



GRAVITY GUARD

New Research Into the
Additional Benefits of
the Anti-Stratification
Additive GravityGuard®

HAMMOND
THE CHANGE CATALYST®

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2408

EXECUTIVE SUMMARY

Following the successful introduction of GravityGuard® to the lead acid battery market, Hammond engaged a respected scientific institute to characterize and evaluate the lead monosilicate material more thoroughly. Beyond the stratification reducing benefits seen in the earlier work, these controlled studies found that GravityGuard® can also improve CCA performance, 2C capacity and extend 17.5% PSoC Cycle Life. We believe that these improvements are significant and may offer value to battery manufacturers and their products.

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BACKGROUND

In 2021 Hammond introduced an innovative lead monosilicate (LMS) material, GravityGuard® to the lead acid battery marketplace. This material was shown to be able to reduce the level of acid stratification in flooded batteries, particularly when subjected to partial state of charge cycling regimes (**FIG. 1**). This was attributed to the network of a silica gel structure created inside the active material (**FIG. 2**). There was also an indication that GravityGuard® may have a positive impact on CCA performance when added to the PAM (**FIG. 3**). This benefit was likely due to the increase in BET surface area realized in the PAM with the addition of GravityGuard® (**FIG. 4**). These findings were presented in the Summer 2021 issue of *Batteries International*. For this work Hammond was recognized by BCI with the 2021 BCI Sally Breidegam Miksiewicz Innovation Award.



NEW AND CONFIRMED FINDINGS

In 2023, Hammond engaged the Institute of Electrochemistry and Energy Systems of the Bulgarian Academy of Sciences (BAS) to conduct a deeper assessment of the LMS material. The aim of the study was to confirm some of the benefits discovered in Hammond's

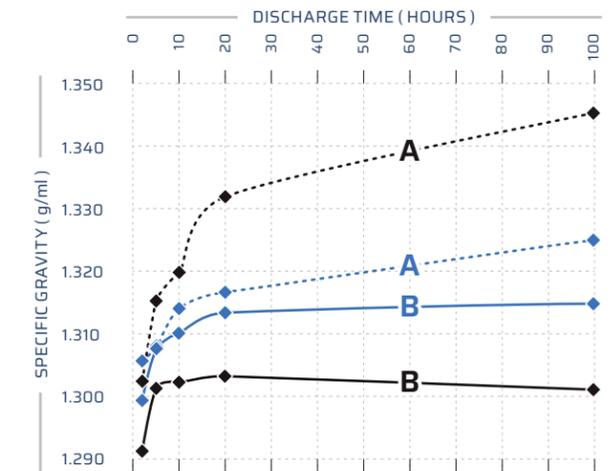


FIG. 1

Plant Scale Stratification Study: Group 27 Flooded

Control Silicate

Bottom of Cell Gravity After Full Recharge

Top of Cell Gravity After Full Recharge

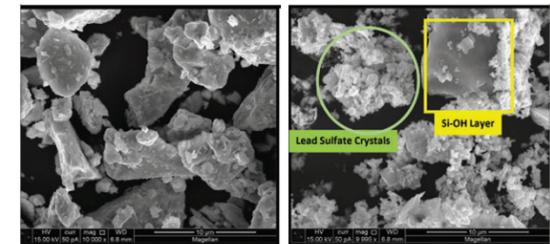
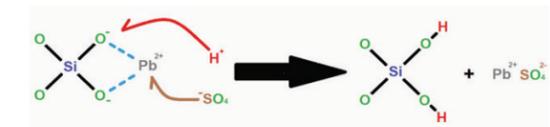


FIG. 2

Silica Gel Structure

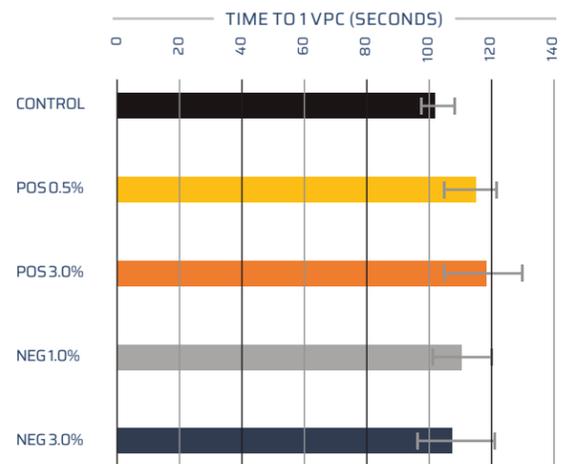


FIG. 3

Cold Crank Seconds to 1VPC

FIG. 4

Surface Area by BET Measurement

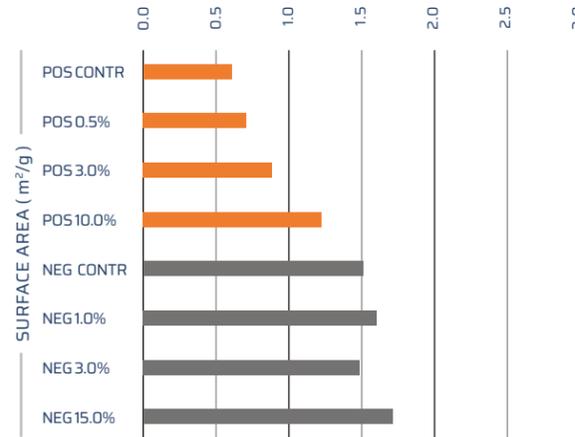


FIG. 5

• EN 50342 CCA
• Voltage at 10s of Stage 1
• $I_1 = 10XC_n$
• $I_2 = 0.6 I_1$ Amps;
• Avg. of 2 Cells
• PAM Loaded Cells

Run 1
Run 2

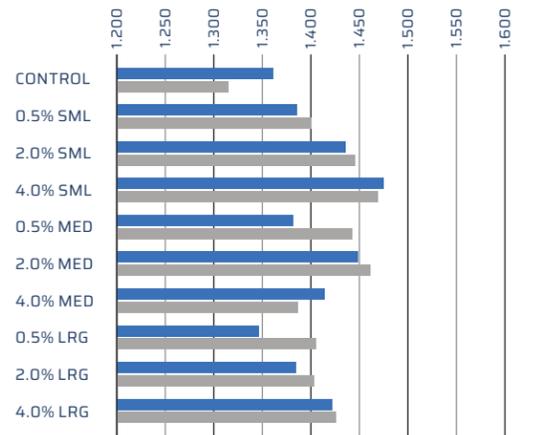
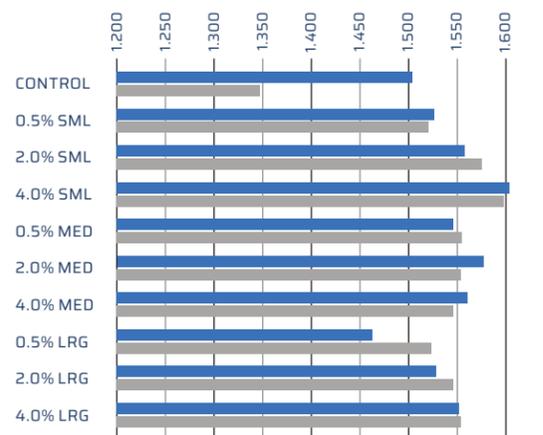


FIG. 6

• EN 50342 CCA
• Voltage at 30s of Stage 2
• $I_1 = 10XC_n$
• $I_2 = 0.6 I_1$ Amps;
• Avg. of 2 Cells
• PAM Loaded Cells

Run 1
Run 2



earlier work as well as to evaluate the material under additional conditions to explore its potential more fully.

Experiments were commissioned employing a Design of Experiments (DOE) format using 2V / 4.5 AH flooded cell configurations. Cells were built using “standard” SLI automotive type materials and characteristics (expander, paste densities, etc.) Cells were built with the following variables:

- Three different LMS loading levels (0.5%, 2%, 4%);
- Three different LMS particle sizes (small, medium, large);
- PAM limited cells (2p/3n) with PAM loaded LMS;
- NAM limited cells (3p/2n) with NAM loaded LMS.

All cells were built and tested at BAS with LMS material supplied by Hammond. Through this study exciting new performance benefits were discovered as well as a confirmation of characteristics seen in previous Hammond studies.

LMS IN THE PAM

With LMS loaded into the PAM in PAM limited cells (2p/3n) clear improvement was seen in the CCA (EN) performance. This confirmed the earlier findings at Hammond. Additionally, improvement was seen in 2C capacity performance. Both the CCA and 2C performance improvement increase with loading level and track well with the resulting increase in BET surface area and porosity enabled by the LMS. The CCA performance comparison is shown in (FIGS. 5-7). (FIG. 8) is an example of a full comparative CCA voltage / time plot for



In this new testing, GravityGuard® was found to improve CCA performance, 2C capacity and extend 17.5% PSoC Cycle Life. This is all in addition to the stratification reducing benefits the product was originally created for.

one of the LMS particle sizes. (FIG. 9) presents an example of the 2C voltage / time performance. (FIG. 10) clearly shows the increase in PAM BET surface area with LMS loading % and (FIG. 11) shows a similar trend with porosity. With respect to particle size, the small and medium size showed the greatest impact. It is noted that at the highest loading level studied (4%) a slight decrease in C20 performance was seen which can be attributed to the relative weight % displacement of lead by the LMS (plates pasted to same overall weights.)

LMS IN THE NAM

When looking at the NAM doped / NAM limited (3p/2n) cells, a different performance advantage was discovered. A significant improvement in 17.5% DoD cycle life (Continuous) was found specifically in cells at the 0.5% and 2.0% loading levels using small and medium particle sizes as seen in (FIG. 12). Although the exact mechanism for the improvement has not been confirmed we believe it is in

FIG. 7

• EN 50342 CCA
• Total Duration / Sec
• $I_1 = 10XC_n$
• $I_2 = 0.6 I_1$ Amps;
• Avg. of 2 Cells
• PAM Loaded Cells

Run 1
Run 2

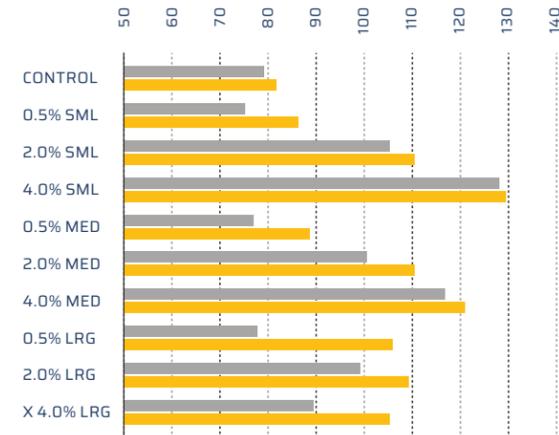


FIG. 8

• CCA EN
• $I_1 = 10XC_n$ A
• $I_2 = 0.6 I_1$ A
• Run 1
• PAM Loaded Cells

Control c1
Control c2
0.5% Small c1
0.5% Small c2
2.0% Small c1
2.0% Small c2
4.0% Small c1
4.0% Small c2

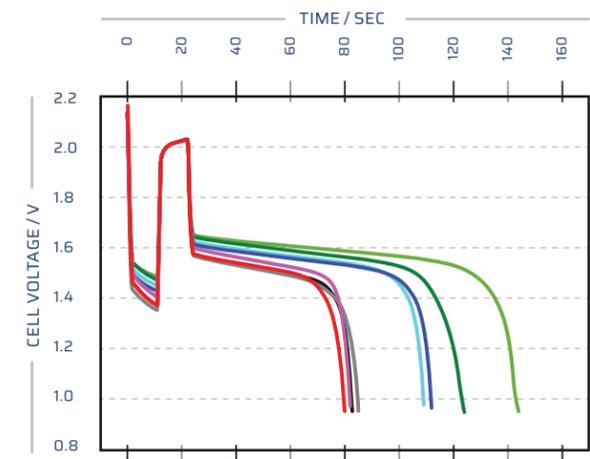
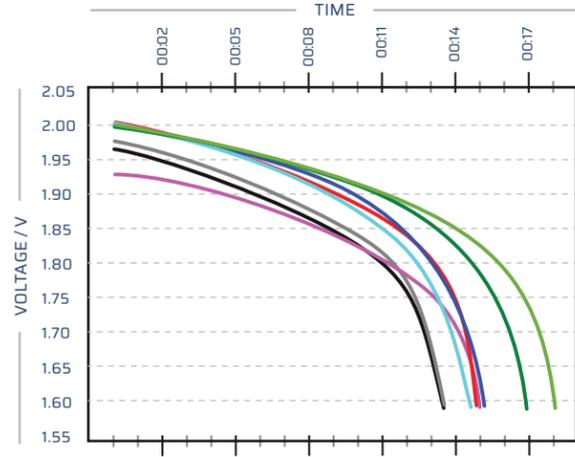


FIG. 9

- 2C
- PAM Loaded Cells

- Control c1
- Control c2
- 0.5% Small c1
- 0.5% Small c2
- 2.0% Small c1
- 2.0% Small c2
- 4.0% Small c1
- 4.0% Small c2



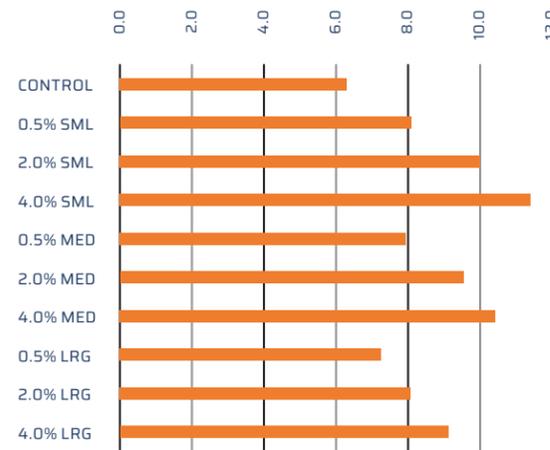
part due to the ability of the LMS to create localized gel zones that can inhibit stratification in the cell (FIGS. 1-2), a common failure mode on this test. Post cycle life SEM / EDX analysis showed that the LMS is still integrated within the NAM structure preserving its affect on the NAM (not presented here). Like the PAM, the LMS did increase the BET surface area of the NAM (FIG. 13), although the correlation to 17.5% performance was less significant. Although not directly measured no significant differences in

The PAM studies tested a range of GravityGuard® particle milling settings, with results indicating that small and medium-size particles offered the greatest performance advantage. Hammond mills the final product to custom particle sizes according to each manufacturer's formulations.



FIG. 10

- Formed PAM
- BET Surface Area, m2/g
- PAM Loaded Cells



water loss or gassing were noted with the LMS doped cells. It is noteworthy that the impact on 17.5% cycle life performance was not significantly effected with the PAM loaded cells, which supports the general view that improvements to the NAM can make significant differences in the overall performance on this test.

SUMMARY AND RECOMMENDATIONS

Testing showed that lead monosilicate, when loaded in the PAM, can be leveraged into automotive SLI and

Start/Stop/Hybrid applications for improved cold cranking performance. It may also show advantages in other applications, such as UPS, where high rate or high power capability, like 2C capacity, is important. Hammond recommends a doping of 2-4% in order to see the greatest improvement in CCA / High Rate performance. It should be recognized that at the higher doping rates a slight decrease in low rate capacity (C20) may be seen if the PAM is limiting and the LMS weight is not compensated for. At the higher doping rates (4%) some change in paste rheology may be seen. Addition of the LMS will generally increase paste penetration which can be adjusted for with slight reductions in water addition to the paste mix.

When used in the NAM, LMS can be used to benefit PSoC life for Start/Stop/Hybrid applications. It may also be considered for other applications, such as Solar, that commonly operate under PSoC conditions. The LMS can be evaluated either as a replacement or as a compliment to the advanced carbons commonly used in these applications. For these applications Hammond is recommending a loading level of 1%. At this level we believe that the expected benefits will be seen without a significant impact to gassing or paste rheology.

The studies indicate that the small and medium particle sizes offer the greatest performance advantage. Hammond can recommend the GravityGuard® particle size that is right for the targeted performance improvement.

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FIG. 11

- Formed PAM
- Porosity %
- PAM Loaded Cells

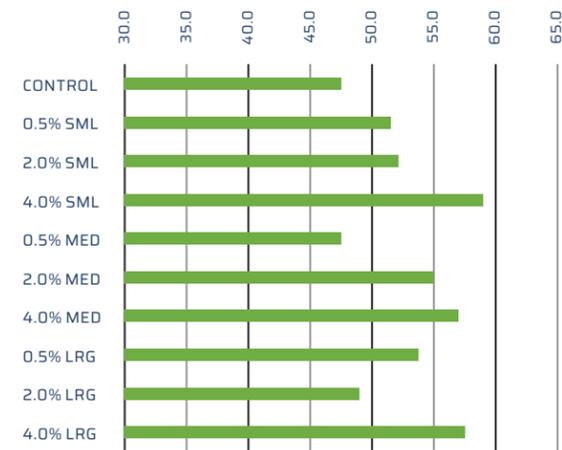


FIG. 12

- 17.5% DoD Cycle Life, Continuous
- EN 50342-6
- NAM Loaded Cells

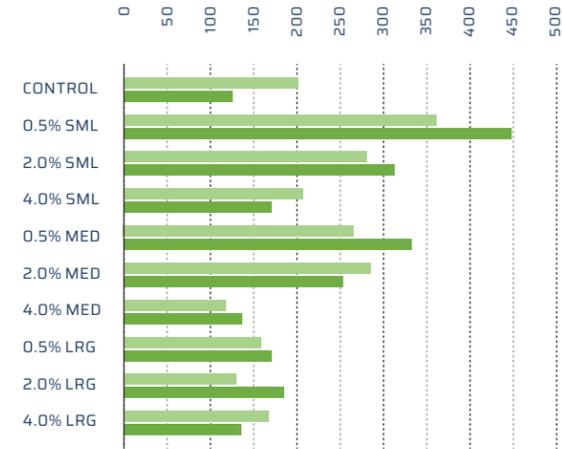
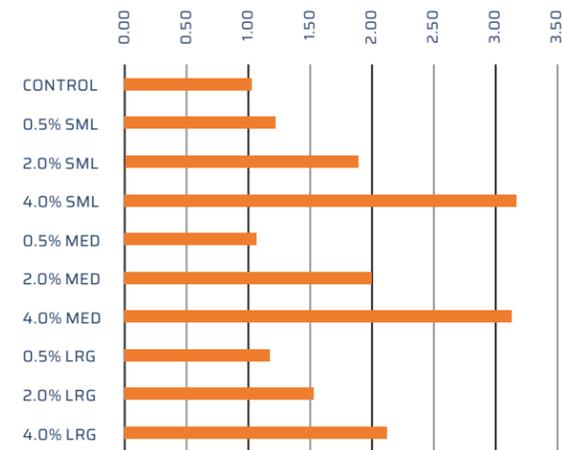


FIG. 13

- Formed NAM
- BET Surface Area, m2/g
- NAM Loaded Cells



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