of Various Alloys**



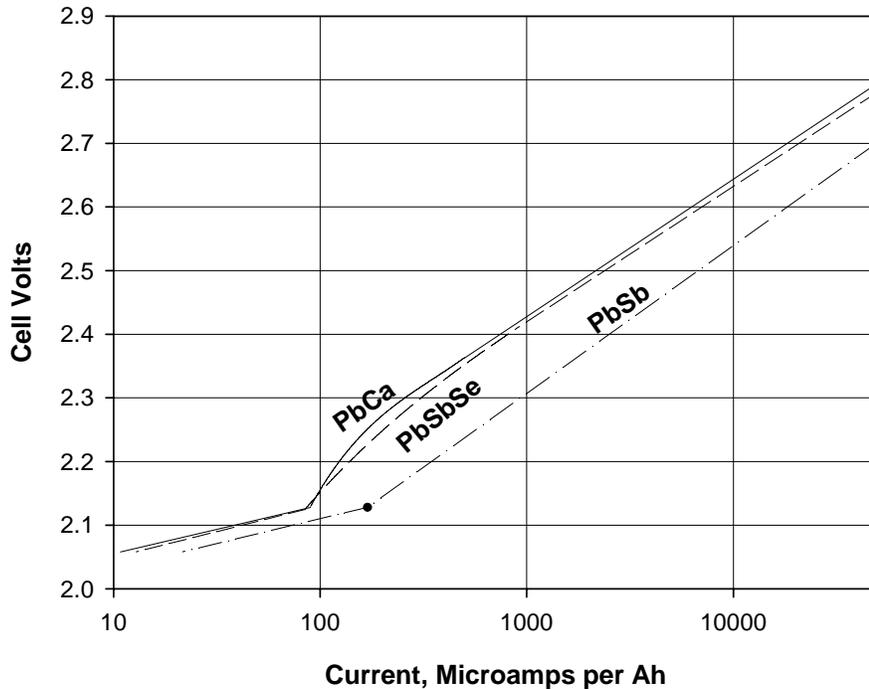
**Float Characterisitics:**

The purpose of float is to maintain the cell in a fully charged state by offsetting any internal losses that occur as a result of self-discharge and to maintain the positive plate polarization voltage at a level that minimizes growth and corrosion characteristics. As such, the grid alloying elements play a major role in determining the float current drawn by any particular cell type.

Tafel testing on the cells shows the float current for the lead calcium batteries to be the lowest of the three alloys tested, followed somewhat closely by the lead antimony selenium cells and lastly by the antimony alloy. Float current values are summarized in Table 2 and graphically depicted in Figure 2.

<b>Table 2</b>	
<b>Cell Type</b>	<b>Float Current, <math>\mu</math>Amps/Ah</b>
Lead Calcium	130
Lead Antimony/Selenium	175
Lead Antimony	225

**Figure 2: Comparison of Cell Voltage vs Charging Current**



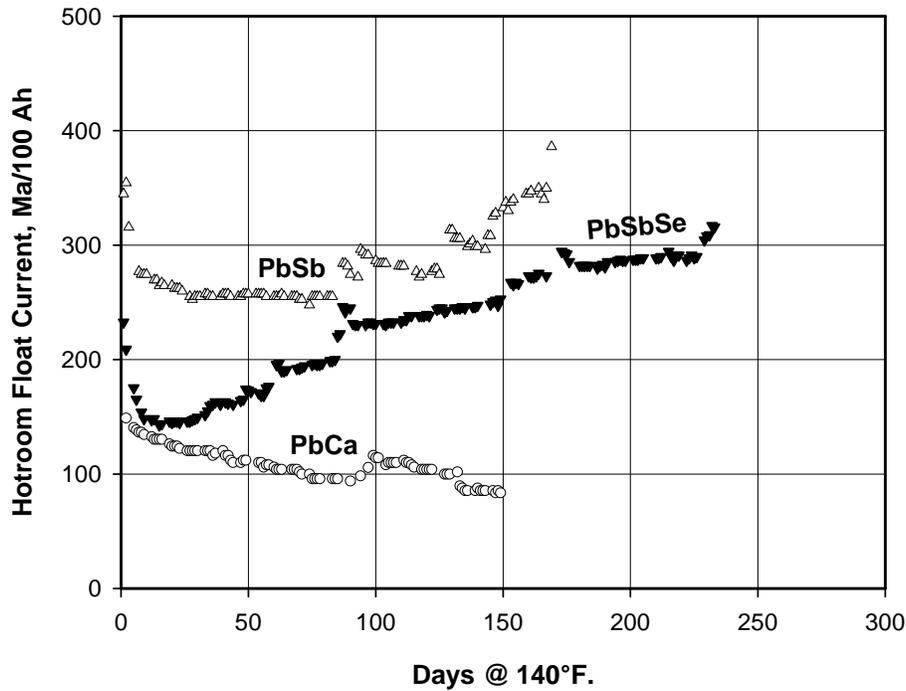
The relatively low as built float current of the lead antimony selenium alloy often invites proponents to claim the float characteristics of lead calcium alloy. As we shall see from examination of the float currents recorded during accelerated life testing that comparison is overstated.

During accelerated life testing at 140°F cell voltages and float current on all cell types was monitored on a continuous basis as presented in Figure 3. The calcium cells exhibit the lowest float current, which is still decreasing after almost 150 days on test, the result of the lessening effect of platinum depolarizer additive. Since there is no poisoning of the negative plate from antimony transfer, the float current for the lead calcium cells is expected to remain low for the remainder of the test period (7).

Both the antimony and low antimony selenium cells show symptoms of antimony transfer. After an initial dip, the float current on the low antimony selenium cells continually rises and after 230 days (~ 8 years) is double its lowest value seen at the beginning of the life test, over 300 ma/100 Ah or over 3 times greater than the value for an equivalent lead-calcium cell for the same period on float. This type of float behavior, strongly mimicking a traditional lead-antimony cell makes it difficult to understand how acceleration factors for lead-calcium alloy can be used for computing life at 77°F on lead antimony selenium alloy during an accelerated life test (8). The antimony cells had the highest initial float current, 250 ma/100 Ah, which remained stable for three years. The current then increases to 350 ma/100 Ah after six years equivalent time at ambient temperature.

The higher float current will lead to more gassing and frequent watering interval. The typical lead-selenium cell designs have taken faster water loss into account by providing additional watering space between the high and low level lines, which makes the jars taller. High gassing rate will result in higher hydrogen vented from cells. The provisions must be made to account for this.

Figure 3: Hotroom Float Currents @ 140°F.



**Longevity:**

Accelerated life testing at 140°F. (60°C) was started on cells built with PbCa, PbSb and PbSbSe alloy. Life testing is still in its infancy and thus it is premature to draw any firm conclusions. All cell types show stable capacity at this juncture. Testing of these samples is still ongoing and will be updated in a future paper.

The accelerated life test was used to collect float current data for reporting on the float characteristics of the various cell types.

An additional accelerated life test has been recently started for the purpose of determining water consumption characteristics. Results will be reported in a future paper.

**Conclusion:**

Data from Stand testing and float current monitored during accelerated life testing suggest there are no fundamental performance differences between lead-selenium (PbSbSe) and lead-antimony (PbSb).

*References:*

1. E.J. Wade, *Secondary Batteries: Their Theory, Construction And Use*, p 291 (1902)
2. *L'Eclairage Electrique*, Vol. XVI., p.133, July 23, (1893)
3. G.W. Vinal, *Storage batteries*, p 142 (1955)
4. H. Bode, *Lead-Acid Batteries*, p 209 (1977)
5. G.W. Vinal, *Storage Batteries*, p 19 (1955)
6. Rand, Mosely, Garche and Parker, *Valve-Regulated Lead-Acid batteries*, p 26 (2004)
7. F.F. Ohntrup, *Lead Antimony or Lead-Calcium? Selecting a Standby Battery*, Reprint from *Plant Engineering* (1974)
8. Rusch, W, Vassallo, K, Hart, H. "Flooded, sealed, flat plate, tubular plate: How does the end user decide on the best solution? BATTCOON 2006