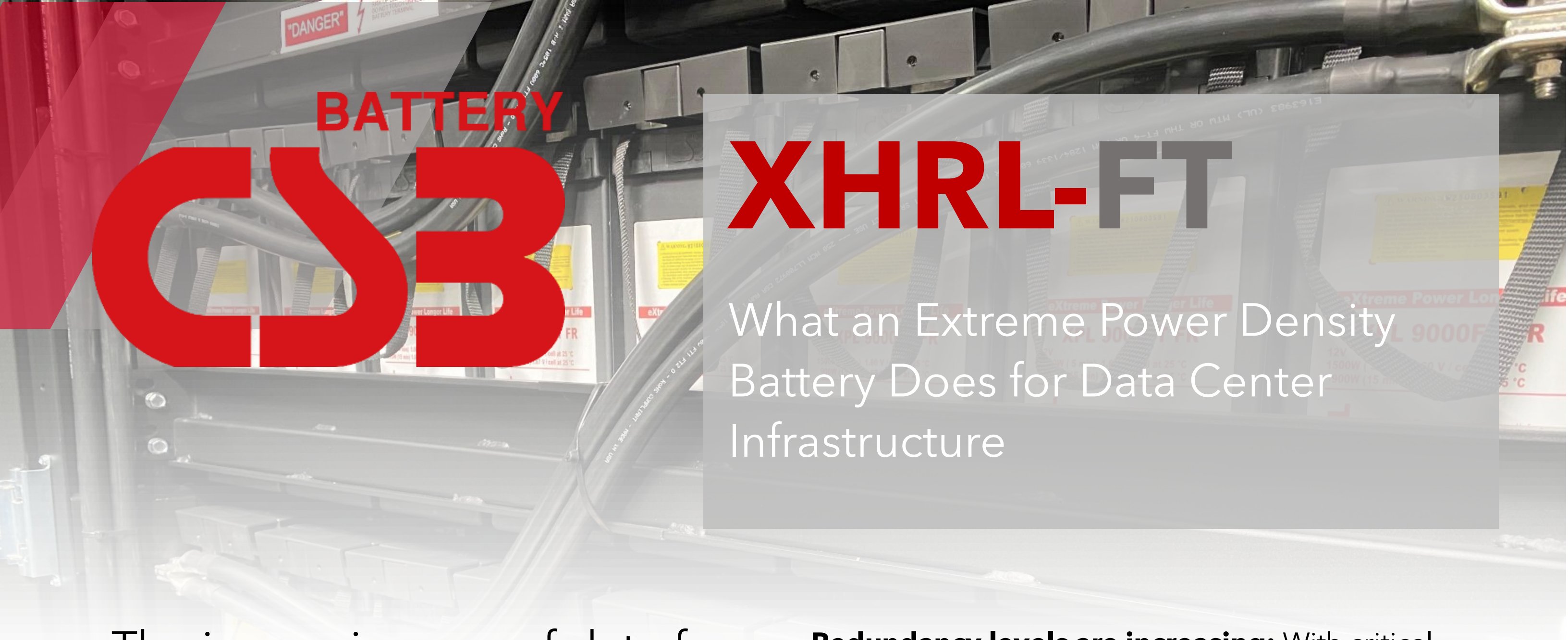

CSB BATTERY

XHRL-FT

What an Extreme Power Density Battery Does for Data Center Infrastructure

The increasing use of data for diverse, power-intensive applications cannot occur without the appropriate digital infrastructure to support and maintain it. Data center capacity increased from 7GW globally in 2000 to an estimated 56GW in 2020[1]. Demand for data center services have accelerated due to companies migrating their in-house IT needs to the cloud, changing regulations involving data sovereignty, which is requiring data to be stored locally instead of offshore, hence increasing the demand for local colocation[2]. As data center expansion continues, below are some major trends involving power protection:

UPSs remain the preferred choice for uninterrupted backup protection: Ensuring that power stays uninterrupted until the generator or other long-duration energy storage starts is top priority of UPS systems. Vertiv's recent survey revealed that AC-UPS systems is the main choice in ensuring availability of data center services, growing from 30% in 2014 to 47% in 2019[3]. Another survey by Data Center Dynamics, shows 90% believe that as long as humans remain responsible for power management, there will be a need for UPS[4]. Frost & Sullivan predicts that the UPS battery market for data centers will be the fastest growing vertical market in the coming years, as it is expected to increase to US$1,157.5M by 2025, at a CAGR of 8.2%[5].

Redundancy levels are increasing: With critical workloads at data centers higher than ever before, any technical failures could lead to catastrophic data losses long, expensive recovery efforts, all resulting in lost revenue streams. According to the Uptime Institute supply side 2021 survey, almost half of the data center suppliers surveyed mentioned that their customers have increased their power redundancy in the past 3 to 5 years, including an increase in N+2 redundancy configurations. In 2018, 7% of the suppliers reported customers having N+2 redundancy, compared to 14% in 2021[6]. The need for more redundancy will spur more demand for UPS systems and batteries at data center facilities.

Standby generators are reliable, but long-duration energy storage has many benefits: Despite some interest in the industry to replace diesel gensets due to rising fuel costs and significant GHG emissions, generators remain a reliable source of emergency power. In February 2021, a major winter storm hit Texas, United States that led to severe power outages throughout the state. With many facilities relying on backup generators to maintain power, these data centers were able to stay online and supply uninterrupted service to their customers[7]. But trends are emerging to use longer duration energy storage to replace generators. In addition to long-duration backup power, energy storage can provide ancillary benefits. These benefits include demand response from unstable utility grid power, frequency regulation, self-consumption to avoid peak utility demand charges.

Power Density on the Rise: More use of data movement and management leads to more power consumption. Global data center electricity use in 2020 was 200-250 TWh, representing about 1% of the world's electricity demand[8]. At the server rack level, more compute-intensive applications such as AI, IoT and virtual reality are leading to an increase in rack densities. According to the 2021 AFCOM annual report, 62% of the respondents reported an increase in the rack densities at their data centers in the past 3 years, with the average rack density at 7-10kW and with some exceeding 20kW.[9] Backing up the increased load profiles will require higher density batteries without lowering the needed runtimes.

Footprint reduction is imperative: As load and redundancy requirements increase, additional UPSs and high-power batteries will be required as well. However, floor space in today's datacenters is at a premium. One of the ways to overcome this issue is to install high capacity, smaller footprint batteries, which would lead to fewer battery strings and cabinets, along with other benefits such as reduced installation and maintenance time and costs. In this regard, high power, front terminal batteries have emerged as a popular option due to their compact design[10].

Given these current data center trends, how does an energy storage technology provide extreme levels of power density to maintain uptime, increase power availability, reduce footprint, and total cost of ownership to a minimum?

Extreme Power Density Batteries for An Ever-Changing Datacenter Ecosystem

CSB is extending the product range of the XHRL series by introducing the **XHRL-FT** batteries, providing the growing data center industry with a premium battery for users requiring high quality, high-rate long life UPS batteries with front access connection. The XHRL-FT incorporates additional design advancements not included in the 1st or 2nd XHRL generation batteries, resulting in front access batteries with the highest power densities found in the marketplace while meeting industry standard footprints at the same time.

CSB is pleased to introduce the XHRL-FT models with the following key features:

- Three new SKUs ranging from 7000W, 8000W and 9000W/battery at the 5-minute rate (600W/cell to 900W/cell 15-min rate).
- Designed to generate large, instantaneous power output for backup applications of 30 seconds or more.
- Top or front terminal connection
- 23" industry standard footprint. They can be retrofitted inside legacy cabinets, making additional capital investments in new cabinets unnecessary during battery replacements.
- Within the 23" size, the XHRL128000FT and XHRL129000FT are the highest power density batteries found in the marketplace.
- As with all other large capacity HRL, XHRL and XPL batteries, the XHRL-FT products have a 12+ year design life at 20°C.

To design lead-acid batteries with higher power output while maintaining their footprint and service life is a formidable task. CSB has overcome this challenge by optimizing the design of the **XHRL-FT**, selecting the appropriate internal materials to generate the desired chemical reactions, and using efficient production processes. Moreover, due to rising environmental concerns worldwide, it is of utmost importance that batteries are manufactured through an environmentally friendly and resource-saving process.

Figure 1 XHRL-FT 12V VRLA-AGM

Optimized Plate Structure:

To increase capacity and high-rate output, the **XHRL-FT** is stacking more plates within the existing cell space. In addition, the grids of the XHRL-FT can hold larger amounts of active substances which improves the utilization rate of the active materials. The design of the internal grid mesh is smaller and denser, which shortens and improves the conductive paths of the energy ions, thus enabling improved performance under high-rate discharges. See figure 2 example on right illustrating this design change.

The above-mentioned design allows the power density of the **XHRL-FT** to increase by 30% within the standard front terminal footprint.

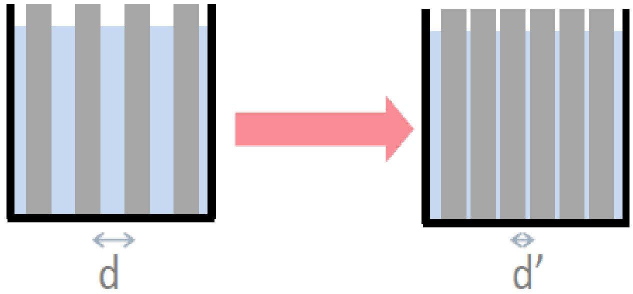

Figure 2 Grid Structure Optimization Example

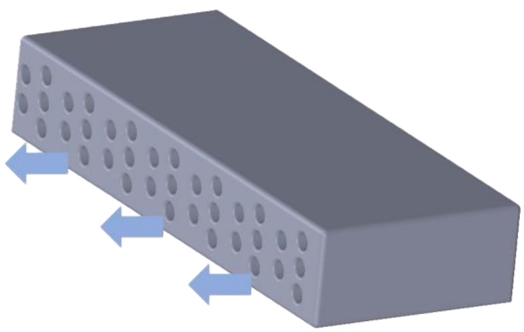

Figure 3 Cutaway Illustration of Hybrid Insulator

Patented Hybrid Insulation

To stack more plates within the existing cell space, the distance between the plates needs to be reduced and a thinner separator must be utilized.

XHRL-FT batteries are designed with high plate group pressure so that internal impedance can be reduced. Under normal circumstances, higher plate group pressure will prevent electrolyte from diffusing easily. This would result in lower battery capacity and excessive accumulation of lead sulfate, which would lead to the formation and growth of lead dendrites.

A thinner separator with growing lead dendrites could cause a short circuit. In this case, using conventional AGM separators might not help to prevent a short circuit, as these separators do not have the sufficient mechanical strength.

The XHRL-FT can overcome this challenge with a new hybrid insulation design that has been patented by CSB (see figure 3 on left). The special separator used on the XHRL-FT series has excellent mechanical strength tested to the highest standard. Organic fibers are added to separator construction which increases elasticity and resistance to puncture. This separator is also hydrophilic, which allows its surface to be highly porous. As a result, diffusivity of the sulfuric acid is enhanced which contributes to the XHRL-FT's capability to provide instantaneous power output.

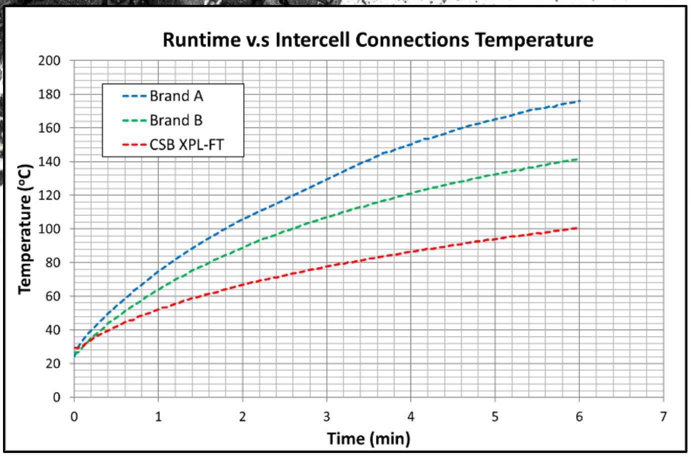

Figure 4 Temperature Comparisons of Intercell Connections

Enhanced Conductivity:

XHRL-FT batteries are used mainly for high-rate applications and the large current generated during discharge will need to be conducted quickly. Otherwise, an enormous amount of energy will be dissipated as heat. In such a state of high heat, it will significantly impact the connection area and increase the risk of battery failure over a period of extended time.

The connection area of the XHRL-FT between the straps and the terminals has adopted a new integrated design, which can effectively shorten the conductive path. Figure 4 (pictured above) shows the increase in temperature at the inter-cell connection area of the XPL129000FT versus other similar front terminal high-rate batteries (based on a 700A discharge). Thanks to the integrated design of the conductive proprietary intercell design of the XHRL-FT, the results show the XHRL129000FT has the lowest temperature increase at the inter-cell connection area during high current discharge. This will lower the risk of battery failure as well as improve the conductivity leading the battery to generate higher power output more frequently.

Exclusive Blend of High-Purity Carbon

Previous studies have shown accumulation of lead sulfate at the negative plate is the primary reason for failure of lead-acid batteries, especially under high power discharge conditions.

Carbon is a conductive substance. The conductive properties of the carbon material can improve the charge acceptance of the electrodes and inhibit the formation of lead sulfate. It could maximize battery performance and extend a battery's cycle life.

At the same time, carbon has high levels of impurity, which could increase the rate of hydrogen evolution at the battery's negative plate, resulting in high water loss during charging. The **XHRL-FT** batteries use a special high-purity enhanced carbon material, which suppresses the hydrogen evolution reaction and lowers the water loss. Therefore, the service life of the XHRL-FT is not sacrificed despite the use of carbon materials.

The carbon used on the XHRL-FT also helps to support improved high-rate performance. Carbon additives possess high porosity characteristics, which allows the sulfuric acid to be stored in its pores and allow large power to be generated during discharge.

Up to 900 Watts Per Cell

Up to 30% Power Density Increase

Pure Lead Construction + Proprietary Additives

Front Access or Top Access Design:

Front terminal batteries such as the **XHRL-FT** are also known as "narrow" batteries. These are mostly 12V batteries with front terminals located on the upper section of the short front side. They can fit in 19 inch or 23-inch racks and cabinets.

When the surface area of the long side is increased, the front terminal batteries provide better heat dissipation performance, which significantly reduces the probability of a thermal runaway occurrence.

When the front terminal battery is installed vertically upright, this ensures area savings of the equipment room but also warrants the battery installation and maintenance are very simple and safe. Refer to figure 5 (pictured right) showing a string of 40 pcs of the XHRL-FT installed in a standard front terminal cabinet.

Users that also opt to use a top-access configuration due to spacing or other DC wiring connections can quickly interchange between top or front access with a simple configuration kit.

Figure 5 XHRL129000FT Battery Cabinet 480Vdc

Cast On Strap Assembly (COS):

The COS assembly process (which is used on all CSB's large capacity batteries including the **XHRL-FT**) is an automated process used for grouping and joining the plates together. This process results in the connection or welding of the lugs to the straps to form a lug-strap joints. Illustrated is this design on the right in figure 6.

If the welding is performed manually, the plate foot and the strap, the plate lug and the strap might be subject to pseudo-welding and lead leakage. The COS assembly process can overcome the above-mentioned issue and provide high quality, stable joints that have low electrical resistance, are mechanically strong, and corrosion resistant.

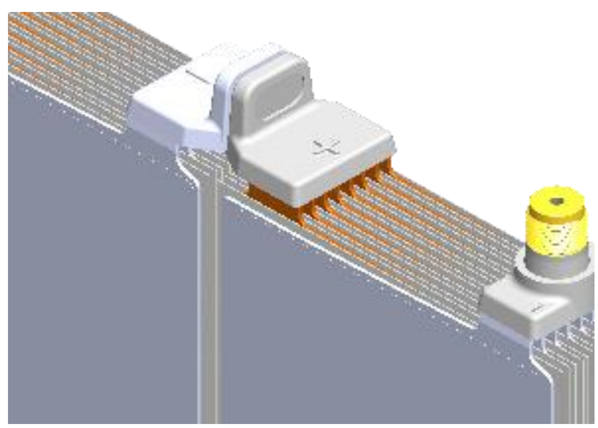

Figure 6 COS Assembly Diagram

In-Case Formation (ICF):

A traditional way to manufacture lead-acid batteries is to place the cured positive and negative plates into a sulfuric acid tank. This is known as the In-Tank Formation process, or ITF. After formation, the plates are removed from the tank, rinsed with water, dried, and assembled into dry-charged batteries. Inevitably, acid mist and lead fumes created during this process stay in the air. Not only does this pose a greater health hazard to the manufacturing operators, but it also requires extensive water resources for neutralizing and cleanup.

CSB's large capacity batteries including the **XHRL-FT** line have adopted the process of In-Case Formation (ICF). The cured positive and negative plates are assembled directly into plate groups, which are then placed inside the battery containers. Sulfuric acid is added directly into the closed container to eliminate pollution caused by the acid mist and lead fumes. The batteries are then formed by undergoing a water bath via a temperature controlled, escalator charging process. Please see the below figure 7 diagram

The ICF process offers the benefits of reduced energy requirements and environmental issues, increased charging efficiency and battery consistency. **Using automated ICF process allows CSB to save approximately 75,587T of water and 60% of CO_2 from fossil fuel combustion annually.**

In addition, in the XHRL-FT manufacture process, plenty of low-carbon or zero-carbon technologies are used (including process improvement, replacement of high-efficiency equipment, and construction of solar panel) to achieve carbon reduction. As the world leader in the VRLA manufacturing industry, CSB has established long-term reduction targets and is planning a practical path to attain net-zero emissions.

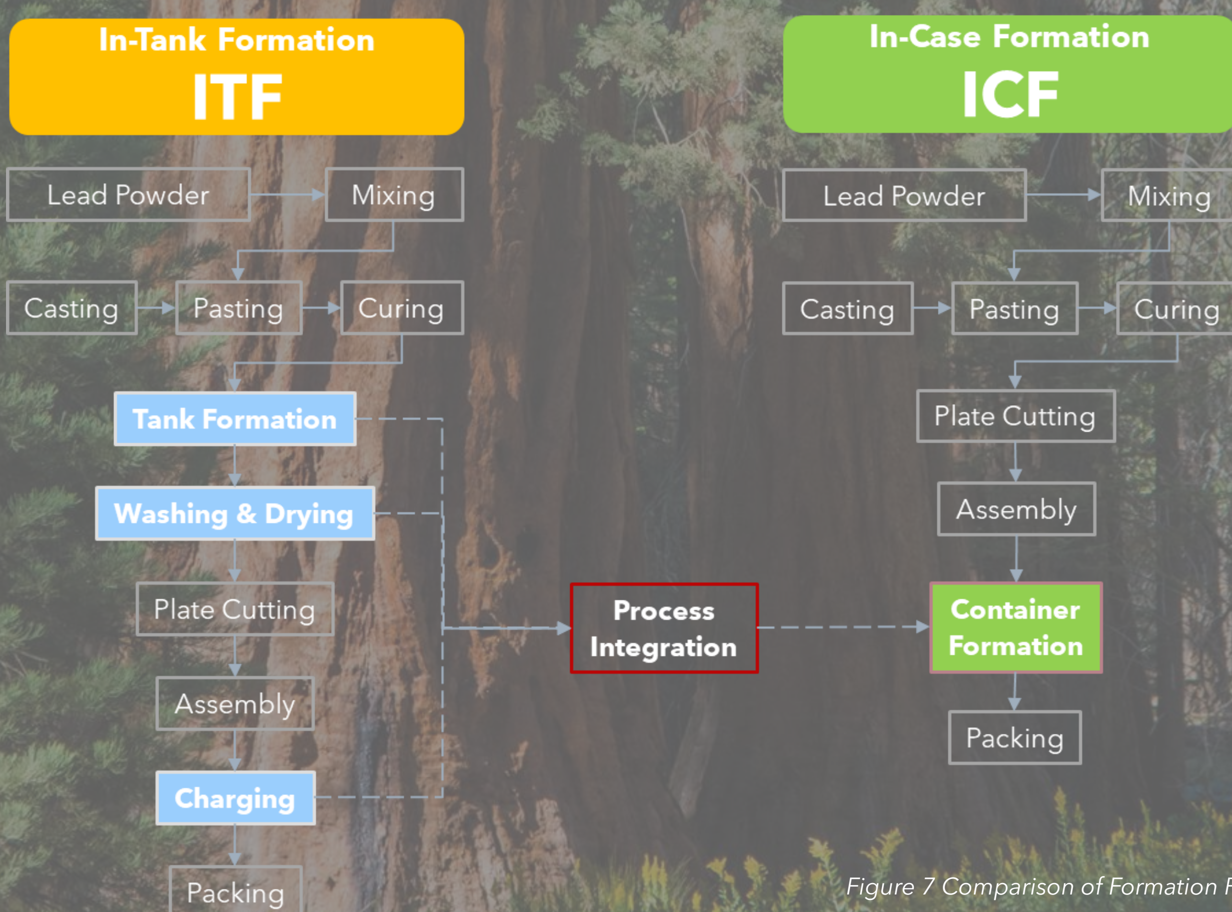

Figure 7 Comparison of Formation Processes

Case Study Example – Reducing Physical Footprint

Another way of interpreting the concept is XHRL-FT can provide the required runtime with fewer strings. This is shown in the below figure 8. As the battery kW load requirements increase to meet the extreme short duration minute required runtime, the option of using the XHRL-FTs becomes more attractive. Depending on the selected batteries and load requirements, the **XHRL-FT** solutions can save additional floor space compared to using competitor front terminal batteries. Fewer strings lead to lower initial investment in cabinets and accessories, as well as less footprint and reduced installation costs. Below are various scenarios between 250kW and 1MW @ 1.67Vpc @ 25°C

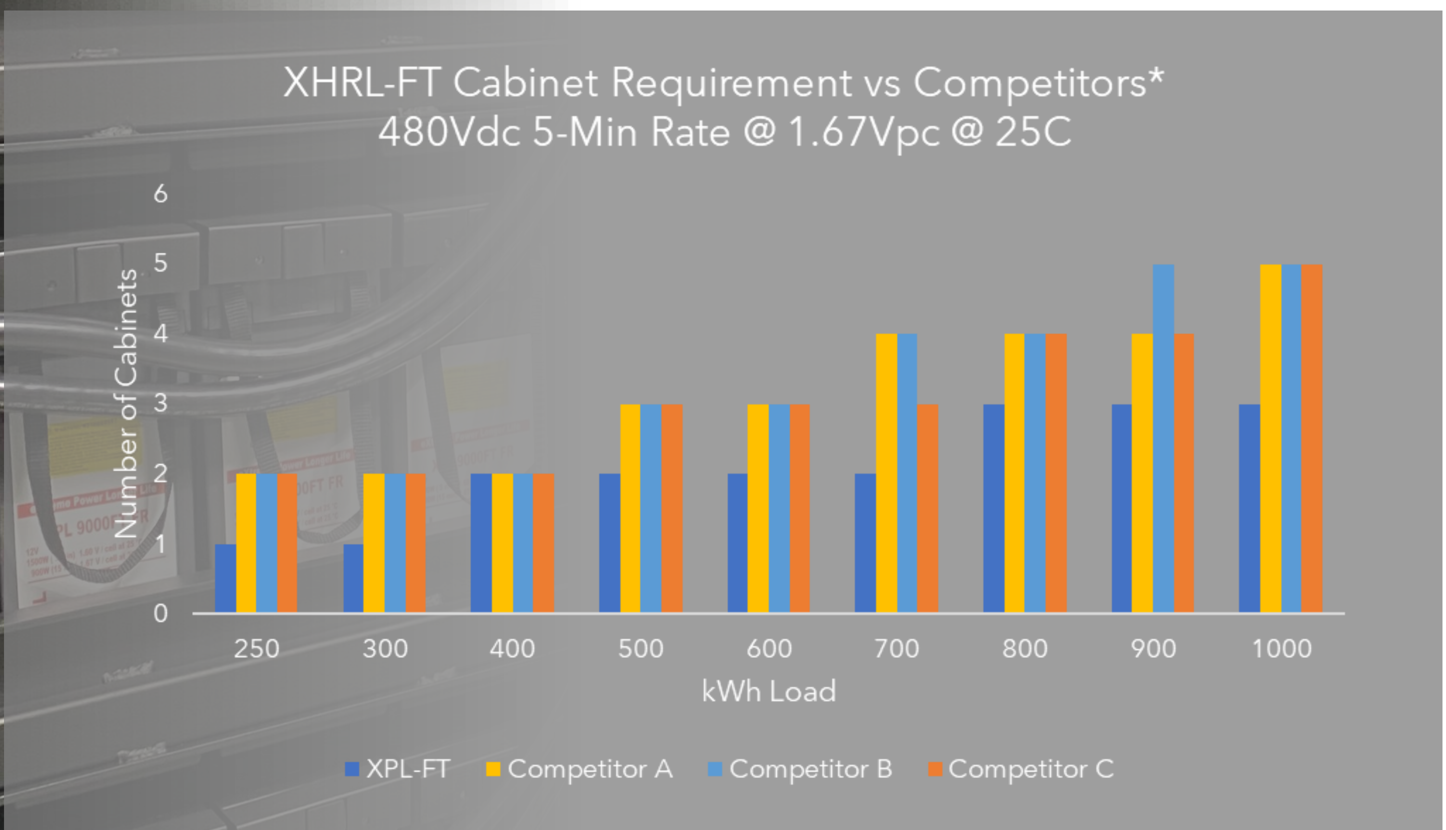

Figure 8 Footprint Reduction with XHRL-FT

**(Competitor Specifications Based on Published Ratings)*

Conclusion

Since CSB introduced the first advanced high-rate UPS battery series XHRL series in 2008, the world has witnessed major events that have significantly affected the lives of many and shifted traditional stationary power paradigms. The 2008 global financial crisis, the recent COVID-19 pandemic, and several political and natural disaster events in between. What has not changed is the desire to innovate by human beings to build new, faster, and more powerful technologies. This never-ending quest is leading to a limitless need for more power to support the digital age, and consequently the need for improved battery performance to backup critical workloads. When the power goes out and critical infrastructure can't operate, the consequences can be catastrophic. CSB's proven, safe and reliable lead-acid products, combined our latest advanced technology in **XHRL-FT** batteries reflect CSB's ongoing commitment to meet increasing needs for more power. As CSB continues to launch new products in the future, CSB remains steadfast in innovating and developing premier quality products for its customers and end users. Contact your local sales representative to learn more.

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About CSB

CSB is a leading and globally recognized manufacturer of VRLA batteries. The company was established in 1987 through a technological joint venture with Shin-Kobe Electric Machinery of Japan. Through its commitment to cutting-edge technology and service, CSB has earned the trust of customers worldwide and forged long-lasting relationships.

- CSB has over 100+ batteries and 13+ different series designed for multiple applications including UPS, Telecommunications, Renewable and Electric Vehicle, among others.
- CSB is focused on Quality management. All CSB's factories are ISO 9001 certified.
- CSB is dedicated to fostering a Sustainable environment, as evidenced by its ISO certifications ISO 14001 (Environmental Management) and ISO 50001 (Energy Management), as well as through its Eco-Friendly production processes.
- CSB possesses global service support capabilities, with factories, sales offices and warehouses located strategically throughout Asia, Europe, and the Americas. We also have an extended network of 150+ key distribution partners across all major regions and countries.

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