



GS Yuasa *HT X Alloy™*

Developed For High Temperature Long Life Applications

For VRLA batteries, industry generally defines four typical life failure mechanisms.

1. Positive Grid Growth
2. Thermal Runaway
3. Dry Out
4. Post Leak

This document describes GS Yuasa's proprietary *HT X Alloy™* proven to inhibit positive grid growth and, therefore lengthen service life in high temperature applications.

There are three key design attributes of GS Yuasa's *HT X Alloy™*.

1. GS Yuasa's Proprietary Low Corrosion Rate Positive Grid Alloy
2. Reinforced Grid Perimeter
3. "X" Minimization

- **Positive Grid Growth Failure Mechanism Explained**

Positive grid growth occurs over the battery's life when the grids deform due to grid boundary corrosion and is accelerated by high temperatures. The deformation causes gaps between the active material which decreases the battery's ability to supply power. This failure mechanism is shown in **Figure 1** below.

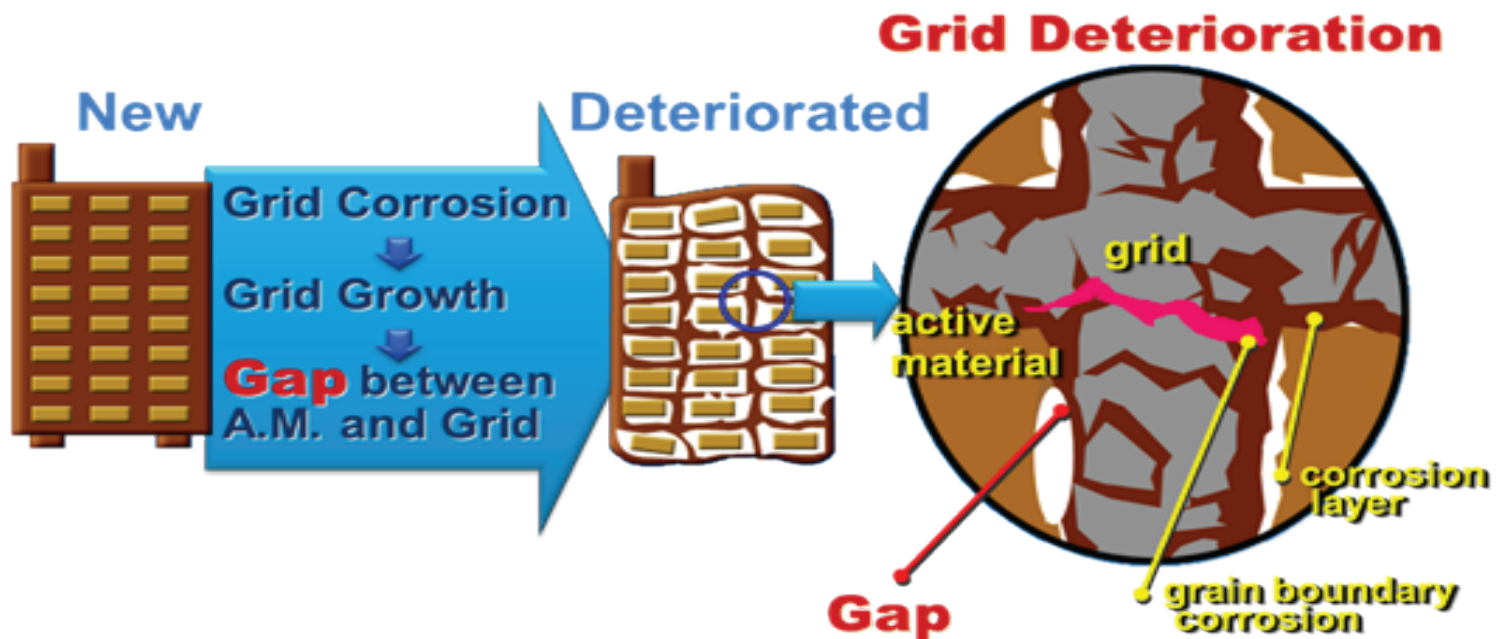


Figure 1

- **GS Yuasa Low Corrosion Rate Positive Grid Alloy**

GS Yuasa starts with primary (non-recycled) lead as the basis for its Low Corrosion Rate Positive Grid Alloy. The alloy contains extremely low amounts of tin and calcium. GS Yuasa developed this grid alloy over 20 years ago. Refer to **Figure 2**.

Low Corrosion Rate Positive Grid Alloy

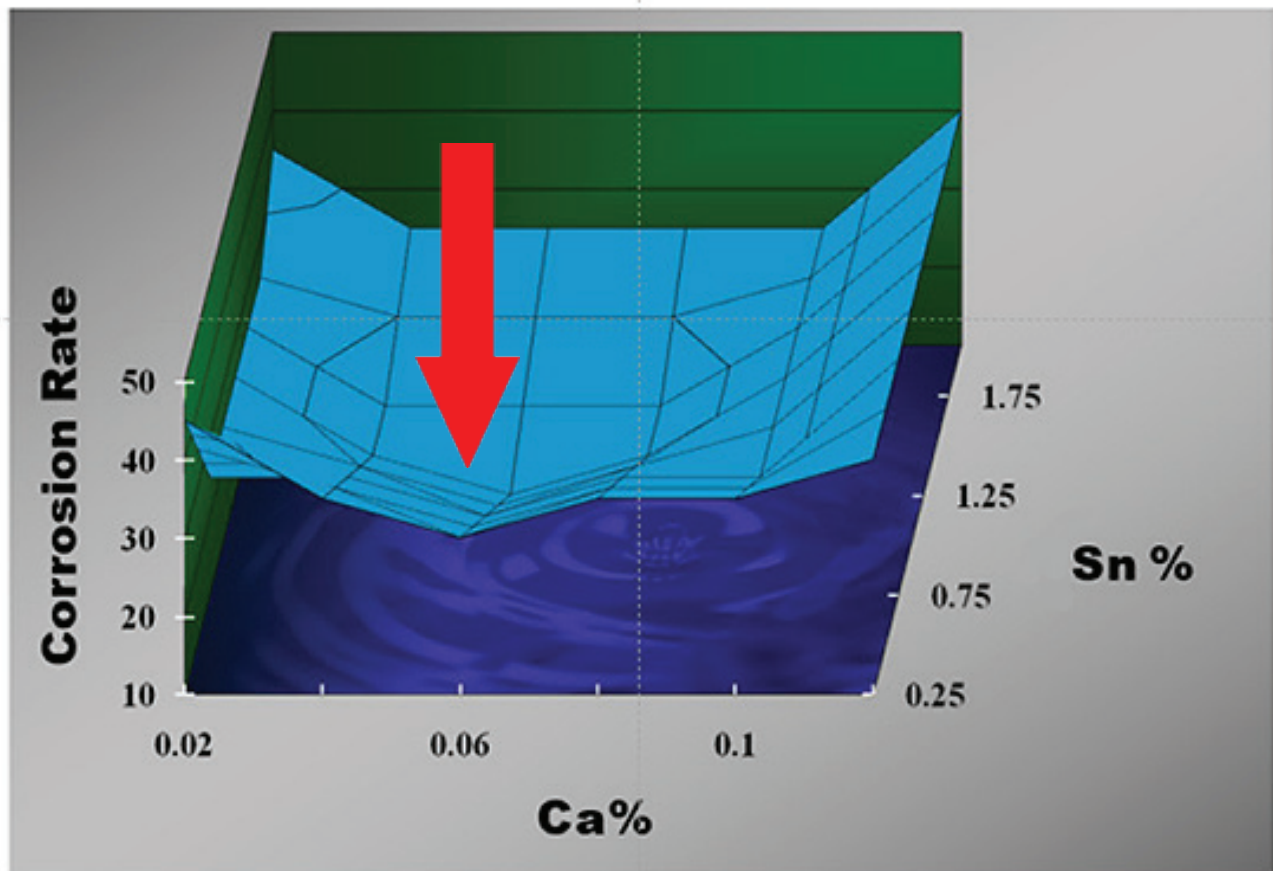


Figure 2

- **Reinforced Grid Design**

As a countermeasure against grid deformation, GS Yuasa uses a thick vertical outer perimeter in the grid design. This strong, thick grid deforms at a slower rate and extends life. This grid design is highlighted in **Figures 3 and 4**.

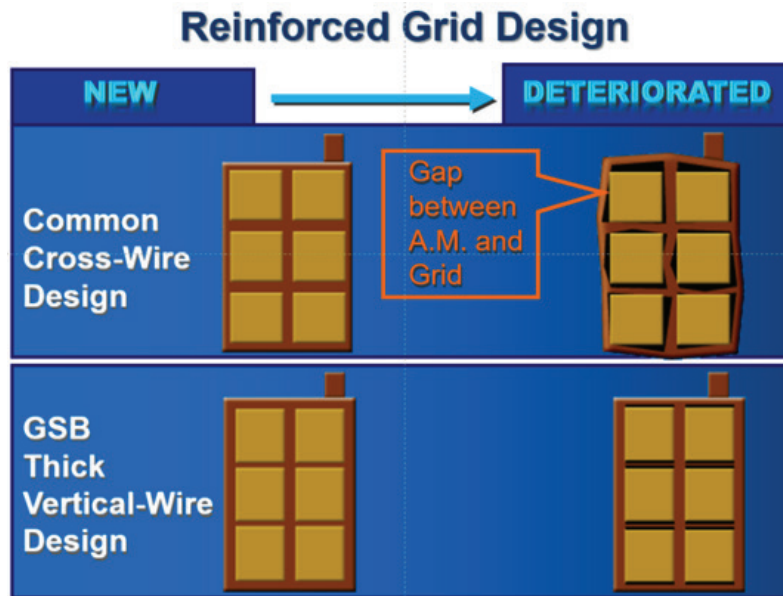


Figure 3

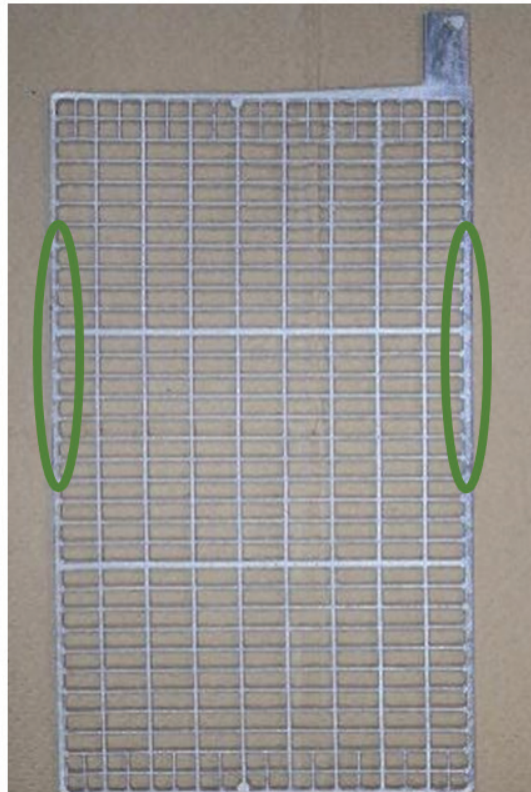


Figure 4

- “X” Minimization and GS Yuasa’s **HT X Alloy™**

Approximately ten years ago GS Yuasa identified a breakthrough that would enhance the Low Corrosion Rate Alloy. All purchased lead for battery manufacturing contains trace amounts of impurities. GS Yuasa conforms to the JIS specification for electrolytic industrial batteries which requires 99.99% purity. GS Yuasa Technology Department’s research identified a specific that, even in miniscule amounts, significantly accelerates positive grid corrosion. This is referred to as “X”. Miniscule amounts of “X” degrade battery life. Using advanced analytical techniques, GS Yuasa’s proprietary lead procurement specifications impose strict PPB limits on the amount of the “X” impurity in purchased lead. All GS Yuasa stationary products, including the **GS Yuasa Energy Solutions’ PWL and PYL High Temperature Long Life Batteries** incorporate our **HT X Alloy™**.

Figure 5 illustrates the benefit of “X” Minimization in GS Yuasa’s **HT X Alloy™**.

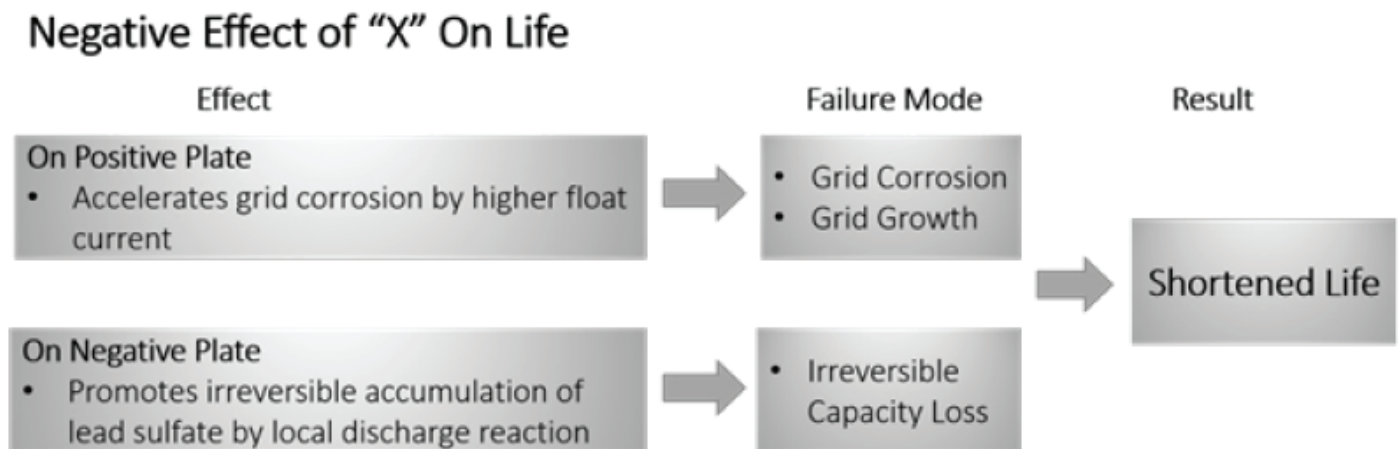


Figure 5

Figure 6 Illustrates the relationship between “X” and float life.

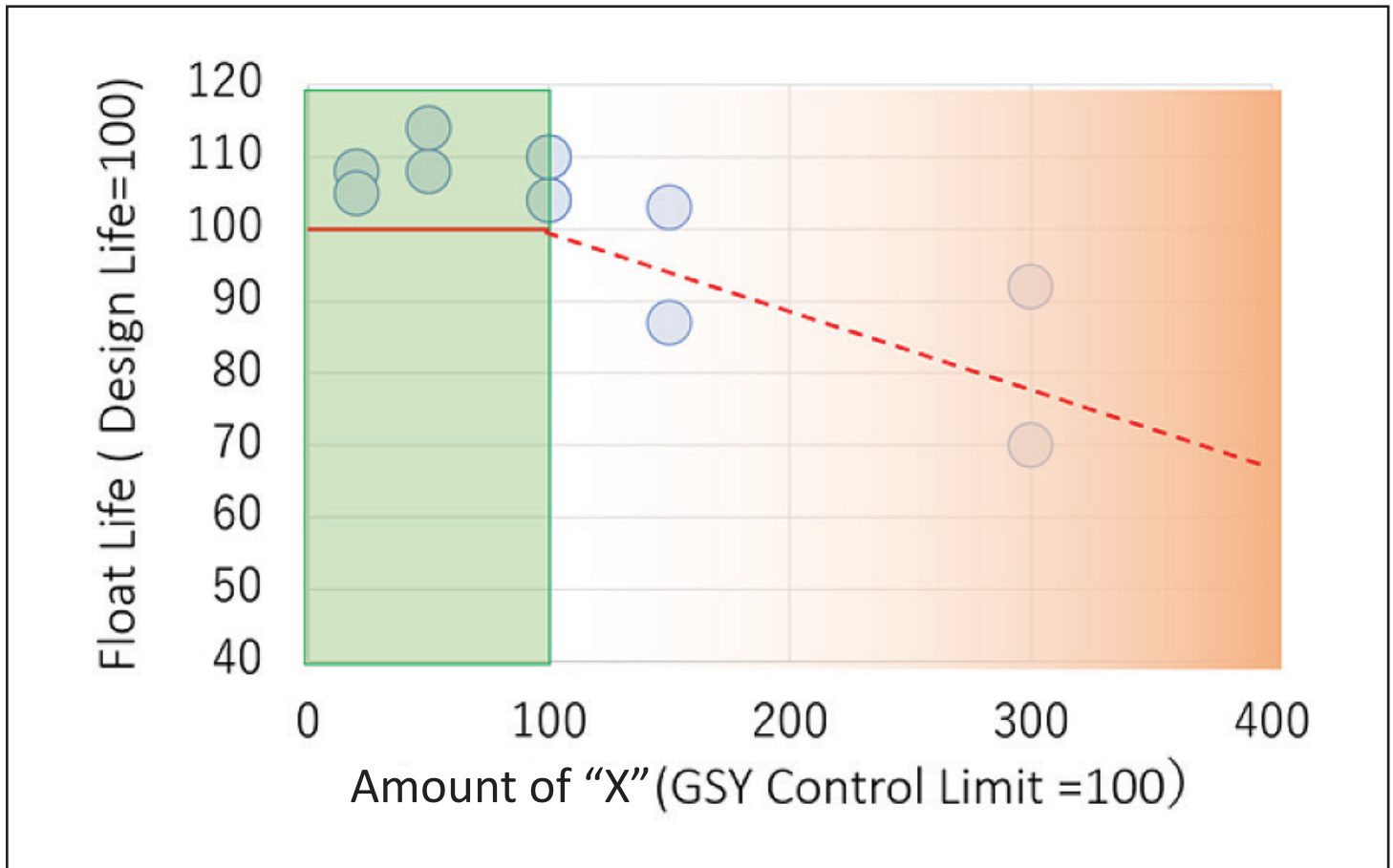


Figure 6

As previously discussed, GS Yuasa adheres to the Japanese Industrial Standard for lead which requires 99.99% lead purity or, conversely, only allows **0.01% impurity**. Additionally, GS Yuasa's proprietary lead specification limits the amount of "X" to a PPB level. The relative scale of the allowable amount of "X" compared to the standard's allowable amounts of impurities Fe and Bi are illustrated in **Figure 7**.

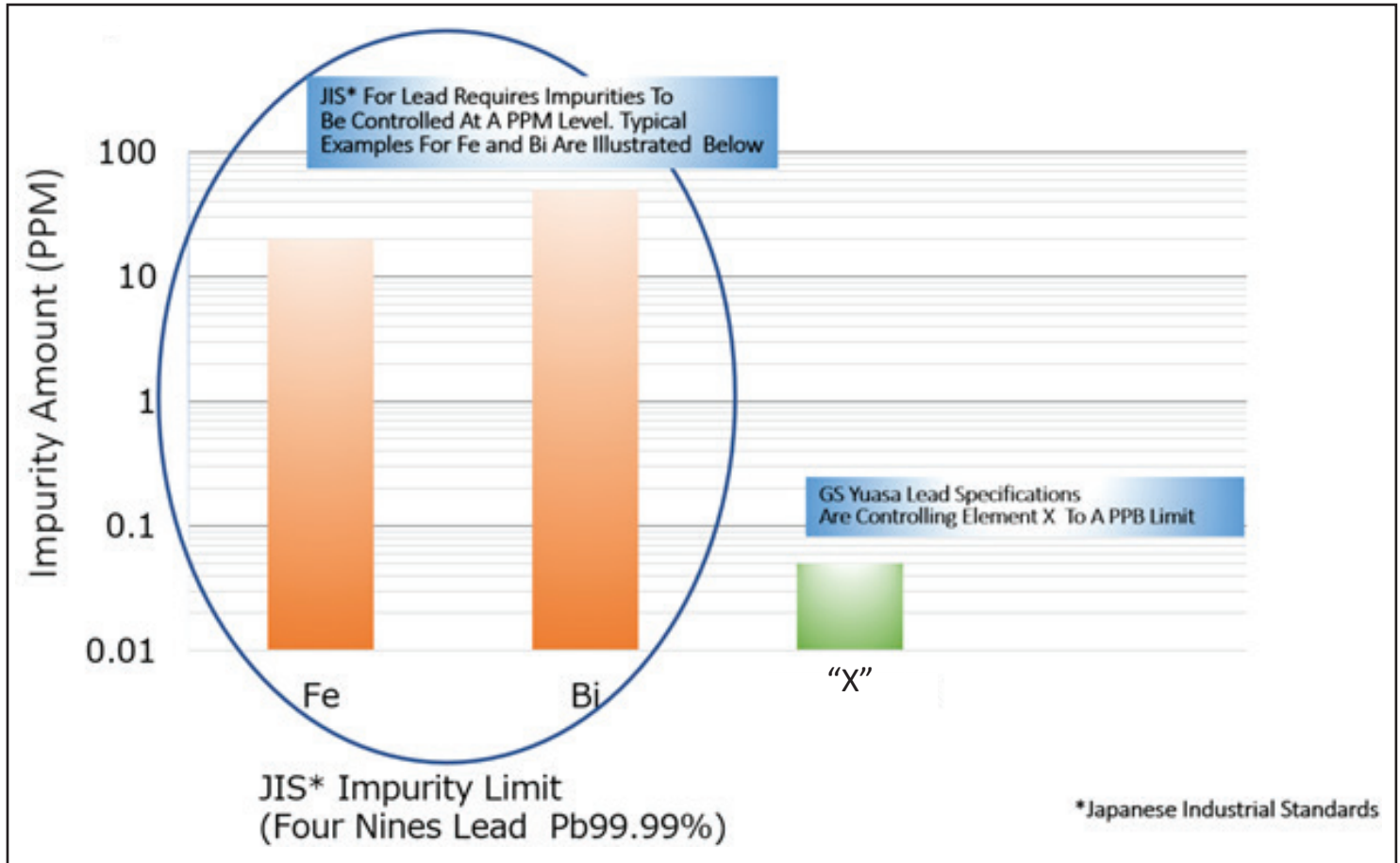


Figure 7

Figure 8 Illustrates the amount of “X” identified in analysis of competitive products. The analysis indicates that “X” is not controlled and typically exceeds GS Yuasa’s specification.

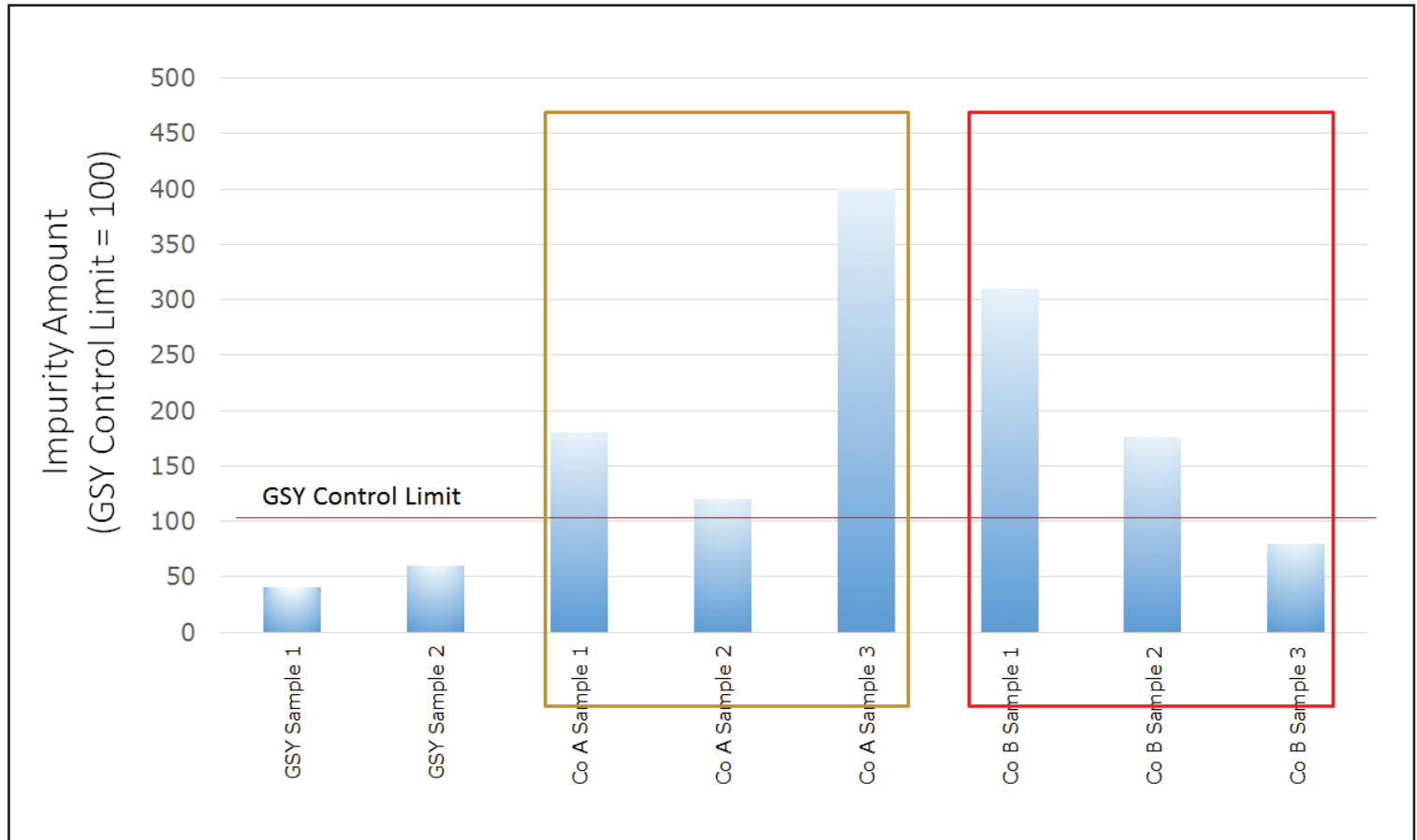


Figure 8

Figure 9 Compares the inconsistent float life performance of a competitive product where “X” is not controlled with the consistent float life performance of GS Yuasa product.

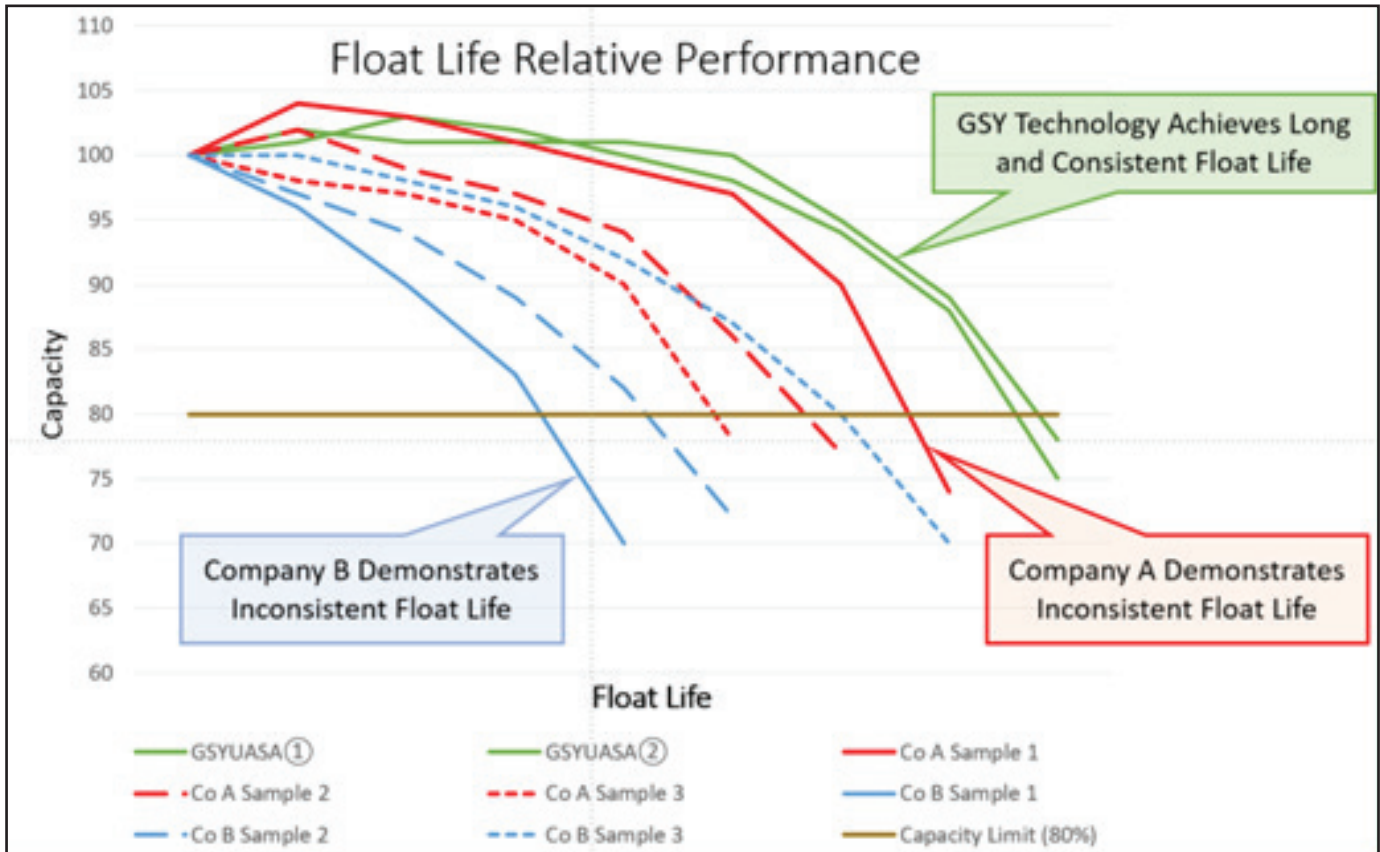


Figure 9

GS Yuasa has performed accelerated life testing on several competing products advertised as “*long life and/or high temperature*”. Those test results are provided in **Figure 10** and are contrasted with Telcordia service life testing of the GS Yuasa Energy Solutions’ PWL and PYL High Temperature 12V VRLA products. This competitive benchmarking clearly demonstrates the superior performance of *GS Yuasa Energy Solutions’ PWL and PYL High Temperature Long Life Products*.

<i>Manufacturer</i>	<i>Description</i>	<i>Technology</i>	<i>Test Start Date</i>	<i>Design Life Spec.</i>	<i>Accelerated Life Test Results</i>	<i>Source of Data</i>
Company 1	12V145Ah	Cast Grid, Catalyst	2016	10 Years @ 35°C	2.7 Yrs. @ 35°C	GS Yuasa
Company 1	2V1520Ah	Cast Grid, Catalyst	2016	20 Yrs. @ 25°C	5.5 Yrs. @ 25°C	GS Yuasa
Company 2	2V1500A	Cast Grid	2016	20 Yrs. @ 25°C	6.7 Yrs. @ 25°C	GS Yuasa
Company 3	12V190Ah	TPPL	2015	20 Yrs. @ 25°C	1.7 Yrs. @ 25°C	GS Yuasa
Company 4	12V190Ah	TPPL	2015	10+ Years @ 25°C	6.7Years @ 25°C	GS Yuasa
GS Yuasa GS Yuasa Energy Solutions	12V155Ah	<i>HT X Alloy™</i>	2015	13+ Years @ 25°C	13.5 Yrs. @ 25°C	Telcordia
GS Yuasa GS Yuasa Energy Solutions	12V185Ah	<i>HT X Alloy™</i>	2015	10+ Years @ 25°C	11.5 Yrs. @ 25°C	Telcordia

Figure 10

- **HT X Alloy™ Summary**

Positive Grid Growth is one of four typical life failure mechanisms. GS Yuasa addresses this failure mechanism and delivers long life performance in high temperature applications with three key design features.

1. **Low Corrosion Rate Pb Ca Sn Alloy**—This alloy utilizes 99.99% pure lead combined with low amounts of calcium as a stiffener and tin to inhibit corrosion at high temperatures. This alloy has been utilized in GS Yuasa long life products for over 20 years.
2. **Reinforced Grid Outer Perimeter**—GS Yuasa products incorporate a stronger outer perimeter around the grid to minimize grid deformation as the product naturally deteriorates over time. By limiting deformation, gaps between the active material and grid and grain boundary are minimized which maintains capacity as the grid deforms.
3. **“X” Minimization**—An and lead impurity, “X”, even in minuscule amounts, has been proven to accelerate positive grid growth. GS Yuasa’s proprietary lead procurement specification controls “X” to the PPB range. Minimizing “X” reduces positive grid growth in high temperature applications and has a secondary benefit of increasing shelf life. “X” Minimization has been utilized in GS Yuasa products for over ten years.



- ***HT X Alloy™ Corroborating Field Studies***

GS Yuasa Energy Solutions has partnered with customers to conduct numerous monitored site trials over the years validating our PWL and PYL products' performance. Recently a trial by a Tier One Carrier and their independent consulting engineer found the GS Yuasa Energy Solutions' PYL High Temperature Long Life product to provide best in class performance among five manufacturers' "high temperature" products.

- ***Conclusion***

The GS Yuasa Energy Solutions' PWL and PYL families have been deployed in high temperature uncontrolled environments for 18 years and have proven to deliver best in class performance. The trial data corroborate the effectiveness of GS Yuasa's ***HT X Alloy™*** as well as our countermeasures for Thermal Runaway, Dry Out and Post Leaks.

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ABOUT GS YUASA ENERGY SOLUTIONS, INC.

GS Yuasa Energy Solutions, Inc. is an American subsidiary of GS Yuasa Corporation, the world's second largest battery company and a 100+ year old Japanese corporation. GS Yuasa Energy Solutions (GYES) was formed in 2019 to address the growing energy storage and reserve power markets. GYES brings together and leverages GS Yuasa Group's advanced technologies with proven American market successes in lithium, telecom, UPS, alarm & security, and energy storage into a single business unit.



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