dragonfly® ENERGY

# THE ROBUST WAY TO POWER LIFTGATES

## $LiFePO_4$ vs. LEAD ACID BATTERY PERFORMANCE


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# ABSTRACT

Liftgates are a common and essential component of transportation and logistics vehicles across many industries. Liftgate operators have been especially familiar with using and continually replacing lead acid batteries in the applications. This test compares the performance of two typical lead acid batteries and two Dragonfly Energy lithium iron phosphate batteries in a liftgate application based on the number of full lift and drop cycles it can perform at given weights and with a 10V cutoff. Both sets of batteries were tested at 0 lbs., 200 lbs., 500 lbs., 750 lbs., 1250 lbs., 1500 lbs., 2000 lbs., 2250 lbs., 2500 lbs., 2750 lbs., 3000 lbs., and 3250 lbs. The results show that lithium can perform more liftgate cycles at the given weights, has a longer lifespan, and has an overall lower cost as the amount of times a battery needs to be replaced in a liftgate application is greatly reduced when compared to lead acid.

# BACKGROUND

As a fundamental component of transport truck models, liftgates have served as a crucial part of logistics and last mile delivery for over 100 years. Allowing for items to be loaded and unloaded with ease has served various markets, both as factory-installed liftgates on many truck models and as after-market add-ons.

Historically, liftgates have been powered by lead acid batteries in a battery bank with dual purpose - liftgate function and chassis starter battery. Liftgate motor manufacturers state that nominal input voltage range is 8V to 16V [1], a problem when lead acid batteries have been the prominent way liftgates have been powered due to their recommended discharge. Lead acid batteries have a recommended discharge of just 50%, and with no voltage requirement set on liftgates, there can be consistent damage on those batteries, resulting in underperformance and a shorter lifespan.

"Liftgates have come a long way in the past 100 years or so, and changes are expected to continuously be made as new and better equipment comes out that allows for lighter weight designs, bigger weight capacities, and faster loading." [2] And better battery technology for liftgate applications is another advancement well-past needed in the industry. In fact, 80% of the problems liftgates users experience are tied to low voltage. [3] Drivers rely on idling to keep their liftgate batteries charged while loading and unloading goods. When idling the vehicle's engine is not preferred or an option at all, an operator becomes dependent on the chassis starter battery and runs the risk of depleting that bank.

If a liftgate is operated too many times without starting the engine or without idling during the entire stop, the driver can, and will likely, experience a starter battery that is depleted to a point where the motor will not be able to start. But there is another option to efficiently power the application long-term - $LiFePO_4$. With the increased usable capacity of lithium iron phosphate, or $LiFePO_4$, the starter battery and auxiliary or liftgate battery bank can be isolated from one another, allowing the operator to use the full capacity of the auxiliary bank without running the risk of depleting the starter battery.

In this study, the historic lead acid battery is compared to the performance and advantages of lithium iron phosphate, including long-term cost savings and increased capacity, in a liftgate application.

# LEAD ACID VS. LITHIUM BATTERY DISCHARGE

Battery manufacturers state that a lead acid battery should only be discharged to 50% to preserve the lifetime of that battery. "Lead-acid batteries are capable of deep discharge, although deep discharges will markedly impact the battery's life." [4] This means that cycling a lead acid battery is ideal in the 100% to 50% discharge window or to about 12.06V, as seen in Fig. 1.

Fig. 1 represents the readings taken via a voltmeter of a flooded lead acid battery. Cycling a lead acid battery within that safe zone, or 100% to 50% depth of discharge (DOD), will ensure a reasonable life expectancy of that battery. Occasionally discharge past the 50% mark, between 40% and 30%, is not recommended and repeated discharging to this range will shorten the battery life. And discharging to 20% and below will cause permanent damage to the lead acid battery and could kill the battery completely.

**REGULAR WET LEAD ACID BATTERY**

Readings taken via Voltmeter after resting for more than 2 hours (i.e., no charging or discharging)

| STATE OF CHARGE (SoC) | 12V | DoD Notes |
|---|---|---|
| 100% | 12.70 | Keeping your state of charge above 50% will give you the best life expectancy. |
| 90% | 12.50 | |
| 80% | 12.42 | |
| 70% | 12.32 | |
| 60% | 12.20 | |
| 50% | 12.06 | |
| 40% | 11.90 | May shorten battery life. |
| 30% | 11.75 | |
| 20% | 11.58 | Likely to damage battery capacity |
| 10% | 11.31 | |
| BELOW 10% DEAD | 10.50 OR LESS | |

**FIG 1.** Lead acid battery discharge voltage readings taken via voltmeter after resting for more than 2 hours (i.e., no charging or discharging). [5]

**VOLTAGE vs. CAPACITY**

For a Single Battery

| | |
|---|---|
| 14.4V | 100% |
| 13.6V | 100% |
| 13.4V | 99% |
| 13.3V | 90% |
| 13.2V | 70% |
| 13.1V | 40% |
| 13.0V | 30% |
| 12.9V | 20% |
| 12.8V | 17% |
| 12.5V | 14% |
| 12.0V | 9% |
| 10.0V | 0% |

**FIG 2.** Discharge voltage and remaining capacity taken of a single fully charged Dragonfly Energy $LiFePO_4$ battery.

An alternative solution is needed to increase run time and investment, and $LiFePO_4$ is the answer. While lead acids have limited discharge without harm to the battery, lithium iron phosphate, or $LiFePO_4$, offers 100% depth of discharge, giving them much more usability and a longer lifespan than the alternatives.

Fig. 2 below represents the voltage level of a lithium-ion battery and the remaining capacity available for each discharge voltage. A $LiFePO_4$ can be discharged to its full capacity, or to 10.0V, without causing damage to the battery and using the capacity in its entirety.

# LEAD ACID VS. LITHIUM BATTERY DISCHARGE

Along with the 100% depth of discharge in $LiFePO_4$ batteries, Dragonfly Energy lithium-ion batteries specifically offer 3,000 to 5,000 cycles and are equipped with a state-of-the-art battery management system, or BMS, to protect the battery from over discharge and other unsafe operating conditions to preserve the life of the battery.

# STATE OF THE ART BATTERY MANAGEMENT SYSTEM (BMS)

A battery management system (BMS) is designed to protect the lithium cells within a battery from becoming damaged. The proprietary BMS inside each model of Dragonfly Energy lithium-ion batteries protects against a number of damaging factors, including high and low voltage.

The BMS allows for 100 Amps continuous, 200 Amp surge for 30 seconds, and 0.5 second surge for loads over 200 Amps, and the system protects against the following conditions:

**HIGH VOLTAGE DISCONNECT (> 14.7V)**

If an individual cell voltage exceeds a prescribed threshold during charging, the BMS will prevent a charge current from continuing. Discharge is always allowed under this condition. If the batteries have not been balanced for a long time, high voltage disconnect could occur at a lower voltage. The batteries will rebalance after several full charges to a voltage between 14.2v and 14.6v.

**LOW VOLTAGE DISCONNECT (< 10.6V)**

If an individual cell falls below a prescribed threshold during discharge, the BMS will prevent further discharge. Although the battery is in "low-voltage disconnect" mode, it will still allow a charging current.

The high-low voltage disconnect capabilities of Dragonfly Energy's BMS is worth noting due to the lack of voltage requirements set by liftgate motor manufacturers. While these lithium-ion batteries will disconnect at a voltage less than 10.6V when operating a liftgate, lead acid batteries will continue to discharge with a great risk of damaging the batteries.

# THE EXPERIMENT

This test compares the performance of lead acid versus lithium iron phosphate batteries in a liftgate application. The test performed was based on load weight (up to the maximum weight of 3,200 lbs.) and how many lifts and lowers each battery bank could perform at various tested weights without a charge and without idling of the truck.

Two fully charged Dragonfly Energy 100Ah 12V lithium batteries (pictured in this paper under the direct-to-consumer brand, Battle Born Batteries) were tested at a depth of discharge of 100% compared to two fully charged flooded lead acid batteries of the same capacity. Because there is a nominal input voltage range of 8V to 16V on liftgate motors without a voltage cutoff and lead acid batteries have a 50% depth of discharge recommendation, this test was performed on both lithium ion and lead acid batteries with a consistent 10V cutoff—the same voltage that the internal BMS detects in Dragonfly Energy Batteries and then disconnects that battery to prevent unsafe operating conditions.

Each weight increment of 0 lbs., 200 lbs., 500 lbs., 750 lbs., 1250 lbs., 1500 lbs., 2000 lbs., 2250 lbs., 2500 lbs., 2750 lbs., 3000 lbs., and 3250 lbs. was placed on the liftgate in the down position. The liftgate was lifted and then lowered, never exceeding the 10V cutoff during operation, testing the number of cycles (lift and lower) at each weight.

# THE RESULTS

The following results in Fig. 3 demonstrate the number of cycles (lift and lower) the liftgate was able to perform with the two flooded lead acid batteries (at a 10V cutoff) compared to the two 100Ah 12V LiFePO4 batteries at various load weights.

These results show the increased number of full cycles the liftgate was capable of when when powered by lithium versus lead acid.

Two 100Ah 12V Battle Born LiFePO4 Batteries, the direct-to-consumer brand of Dragonfly Energy.

At 0 lbs., the liftgate performed 528 full lift and lower cycles with lithium, a 54% increase compared to 342 cycles when lead acid was used. At 1,500 lbs., lithium performed 252 full cycles and lead acid performed 163, also a 54% increase with lithium.

Overall, this test resulted in lithium performing 54% more cycles than lead acid batteries.

## THE RESULTS

**LIFTGATE AMP DRAW AND EXPECTED CYCLES**

| Weight | Time Up(s) | Average A Up | Cycle Time with Down(s) | Ah Expected | 2 DF10012s Cycles | 2 Lead Acid Cycles |
|---|---|---|---|---|---|---|
| 0 | 8.67 | -105.23 | 14.71 | 0.38 | 528 | 342 |
| 200 | 9.12 | -110.67 | 15.16 | 0.41 | 493 | 320 |
| 500 | 9.77 | -121.36 | 15.80 | 0.45 | 440 | 285 |
| 750 | 10.25 | -126.41 | 16.28 | 0.48 | 413 | 267 |
| 1250 | 11.40 | -164.52 | 17.43 | 0.65 | 310 | 201 |
| 1500 | 13.68 | -175.95 | 19.71 | 0.79 | 252 | 163 |
| 2000 | 14.55 | -181.49 | 20.58 | 0.86 | 233 | 151 |
| 2250 | 14.86 | -185.84 | 20.90 | 0.89 | 224 | 145 |
| 2500 | 16.01 | -190.00 | 22.04 | 0.97 | 206 | 134 |
| 2750 | 17.22 | -195.00 | 23.26 | 1.06 | 189 | 123 |
| 3000 | 18.50 | -205.00 | 24.53 | 1.18 | 170 | 110 |
| 3250 | 19.84 | -215.00 | 25.88 | 1.31 | 153 | 99 |

**FIG. 3.** Calculated time in liftgate application when lift moves up and full cycle time (up and down) and number of full cycles completed up to 3250lbs. at a 10V cutoff with two DF10012s and two flooded lead acids.

## VOLTAGE DROPOFF - PEUKERT'S LAW

In addition to the increased performance of lithium-ion batteries compared to lead acid in the experiment and the nominal input voltage range of 8V to 16V on liftgate motors that will cause permanent damage to those lead acid batteries over time, it's also important to note the Peukert Exponent and the effects it also has on the performance of lead acid.

# VOLTAGE DROPOFF - PEUKERT'S LAW

Peukert's Law explains how the rate of discharge in a battery influences its actual capacity. The law shows that if you run a battery at a high rate of discharge, then its internal resistance creates a voltage sag which shortens how long that battery will last. [6] Peukert's Law has a much greater effect on lead acid than it does on lithium, shown in Fig. 4 below.

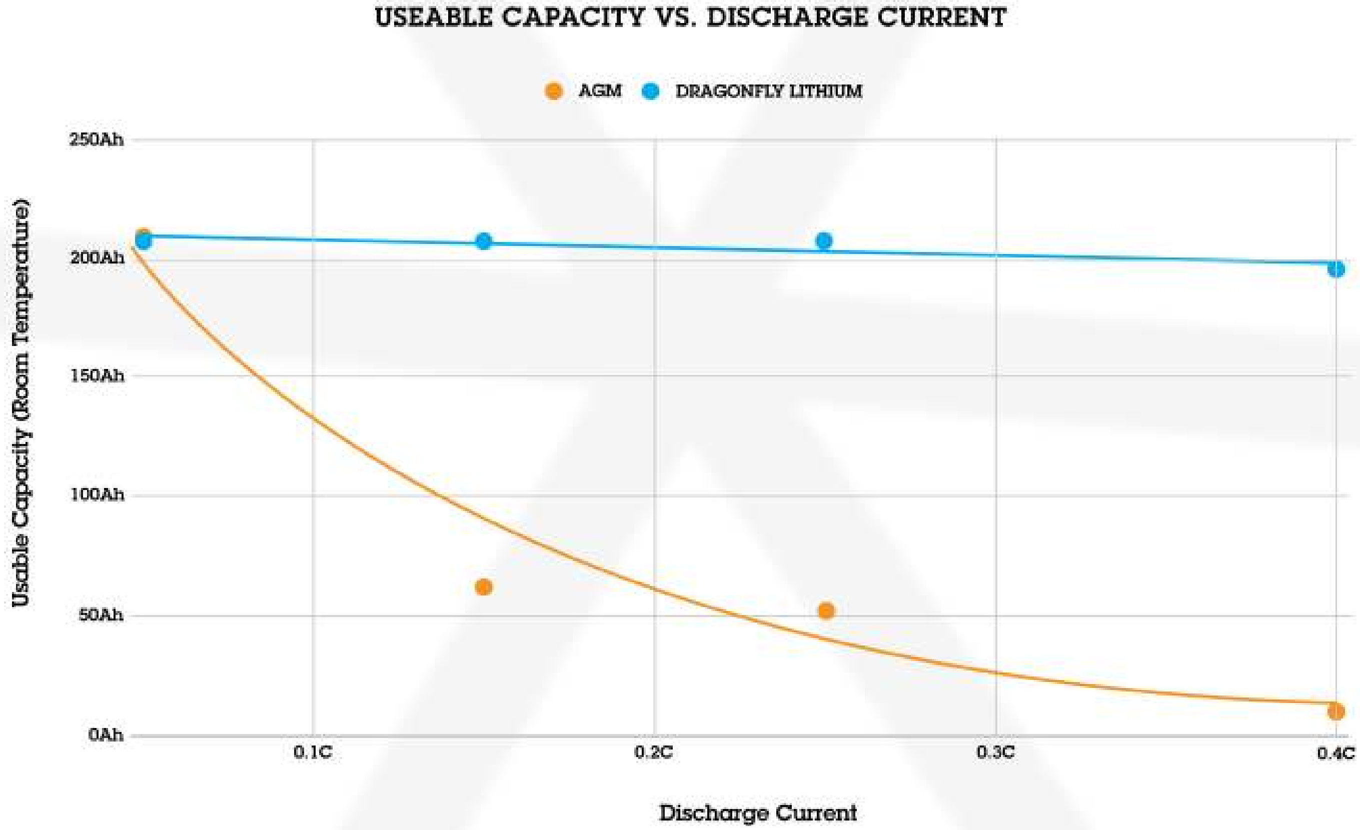


**FIG. 4.** Results explaining the Peukert Exponent—the usage capacity versus the discharge current of a lead acid battery and a Dragonfly Energy $LiFePO_4$ battery.

In the liftgate instance, the application requires a high rate of discharge, causing the lead acid batteries to suffer from the Peukert effect, meaning the liftgate does not actually get all the energy that the batteries are putting into it.

# CONCLUSION

The results of this study demonstrate that lithium-ion batteries outperform lead acid in a liftgate application with complete discharge (with a 10V cutoff) based on the number of full cycles the liftgate is able to perform. Lithium also has the BMS to protect its lifespan and will outlast the competition, while lead acid continually experiences a 100% and 10V discharge, causing permanent damage and a shorter lifespan.

With these results and with lithium performing 54% more cycles than lead acid, we can conclude that lead acid batteries will need to be replaced more often than when lithium is used in a liftgate application, resulting in higher costs long-term.

For example, at 1250 lbs., lithium would perform 310 liftgate cycles in one day while lead acid would perform 201 liftgate cycles in the same time period, assuming that the lead acid battery can reach its rated battery life cycles of 1,000. At the same weight, lithium would perform 9,455 liftgate cycles in one month while lead acid would perform 6,405 cycles. In one year, lithium would perform 113,150 liftgate cycles and lead acid would perform 73,000 cycles. And in the lifetime of the lithium battery (5,000 cycles), it would perform approximately 1.5 million liftgate cycles while lead acid would perform approximately 201,000 liftgate cycles at its expected lifespan (only 1,000 battery cycles).

While this test was performed to find the limits of these two different battery types under ideal circumstances for fair results—with a constant 10V cutoff, a controlled environment, and consistent outside factors—there are several outside variables in real world situations that would affect the performance of lead acid. Therefore, the above liftgate cycle expectancies are estimated based on the circumstances of the test, and outside factors would inevitably work against the performance of lead acid.

So, although these are expected outcomes based, this test proves that liftgate operators would be purchasing between 7 and 8 life cycles of lead acid batteries compared to just 1 life cycle of a Dragonfly Energy lithium-ion battery.

In a battery test study performed by Mortons of the Move, the cost of lithium was compared to lead acid over the course of the lifetime of each type of battery. [7] In Fig. 5 below, the results show that at 100% depth of discharge (the same discharge performed in this experiment), a Dragonfly Energy lithium battery cycled 5,000 times while a flooded lead acid cycled 100.

When you compare those results and the cost of each battery, lithium costing $900 and lead acid costing $90, you conclude that lithium has a lower cost of only $0.18 per cycle while lead acid at $0.90 per cycle.

# CONCLUSION

Ultimately, this study proves that not only does Dragonfly Energy lithium iron phosphate outperform flooded lead acid, but over the course of its lifetime, also costs less than the continual use and replacement of lead acid.

**MANUFACTURER INFORMATION**

| Name | Cost per Battery | Rated Capacity AH | 50% Cutoff Voltage | 80% Cutoff Voltage | 100% Cutoff Voltage | Lifecycles 50% DOD | Lifecycles 80% DOD | Lifecycles 100% DOD |
|---|---|---|---|---|---|---|---|---|
| DF10012 | 900 | 100 | N/A | N/A | 11.8 | 12000 | 7000 | 5000 |
| Flooded | 90 | 105 | 12 | 11.6 | N/A | 800 | 300 | 100 |

**FIG. 5.** This data compares the cost, rated capacity at 20-hour discharge (for the lead-acid), recommended cutoff voltages from the manufacturers, and expected life cycles from the manufacturers for Dragonfly Energy $LiFePO_4$ and flooded lead acid batteries.

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