WHITE PAPER

GEL batteries Comparison vs. AGM

Source: EXIDE TECHNOLOGIES

INTRODUCTION

Sonnenschein - a brand with a heritage of more than 100 years of high quality battery manufacture in Germany.

60 years ago, the Sonnenschein company laid the foundation for unrivaled success by inventing Gel batteries. The continuous improvement of the dryfit technology ensures that dryfit® Gel batteries always represent the most up-to-date level of engineering expertise.

dryfit® Technology

KEY FEATURES OF GEL BATTERIES

*Gel batteries are known to be the **premium** technical product of all VRLA batteries (Valve Regulated Lead-Acid)*

1. Maintenance-free (no topping up)

2. Long service life

3. High number of cycles (IEC 60254-1)

4. Extraordinary deep discharge protection

5. Low self discharge rate

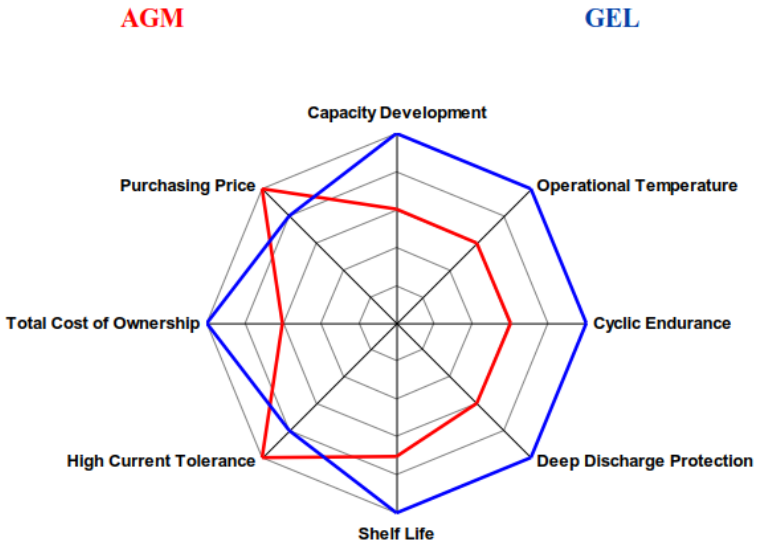
6. Superior shelf life

7. No acid stratification

In the next paragraphs, different topics will be addressed:

- ***GEL VS AGM***
- ***TECHNICAL COMPARISON***
- ***CONCLUSIONS***

GEL VS AGM



As can be seen in this graphic representation, dryfit® Gel batteries give multiples advantages compared to the AGM batteries, such as a significantly lower total cost of ownership than an AGM battery and a more sustainable performance along the battery life.

Main important points to highlight are the battery life and the capacity stability.

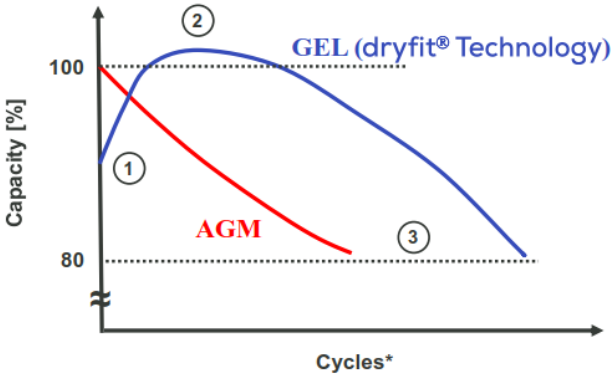
Battery life:

***The dryfit® Gel batteries used in Pramac trucks have a cyclic endurance of 700 cycles**, against the wide range of AGM batteries with an average of 350 cycles (IEC 60254-1).*

*When comparing these data, it means that a Gel dryfit® battery **lasts two times** the average life of an AGM battery, so a significant lower cost of ownership along the life of the truck.*

Capacity development:

The graph below shows the capacity behavior of the two types of battery along the use. dryfit® Gel batteries reach the maximum capacity after few cycles of use and then maintain a stable value for long use before starting to lower capacity while AGM batteries have a significant reduction in capacity after few cycles.



Phase (1)	Starting Capacity	GEL: $C_{actual} < C_{nominal}$
		AGM: $C_{actual} = C_{nominal}$
Phase (2)	After a few cycles	GEL: $C_{actual} \geq C_{nominal}$
		AGM: $C_{actual} < C_{nominal}$
Phase (3)	End of service life	GEL: GF-Y 450 cycles* GF-V 700 cycles*

* According to IEC 60254-1

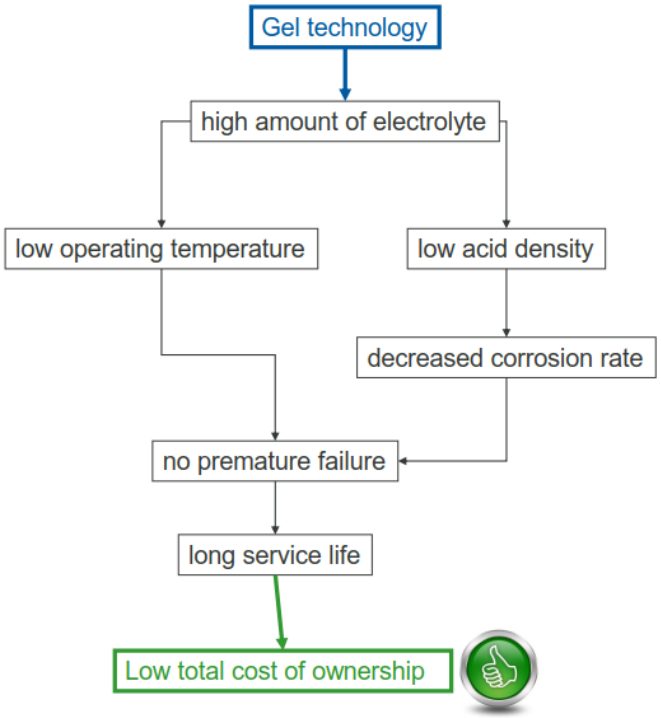
TECHNICAL COMPARISON

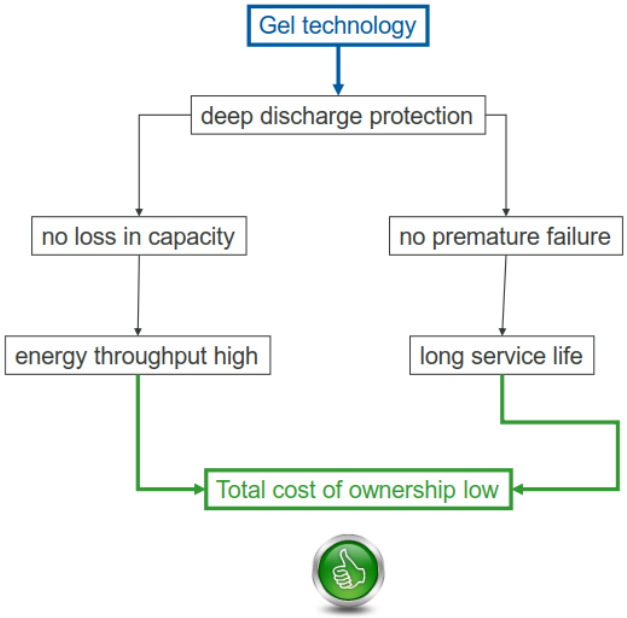
Amount of Electrolyte:

- ***The amount of electrolyte inside dryfit® GEL batteries is significantly higher (up to 20% more) compared to AGM batteries of the same box dimensions.***
- *The available cell volume of Gel batteries is completely filled with electrolyte, thus providing a level of electrolyte sufficiently higher than in AGM batteries.*
- *Accordingly, Gel batteries are enabled with a low acid density, which decreases the corrosion rate and increases the operational life of a lead-acid battery.*
- *At the same time, a significant reservoir of electrolyte defines high heat capacity, which ensures that the impact of temperature variations is moderate. Therefore, the average operating temperature of Gel batteries is lower compared to AGM batteries. This has a positive effect on the lifetime of Gel batteries.*

Deep Discharge Protection:

- ***dryfit® GEL batteries are mass-restricted systems while AGM batteries are acid-restricted.***
- *Based on their large electrolyte content, Gel batteries have an integrated deep discharge protection.*
- *Gel batteries are mass-restricted systems that contain sulphuric acid, even when completely discharged, preventing growth of large lead-sulphate crystals on the plates. As a result, the structure of the active mass (carrier of the electrical energy) is protected against irreversible damage, which ensures that the capacity recovers after a deep discharge event.*
- *AGM batteries are acid-restricted systems, containing only an aqueous lead-sulphate solution when deeply discharged. Such a solution supports the growth of large lead-sulphate crystals. These big crystals cause irreversible damage to the structure of the active mass (carrier of the electrical energy). Therefore, the capacity does not fully recover after a deep discharge event.*



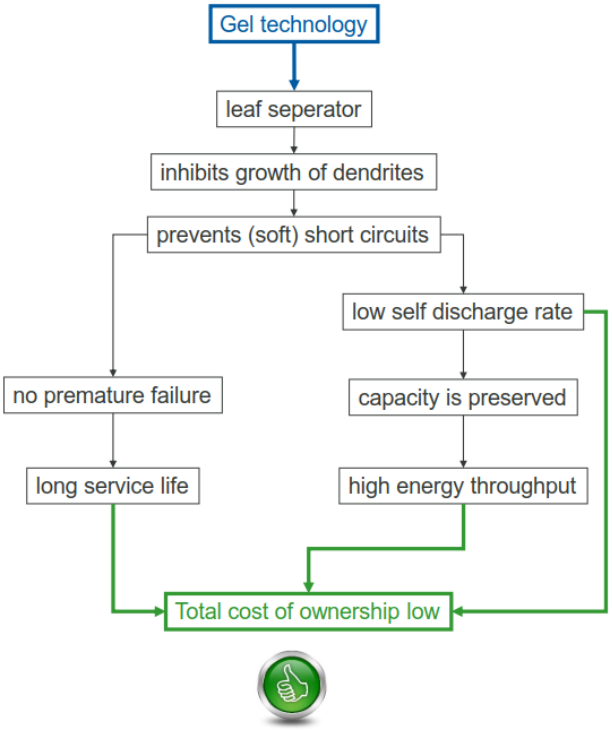


Separator:

- ***dryfit® GEL batteries are manufactured with high quality micro porous leaf separators, while in AGM batteries a macro porous glass mat fulfils the separator and the electrolyte absorbency function.***

- *High-quality micro porous leaf separators for Gel batteries are effectively avoiding (soft) short circuits, especially in the case of deep discharge events. Moreover, leaf separators are very resistant: Even if they are soaked with electrolyte, their tear-resistance properties are equal to the dry state.*

- *The macro porous glass mat of AGM batteries supports the growth of lead-sulphate dendrites. These dendrites can penetrate the separator and cause (soft) short circuits. As a result, the self-discharge rate increases and the available capacity decreases. Moreover, the tear resistance of a glass mat separator soaked with electrolyte is significantly decreased compared to the dry state (similar to paper towels).*

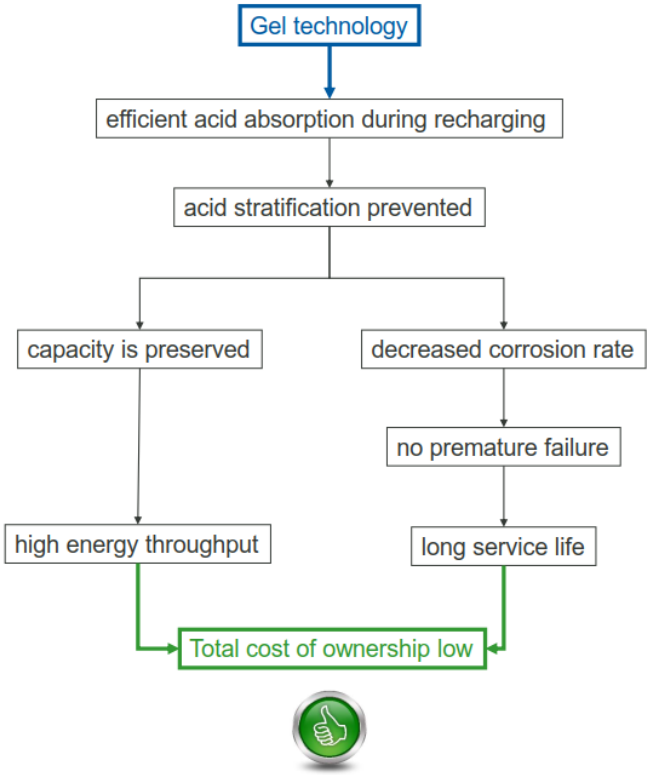


Acid stratification:

- ***dryfit® GEL batteries are very efficient at absorbing the sulphuric acid released during recharging, while AGM batteries have a lower absorption effectiveness.***

- *During the recharging process of a lead-acid battery, the lead-sulphate in the plates is transformed back into active mass, while sulphuric acid is released. For valve regulated lead-acid (VRLA) batteries it is essential to efficiently absorb the released acid, otherwise acid stratification takes place. In this case, the acid density at the lower ends of the plates is higher than in the upper region.*

- *Acid stratification leads to the following effects: Due to the unequal acid concentration inside the battery the active mass in the upper part of the plates cannot be fully discharged, while the lower regions of the plates will be frequently deep discharged. This leads to an accelerated loss of capacity. Additionally the high acid density on the lower region of the plates increases the corrosion rate and decreases the service life of a battery suffering from acid stratification.*

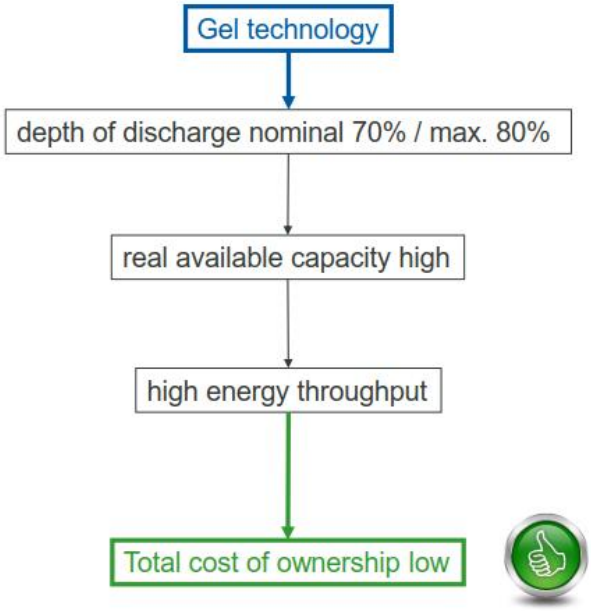


Capacity:

- ***In most cases the nominal capacity of Gel and AGM batteries are different at comparable box size.***

- *AGM batteries commonly display a higher nominal capacity as their set of plates is assembled with a high compression rate, which results in a compact construction. Nevertheless, the real available capacity per cycle is lower, because the maximum depth of discharge (DOD) is often limited to 60% to ensure the cyclability.*

- *Gel batteries must have an adequate distance in between plates to ensure sufficient Gel fills the space. Therefore, the nominal capacity - relative to the box size - is normally lower than for AGM batteries. However, the real available capacity of Gel batteries is in most cases higher than that of comparable AGM batteries, because a DOD of 70% up to 80% is permitted.*

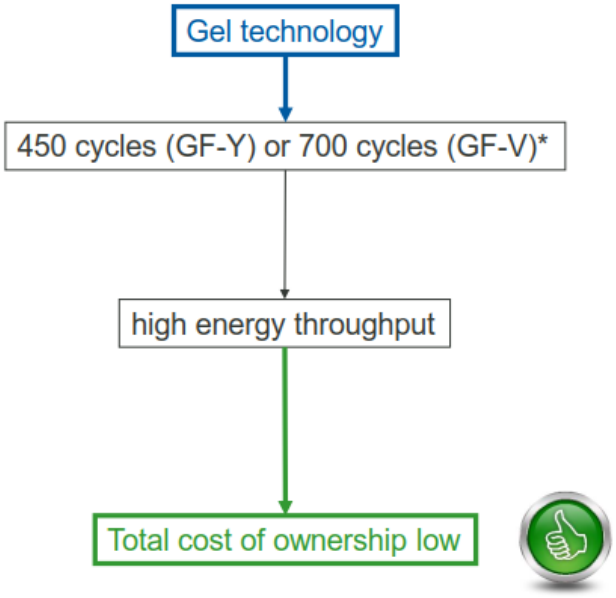


Cyclic endurance:

- ***dryfit® Gel batteries offer more cycles and higher energy throughput over their lifetime than AGM batteries.***

- *The cyclic endurance of the different AGM batteries has a wide range; an average value is 350 cycles (IEC 60254-1). More cycles can be achieved if the depth of discharge is decreased to 60% or lower. Therefore, AGM batteries offer significantly lower energy throughput over the lifetime than Gel batteries.*

- *dryfit® Gel batteries are available in two different ranges with a cyclic endurance of 450 cycles (GF-Y) or 700 cycles (GF-V) at 70% DOD in compliance with IEC 60254-1 (standard for traction batteries). The energy throughput over the lifetime is therefore higher compared to AGM batteries.*

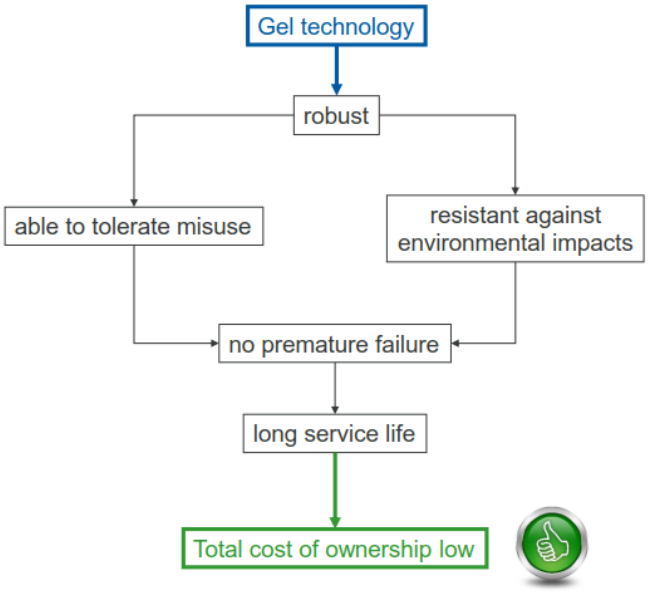


Robustness:

- ***dryfit® Gel batteries are more robust than AGM batteries.***

- *Robustness means batteries have a long service life, even under harsh conditions like increased operating temperatures, heavy cyclic load and sometimes-deep discharge events.*

- *dryfit® Gel batteries are much more robust when encountering these stress factors than AGM batteries, where a small distortion of this precariously balanced battery system can cause an accelerated capacity loss and premature failure.*



High currents:

- ***In most cases, AGM batteries can handle higher currents than Gel batteries of the same box size.***

- *Due to their method of construction and design, the distance between the plates inside AGM batteries is quite low therefore AGM batteries can handle quite high currents. Nevertheless, this characteristic does not result in longer running time in real applications.*

- *Inside Gel batteries the distance between the plates is greater compared to AGM batteries. Therefore, the maximum currents are lower. Normally this has no negative impact on the running time in a real application. If higher currents are really needed for the application, a Gel battery with higher capacity should be chosen.*

TPPL:

- ***Thin-Plate Pure-Lead (TPPL) Technology, also known as pure lead batteries, are AGM batteries and share all benefits and drawbacks with them***

- *In TPPL batteries, thinner lead plates are used to increase the capacity and peak currents. At the same time, the corrosion is decreased by a very low alloy content (pure lead).*

- *However, lead grids with very low alloy content still corrode. In TPPL batteries, the grids are so thin that an early failure cannot be excluded. Additionally, the thin lead grid does contain a smaller amount of active mass that has also a smaller contact area where it is attached to the grid. These effects sum up to a potentially reduced lifetime of such a battery*

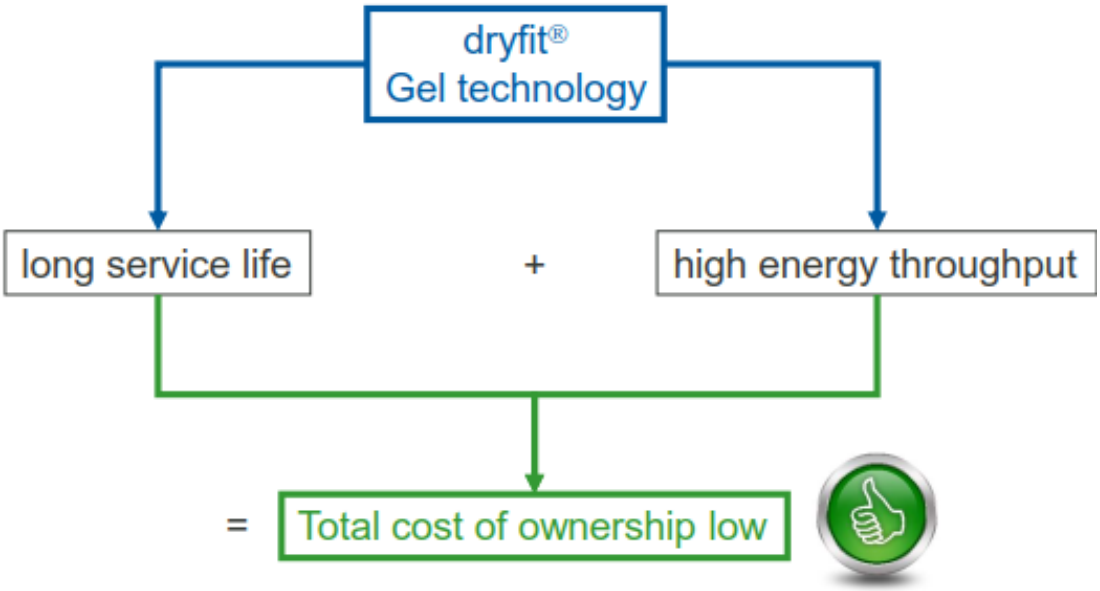
Technical overview

In the table below, you can find the summary of the behavior of the two types of batteries, concerning the different technical aspects.

	GEL	AGM
Amount of electrolyte	**high** use of the entire available cell volume	**limited** use of the available glass matt volume
Heat capacity	**high** excess of electrolyte	**low** 15-20% lower amount of electrolyte compared to Gel
Deep discharge protection	**high** growth of lead-sulphate dendrites is suppressed	**low** growth of lead-sulphate dendrites is promoted
Acid stratification	**negligible** effective acid absorbtion during the recharging process	**problematic** acid absorbtion effectiveness low during the recharging process
High currents	**moderate** distance between plates high	**high** distance between plates low
Service life	**high** low acid density, low corrosion rate moderate average operational temperature	**moderate** high acid density, higher corrosion rate higher average operational temperature

CONCLUSIONS

In conclusion, the Gel dryfit® batteries can ensure a long service life and high energy throughput, offering in this way a low total cost of ownership.



Source: Exide technologies

Exide Technologies is one of the largest battery manufacturers with operations in more than 80 countries.

GNB® Industrial Power - a division of Exide Technologies - offers a wide range of energy storage products and services, including solutions for forklifts and electric vehicles.

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