WHITEPAPER

gridXtreme VR

High Performance Pure Lead (HPPL)

The energy storage for tomorrow's data centers

► TABLE OF CONTENTS

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The energy storage for tomorrow's data centers

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► INTRODUCTION

In an increasingly digitalized world, safeguarding data centers is an essential application of energy storage systems and was therefore the focus of the development of HOPPECKE's high-performance HPPL pure batteries.

Installed in UPS systems, they are used to eliminate network disturbances as classified in the European standard EN62040-3. These include dips, peaks, voltage fluctuations and transients (short-term, stochastic disturbances).

In the event of a temporary complete failure of the mains power supply, batteries use their stored energy to ensure the continuous operation of the IT load and critical infrastructure components. A backup time of ten to 15 minutes is usually selected. In the event of a prolonged interruption of the mains power, enough backup time should be available so that the supply of the load can be transferred to emergency power supply systems such as diesel generators. Nowadays, however, generators can be switched on and brought up to speed much faster and thus loads can be transferred to the emergency power supply system much faster than was previously the case.

What does this mean in concrete terms for the application from the point of view of energy storage, what special features does HPPL have in comparison with classic AGM technologies and how can you benefit from the use of this storage technology?

In the following whitepaper we will try to answer these questions.

► STRUCTURE OF AGM BATTERIES AND ESSENTIAL DIFFERENCES TO HPPL TECHNOLOGY

Structure of AGM-Batteries

AGM batteries are maintenance-free lead batteries in which the gaseous oxygen produced by water decomposition at the positive electrode migrates to the negative electrode where it is recombined with the hydrogen ions available in the electrolyte to form water. Batteries of this design are maintenance-free for the entire service life regarding refilling with water.

The oxygen transport to the negative electrode is made possible using a so-called “Absorbent Glass Mat”, which fixes the electrolyte by capillary power, separates the positive and negative electrodes from each other and provides additional space for the oxygen transport. By absorbing the electrolyte in the glass mat separator, additional acid volumes and a sludge space, as with conventional lead batteries, can be dispensed with. A high energy and power density, compared to other lead batteries, are therefore typical characteristics of AGM batteries.

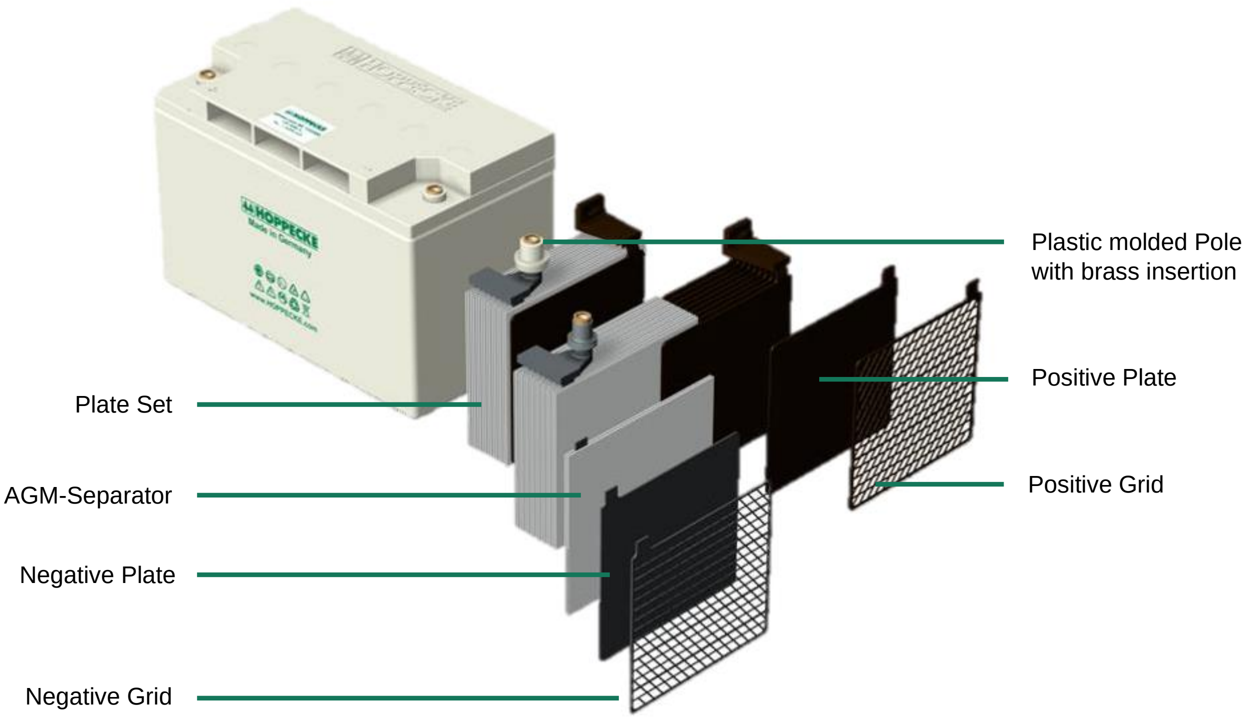

Figure 1: Structure of AGM batteries

HPPL–Batteries (series: grid | Xtreme VR)

HPPL batteries also belong to the family of AGM batteries and therefore follow the basic structure with the difference that the electrode thicknesses used correspond to only a fraction (approx. ¼) of classic products. The potential of this technology derives in maximizing the number of electrodes used. This results in a larger electrochemical reaction surface and is trend-setting in terms of energy and power density for lead-acid storage technologies.

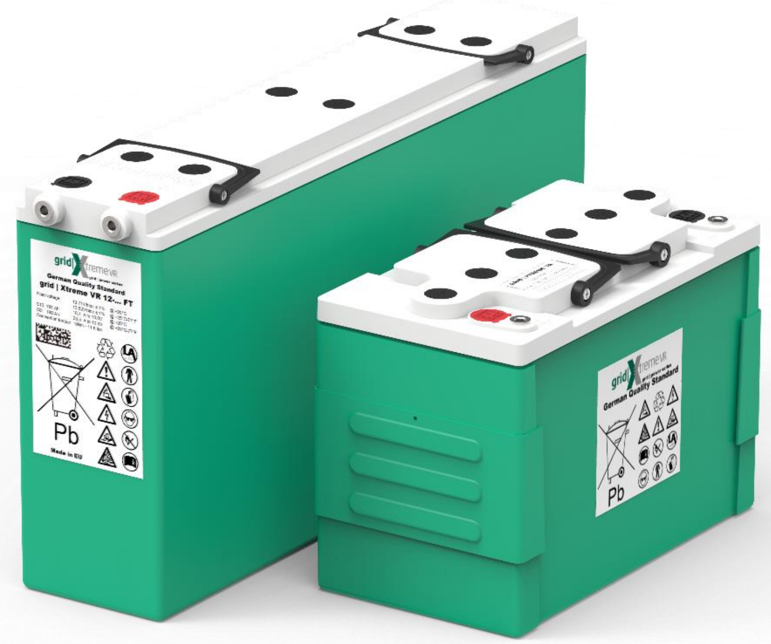

Figure 2: HPPL-Battery (Front-/ Top-terminal-version)

The advantages of an enlarged reaction surface are also evident during recharging. While classic lead-acid batteries are usually charged with charging currents of 5 to 20 A per 100 Ah, the permissible range for this technology has been extended to 40 A per 100 Ah. This can be used in critical applications and with given infrastructure to significantly reduce the recharging time of the system.

In addition to a good cycle capability, maintenance-free HPPL batteries are also characterized by a very low gas emission and self-discharge rate, which allows extended storage times compared to classic VRLA batteries.

► AGEING MECHANISMS THAT AFFECT THE PERFORMANCE OF A LEAD-ACID BATTERY OVER TIME

To understand the basic advantages of pure lead technology (HPPL), it is important to consider the essential aging mechanisms of lead-acid batteries in stationary applications (standby parallel operation) and to illustrate their influence on the performance of the storage system over the service life.

Positive grid corrosion

Each lead-acid battery consists of a parallel connection of positive and negative electrodes surrounded by diluted sulphuric acid and separated from each other by an electrolyte-permeable separator to prevent mutual contact. Electrodes are metallic support grids into which positive or negative active mass is inserted. In addition to accommodating the active masses, the support or conducive grid also serves as a current collector to lead the stored energy out of the battery with as little loss as possible.

In a corrosive environment, such as that prevailing in lead-acid batteries, metallic lead tends to corrode to lead oxides over the service life. While all negative discharge components of a lead-acid battery are protected from corrosion by their potential (cathodic protection), this does not apply to the positive components. On the contrary, the high electrical potential of the positive active mass leads to the thermodynamic oxidation of all associated metallic components. This process is called positive grid corrosion and is always present in all lead-acid batteries.

The corrosion mechanism described above ultimately has two destructive effects on the battery.

Effect 1: The battery loses its conductivity as the corrosion of the discharge components progresses, which increasingly impedes the flow of current. While decreasing conductivity goes completely unnoticed during medium to long discharge times, the effects are significant in high current applications such as those found in data centers today. Due to a higher voltage drop within the battery, the selected final discharge voltage is reached earlier and furthermore, the bridging time of the system is negatively influenced.

Service life promises, which usually refer to the nominal current of a 10-hour discharge, are no longer applicable under such conditions. Instead, the criterion for the end of life (80% of the projected capacity or bridging time) is reached significantly earlier in designs with significantly higher currents (discharges < 1 h).

Effect 2: The chemical conversion of metallic lead to lead oxides, known as corrosion, leads to a reduction in density within the end products as a result of the absorption of oxygen and thus to an increase in the volume of the electrode grid. Lead, which is converted into lead oxides along the surface or in its grain boundaries, creates mechanical stresses in the remaining metallic lead and thus inevitably causes grid growth. (Fig. 3) Porous structures of active masses usually cannot compensate for these volume changes and increasingly lose electrical contact with the metallic support or conductive grid, which in turn leads to a loss of capacity and a further reduction in battery conductivity.

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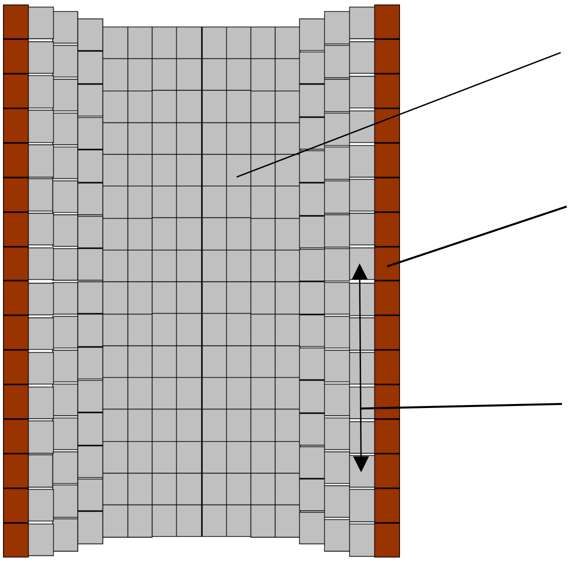


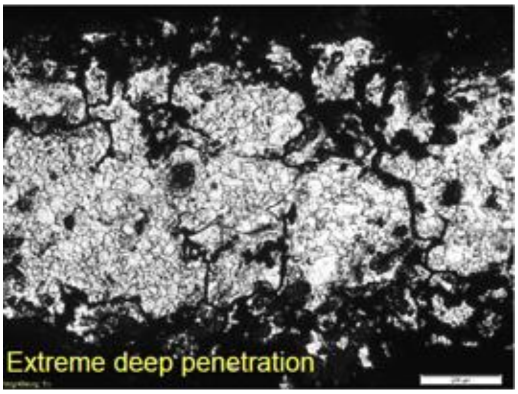
Figure 3: Grid bar with superficial corrosion

Grid corrosion as an aging process in lead-acid batteries cannot be completely avoided, but application-related factors such as the average operating temperature or the float charge voltage can have a considerable influence on the dynamics of the process. Design features determined by the manufacturer, such as the choice of grid alloy, also play an important role in the rate of corrosion. High-purity lead has the lowest corrosion rates in comparison to all known lead alloys and is therefore clearly superior to them. Nevertheless, lead battery production is still characterized by the use of lead alloys in the area of grid production, which is due to requirements for mechanical strength and processability within production.

Corrosion properties of lead alloys are mainly determined by the solidification process of the melt or the incorporation of the alloy components into the crystal structure of the lead. Calcium as an alloy component of grids of sealed lead-acid batteries is mainly deposited at the grain boundaries of the lead, whereby normal surface corrosion is additionally accompanied by intergranular corrosion along the grain boundaries.

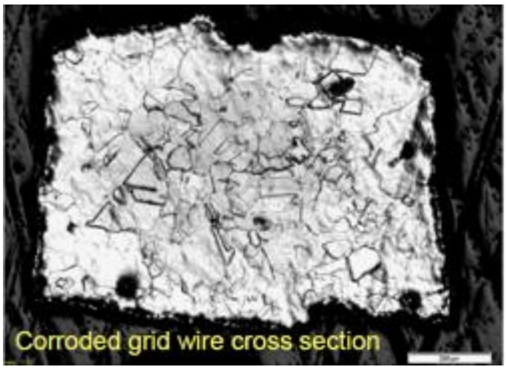
Deeper structures in the grid are thus exposed to destruction rather quickly, causing the integrity of the support or conductive grid to suffer permanently (Fig. 4).

In the best case, high-purity lead as a grid material is free of alloying elements or impurities, so that intergranular destruction of the grid does not occur and only a slow progressive surface corrosion is observed (Fig. 5). In comparison to conventionally manufactured grids, pure lead grids can therefore be designed many times thinner and still set standards in terms of service life.



Three-dimensional corrosion on the grid bar

Figure 4: Corroded lead-calcium grid



Corrosion on grid bar only superficial

Figure 5: Corroded pure lead grid

High current performance over the service life

The compact design of classic AGM batteries enables very high discharge currents in the range of a few minutes, so that this technology is often the first choice when equipping the emergency power supply of data centers. In the event of a mains failure, high power outputs of several 100 kW must be provided by the battery system without interruption until the emergency power generators are started. While new systems in this discipline function reliably, performance losses become visible after only a few years of operation. Even service life specifications, which are usually defined for batteries, or the customer's expectations derived from them, are not applicable in high-current applications.

What is the reason for this?

Like all electrochemical energy storage systems, stationary battery storage systems are subject to aging. This manifests itself in a decrease in capacity and electrical conductance, since, for example, the internal discharge cross sections of the battery are reduced (corrosion). If the functions of the stationary battery can no longer be guaranteed to a sufficient degree according to the specifications/definitions, the end of the useful life is reached.

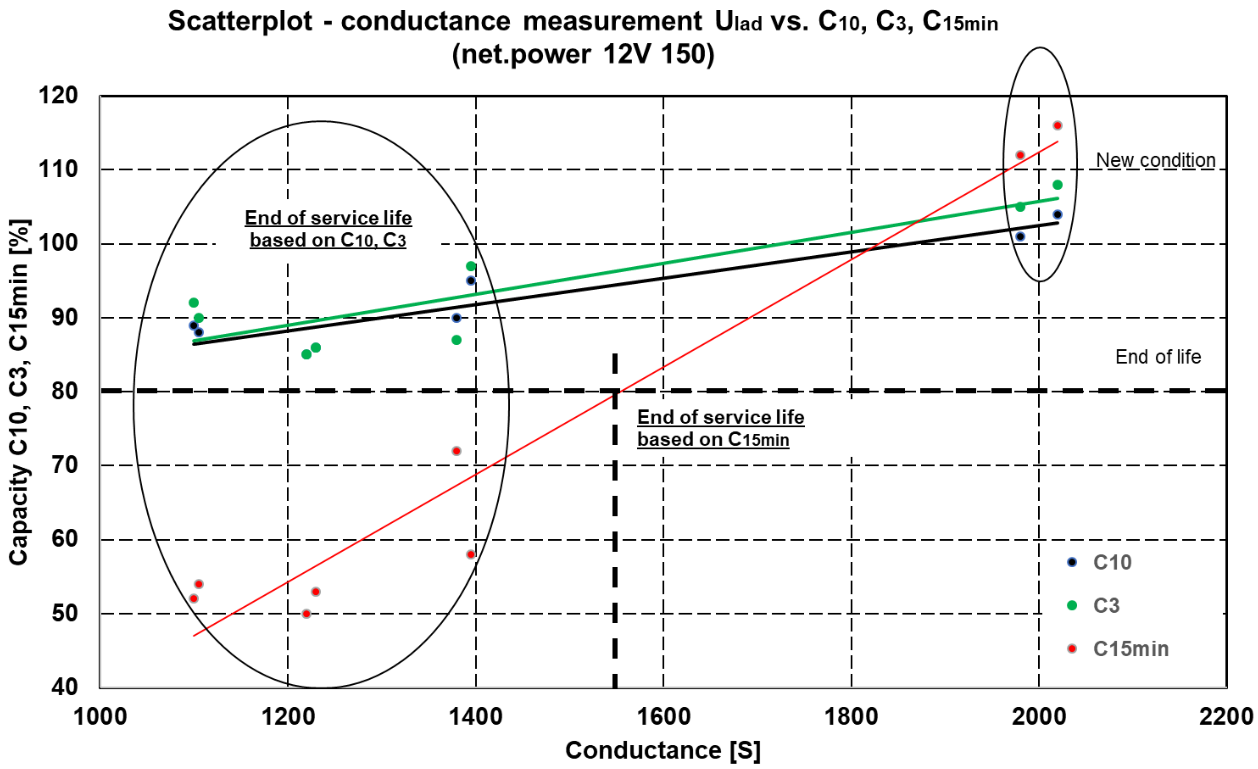


Figure 6: Nominal capacities depending on the conductivity of the battery

Usually the service life is exceeded if 80% of the projected capacity or bridging time (battery capacity shown in the current range) is not reached. This natural aging process and thus the expected service life plays an important role, especially in high current applications.

In principle, all discharge currents lead to more or less considerable voltage drops across the internal resistance of the battery. This usually manifests itself in a decreasing terminal voltage with increasing current. Corrosion-induced reductions in the discharge cross sections over the service life also influence this terminal voltage and further reduce the time range in which the battery system can safely conduct a defined current. While age-related changes in the conductance have only a minor effect on the 10-hour nominal capacity of a battery, their influence is significant during discharges with high currents. (Fig. 6)

Usual service life statements of lead batteries refer to the nominal current of a 10-hour discharge. In high-current applications, these specifications are reduced to approx. 50-60%, which makes an early replacement by a new system necessary.

The use of pure lead batteries (HPPL) can be advantageous in such applications for several reasons. By maximizing the number of installed electrodes in a given volume, increased discharge values are achieved, or smaller installation spaces can be realized for given discharge currents, thus reducing infrastructure costs.

In addition, the significantly slower corrosion mechanism, which is limited to the surface, results in only minimal material removal in pure lead acid batteries, so that the integrity of the supporting grid and thus the conductivity during the service life suffers less. For this reason, pure lead acid batteries can provide high discharge currents over a longer service life with the same design life classification and thus postpone the necessary battery replacement by several years compared to classic AGM batteries.

High operating temperatures

Uninterruptible Power Supplies (UPS) ensure the supply of critical electrical loads in case of disturbances in the power supply system. The electrical energy required for backup is usually provided by a battery system that remains fully charged for almost its entire service life. In order to ensure smooth operation over several years, great attention is paid to the average operating temperature in addition to regular maintenance.

The reason for this is the temperature dependence with those chemical reactions - such as positive grid corrosion as an aging process of stationary lead batteries - take place. An increase of the average operating temperature by 10 K halves the battery life, if no other aging effects, such as drying out of sealed batteries or softening of mass due to cyclic loading, have an influence. For this reason, the battery rooms of larger UPS systems are air-conditioned and the battery and equipment technology are physically separated. This separation of the system components with different temperature levels, which makes sense from a technical point of view, is beneficial to the battery life, but it also increases the associated operating costs (and thus the TCO) for the user.

From this point of view, pure lead batteries (HPPL) are also a worthwhile alternative due to their extended operating temperature range. Without sacrificing service life compared to classic AGM batteries, the battery and equipment technology can be housed in the same room and the system can be operated at an average temperature of 30°C in a resource-saving manner.

On average, an air conditioning system has to use about 4% more energy for each additional degree by which a battery room has to be cooled down. An increase of the average operating temperature from 20°C to 30°C is therefore accompanied by a 40% saving potential in energy costs.

► "GRID | XTREME VR" IN DATA CENTERS

Pure lead acid batteries (HPPL) from HOPPECKE are marketed under the product name grid | Xtreme VR. The name already implies that this is a series with extraordinary characteristics, which at the same time has the potential to revolutionize larger UPS applications in data centers. While some of its features also come into play in other applications, the advantages of corrosion-resistant and durable thin-plate technology seem to take full effect especially in UPS applications. The most important properties of the technology, as well as the customer benefits derived from them for data center users, are listed in Table 1 below.

Property	Customer benefit
Increased power density	▪ Smaller capacity ▪ Reduced infrastructure costs
Low corrosion rate	▪ Longer service life in high current applications ▪ Lower TCOs
Extended operating temperature range	▪ Higher operating temperatures without loss of service life compared to classic AGM batteries ▪ Lower energy costs for air conditioning ▪ No separate rooms for battery and equipment technology necessary ▪ Lower TCO's
Fast charging capability	▪ Faster operational readiness after discharge ▪ High energy efficiency
Extended recharge intervals	▪ 24 months at 20°C, thus avoiding recharging in case of project delays
Dual – pole design	▪ Easy impedance measurement on wired battery through separate measuring contacts

Tab. 1: Characteristics and customer benefits of grid | Xtreme VR compared to classical AGM technologies

During the development of the grid | Xtreme VR series, the focus was deliberately placed on the revision and optimization of all components in order to be able to fully utilize the performance gain of pure lead technology.

Essential for the function of AGM batteries is the installation of the plate set under precompression (set pressure) in the cell container. This set pressure is significantly important for the internal recombination of oxygen and hydrogen, and for the stabilization of the installed active masses to increase the cycling capability. The required set pressure can be ensured over the service life of the battery either by using form-fitting racks or troughs, or by the design of the battery container and the selection of the cell container material.

Innovative battery receptacles have been developed by appropriate shaping in combination with high-quality plastics, which also ensure the functionality of the battery under consideration of a maximum temperature load and given ageing effects. In the top terminal version, the load level of a form-fit installation can also be achieved by optionally attaching patented metal reinforcements to the end walls. Users of HOPPECKE HPPL top terminal batteries with metal reinforcements can thus choose a cost-effective standard installation in battery cabinets or on racks, and additionally benefit from the advantages of the HPPL technology in terms of service life.

Batteries used to secure critical infrastructure elements are usually regularly maintained and subjected to regular discharge tests to ensure long-term operational readiness. These discharge tests do not usually correspond to a capacity test in accordance with DIN regulations, but rather to a time-limited load test with discharge values less than or equal to the nominal load. The purpose of this test is to ensure that the battery system continues to provide the required performance while at the same time safeguarding the critical system components.

Alternatively, the dual pole design of the grid | Xtreme VR series allows the user to perform impedance measurements very easily using separate measuring contacts on connected block batteries without affecting the system availability. The condition of the battery system or individual blocks can thus be reliably determined at any time, which increases the operational availability and makes it possible for the user to plan a future replacement of the battery system.

► CONCLUSION

This whitepaper has shown the fundamental advantages that HPPL batteries offer compared to classic lead technologies and why data center users in particular benefit from these properties. In addition to a reduction in operating costs, the technology is also characterized by superior resilience and reliability.

With the introduction of further models and variants, other industries will also benefit from this technology in the future and the long success story of the lead battery will continue

► ABOUT HOPPECKE

HOPPECKE Batteries is the largest producer of industry battery systems in European ownership. Since 1927, the family company has been developing and producing in Germany, and thanks to its leading research and development activities, it has all reliable and innovative storage technologies in its product portfolio.

Electric energy is required everywhere and in ever more applications. In this world, where everything becomes electrical, HOPPECKE is your partner and expert. We understand our customers and with our energy solutions, designed for safety and availability, we serve four principal areas of application: emission-free drives (trak), secured power supply (grid), storage of regenerative energies (sun) and railway and metro-systems (rail).

From the comprehensive product programme of batteries and cells to complete energy systems with the most modern charging technology, monitoring units and engineering to consumption dependent energy billing – our portfolio always contains the suitable product tailored to the individual customer requirements. With the development of marketable, forward-looking energy storage solutions, HOPPECKE makes an important contribution to solve the societal challenges that result from the implementation of the global climate protection goals.

Since its foundation in 1927 HOPPECKE has been owned by the Zoellner family. Today, Dr. Marc Zoellner is the fourth generation of the family to manage the industrial company as a family business. With its headquarters in Brilon-Hoppecke and 23 subsidiaries, representative offices, partners and distributors as well as production and assembly facilities worldwide, the company employs more than 2080 people and generates a turnover of over 430 million Euro.

INTILION - the new brand from HOPPECKE

Since April 1, 2019 there has been a new company in the HOPPECKE Group, INTILION GmbH. It represents another milestone in the company's successful history. INTILION stands for lithium-based systems and innovative operator models for industrial traction and stationary battery storage applications. INTILION always pursues the goal of achieving even stronger customer loyalty and agility. It is the partner for future-oriented lithium-ion energy storage solutions and innovative business models.

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