



firefly
energy

Oasis™ BCI Group 31 Truck Battery

White Paper

Microcell Technology™
Powering the Future
of battery technology

Oasis™ Group 31 battery outperforms conventional lead-acid batteries:

- 50% greater deep cycling performance
- Recharges up to 3 times faster
- Supplies a 45% increase in energy density
- Delivers 65% of rated power capacity at -20° C
- Highly resistant to corrosion, sulfation and vibration

RD 100 Winner of the 2007 R&D 100 Award

Winner of the Wall Street Journal 2007 Technology Innovation Award

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Introduction

The enactment by the state of California of stringent anti-idling requirements beginning January 1 2008 is the latest major example of cities and states that are implementing diesel pollution standards which pose significant challenges to trucking companies and drivers alike. Drivers who relied on running their diesel engines at night to power their sleeper cabs' "hotel loads" (air conditioning, lights, TV, etc) now have to find alternative methods of maintaining comfort and convenience while they rest. One alternative is to rely on batteries to provide engine-off power to these loads. However, classic "Group 31" sized lead acid batteries, which have historically been bought by trucking industry based on "Cold Cranking" (CCA) and low price, won't stand up to the repeated daily strain of full discharges and recharges. A more robust battery solution is needed.

Firefly Energy is bringing the most powerful and longest running BCI Group 31 battery to the trucking industry in 2008. By taking advantage of Firefly Energy's unique carbon foam cell architecture, the new Oasis™ Group 31 battery is capable of powering



"engine-off" overnight loads without the fuel consumption, pollution, and maintenance issues associated with heavier diesel auxiliary power units. The Oasis battery offers the highest continuous reserve capacity, and the fastest recharge capability of any battery available to the over the road trucker today. In addition to power, Oasis will last three times longer than current Group 31 batteries. The carbon foam powered Oasis battery--based on Microcell technology--makes lead-acid batteries obsolete.

Battery Objectives and Challenges

In the design of any high performance battery, there are always four major overriding objectives:

- 1) Maximize specific energy (energy storage per unit of weight, measured in watt-hours per kilogram) over designated discharge scenarios.
- 2) Maximize the specific power (power per unit of weight, measured in watts per kilogram) over designated high rate discharge scenarios.
- 3) Maximize battery life, not only in environmental durability but most importantly in cycle life (number of possible charges and discharges).
- 4) Do it all at the lowest possible cost.

The final point has traditionally driven lead acid battery producers to the use of low cost lead materials, which of course has limited the first three criteria. Given the long-standing use of lead metal, improvements in battery current collector (i.e., grid) design

and advances in lead-alloys appear to be reaching a plateau. There are long-standing problems with lead acid batteries which will prevent the successful use of this battery type in engine-off support of trucking loads, as described below.

Major Problems with Classic Lead Acid Batteries

Cycle Life – (# of discharges/charges) As users have come to know portable battery products in cell phones and laptop computers, they have correspondingly become comfortable with the process of bringing a battery down to almost “0” charge and then bringing it back to full, complete charge and power capabilities within hours. Traditional lead-acid batteries, because of their inherent design and active material utilization limitations, only provide relatively good cycle-life when less than about 80% of the rated capacity is removed during each discharge event in an application. A battery of this type suffers a significant decrease in the number of times it can be discharged and recharged when 100% of the rated capacity is consumed during a single discharge in an application. Many new products that historically used lead-acid batteries are now requiring a significant jump in cycle life. The repeated daily discharge of a classic lead acid battery is a punishing application which dramatically shortens that battery’s cycle life, which, absent a better battery solution, leaves trucking companies with no choice but to increase the frequency of lead acid battery purchase and replacement.

Sulfation Build-Up - When a lead acid battery is left or kept in a partially or fully discharged state for a period of time, the lead chemistry forms large lead sulfate crystals which are often referred to as hard lead sulfate. This low surface area, non-conductive lead sulfate blocks the conductive path needed for recharging. Even a well maintained battery will lose some capacity over time due to the continued growth of large lead sulfate crystals that are not entirely removed during each recharge. So while a trucker might have the first full night’s use of a battery-powered supplemental air conditioning system, subsequent nights will see a continued drop in run time, due to the inability to bring the lead acid battery back to 100% state-of-charge. Eventually, the battery can no longer accept a charge, is irreversibly damaged, and must be replaced.

Cold Temperature Battery Capacity – Anyone who has started a car in the depths of winter knows the “rer-rer-rer” sound. That is due to the fact that the capacity of a lead acid battery at 70 degrees Fahrenheit falls rapidly as temperatures drop. At minus 20 degrees, a lead acid battery has a small fraction of its normal capacity to support starting and run time, due to the basic limitations of the lead metal grids inside the battery to efficiently convert the chemistry into energy. This problem is magnified in diesel truck engines, as their high compression and sheer size makes them much tougher to start than automobile engines.



Hot Temperature Life Reduction – Batteries which are operated in the southern United States have much shorter life than batteries operating in northern climates. This is due to the fact that heat accelerates the rate of lead metal corrosion inside the battery. To allow for this fact, some batteries are made with thicker lead metal grids, which provide longer life. However, the trade-off is a sacrifice in power density, cost, and battery weight. Trucking companies are sensitive to weight increases, however, and have coped in the past by actually reducing the number of on-board lead acid batteries. The results however have been increased starter and alternator damage due to weak starting voltage.



In summary, the classic lead acid battery long ago reached a performance plateau. Lead acid batteries have always faced severe trade-offs with respect to power, capacity, weight, life, and cost. To make an advance in battery technology that goes beyond evolutionary engineering improvements requires a paradigm shift to new materials and/or new processes. Firefly's Microcell carbon foam technology breaks through these constraints and creates a much higher set of trade-offs, enabling new levels of performance, reliability, and affordability, while removing almost all limitations of current lead-acid battery products.

As outlined below, Firefly's "Oasis" battery holds significant benefits over any conventional Group 31 lead acid truck battery currently available to the trucking industry. In conjunction with a battery APU (auxiliary power unit), Oasis offers a substantial and multi-faceted value proposition to the trucking industry:

- Unprecedented cycle life; laboratory testing showed over 1000 cycles at 100% DOD (Depth of Discharge); something never before achieved by classic lead acid batteries.
- Strong reserve capacity at over 215 minutes; consistent full capacity throughout life, not just the first time discharged.
- Increased power and energy density improvements of 25%-30% over the closest competitors.
- Superior cold weather performance with 20% to 40% improvements in capacity.
- Dollars per cycle at 1/2 the cost of the best performing lead acid battery alternative.
- The Oasis battery significantly lowers environmental impacts of lead use compared to traditional lead acid batteries.

Can you afford to stay with the cheap alternative with the upcoming challenge of daily "key-off" deep-discharge battery applications"? Read on and decide for yourself.

The Technology

The key to Firefly's technology lies in the replacement of the heavy, poor conductive lead metal negative grid in lead-acid batteries with something new. In place of the conventional grids, Firefly's Microcell technology uses a lightweight, carbon-based material having an extremely porous "foam" structure that provides approximately 2000 times the surface area of a lead metal grid. The many benefits of this new "architecture" to the battery, and more importantly to the end user, are discussed in the following.

Group 31 Market Performance Analysis

There are significant attributes of Firefly Energy's technology that provide a variety of benefits to the trucking industry. The basic question that we shall address in this White Paper is the following: How much better is Oasis than a conventional lead acid battery in an APU application, and how does this impact the bottom line in terms of operational costs? We all know that historically, when it comes to lead acid batteries, warranties have been a pro rata sales tool to sell a replacement battery. The fine print in most warranties requires strict monitoring and records with regards to maximum discharge percentages, temperature, cycles, recharge, and rates. You can talk about cycle life, depth of discharge limits, user abuse, manufacturer failure analysis, long term storage at low state of charge, and the list goes on. To get to the true value of a battery and reduce the risk for the end user as well as the manufacturer, you must address the root causes of battery failures and reduce or eliminate those failure modes that give rise to them. Only in this fashion can the real cost benefits to everyone be established and recognized. For the purposes herein, let's address each of the attributes of the Firefly Oasis and define the risk reduction and reward as compared to the conventional lead acid batteries that are available in the market today in the Group 31 truck battery format.

Power and Energy Density Comparisons

You might ask yourself, what do power and energy density have to do with failure mode reductions and what benefits do I obtain? In any given application in the trucking industry where Group 31 batteries are used, there is a known need for power (i.e. "watts" for no-idle solutions or hotel loads), or plain cranking "amps" (to turn the engine). If the battery supplying that power were oversized (which it cannot be in a trucking application due to the use of the commonly sized Group 31), or in Firefly's case more energy and power in the same volume of space, then the strain on the battery, or ratio of energy demanded over energy available, is reduced. This results in shallower depths of discharge (DOD) for a known load. As will be discussed later, Firefly technology will allow these lower DOD's with minimal effects on the life of the battery. In order to compare classic lead acid battery technology to Oasis, Firefly purchased a variety of Group 31 batteries now on the market and considered the "BEST" in the industry.

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Figure 1 shows how the energy and power performance values stack against Firefly as tested side by side on the identical test equipment in the same environment.

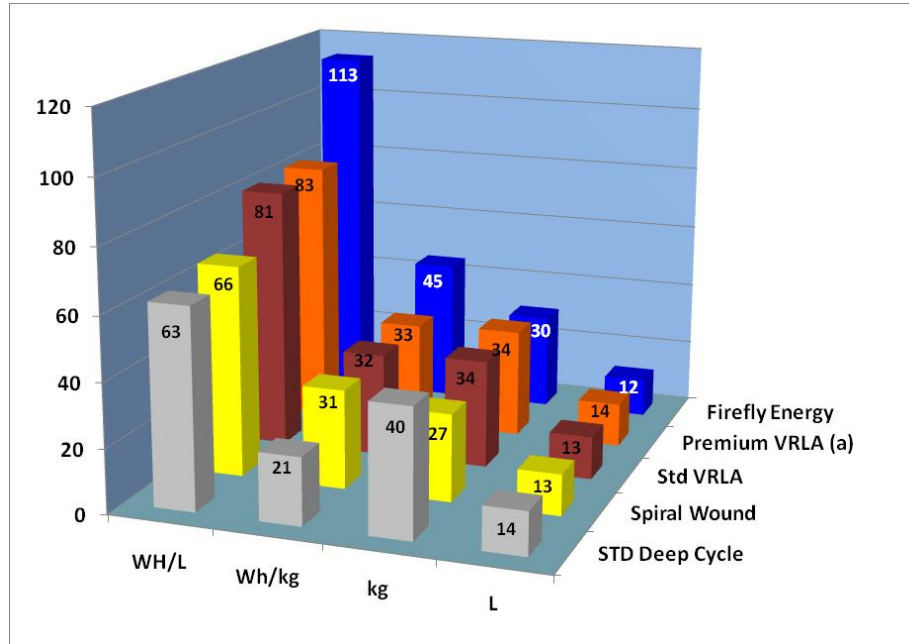


Figure 1 - Energy and Power Density Comparisons

As can be seen in this graph, the Firefly Oasis battery is clearly superior in all important power and energy measurements. This is a direct result of the high surface area microcell foam structure, which lowers weight and increases energy capacity. Oasis outperforms every lead acid product on the market today. What this means for the end-user is twofold. Either longer run times are gained for the equipment being utilized in the truck, or the option is allowed for adding additional equipment without impacting current product performance, run times, or battery life. The actual values tested for reserve capacity will be discussed in a later paragraph.

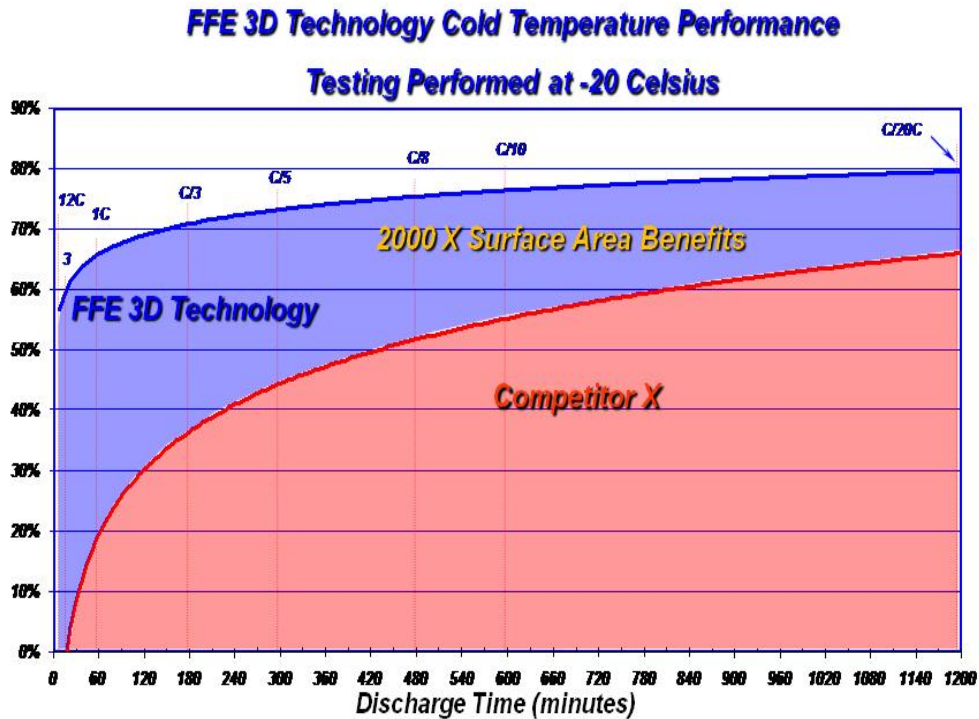
Superior Cold Weather Performance

Every battery, regardless of technology, is an energy storage device that performs an electro-chemical reaction in which ions are shuffled between the positive and negative electrodes. The law of kinetics applied in chemical reaction rates is best described by the Arrhenius equation which is a simple, but remarkably accurate formula for the temperature dependence of a chemical reaction rate. So what does all this technical mumbo jumbo mean? When it gets cold the battery's chemical reactions slow down, and if it gets cold enough, they virtually stop. Let's face it, batteries do not work well in cold weather.....or do they? When you discharge a battery, the initial chemical reaction is taking place on the surface of the negative plate. The more surface area you

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have in contact with the electrolyte, the more instantaneous energy you have available. The reason why super and ultra capacitors work so well in cold weather is that there is a tremendous amount of surface area in contact with the electrolyte due to very thin plates and lots of them. So, if a battery company could devise a method by which to significantly increase the lead surface area of the negative electrode you would have a battery that looks like a super capacitor at the beginning of a high rate discharge. As previously stated, the Firefly battery uses a carbon foam negative electrode that provides approximately 2000 times the surface area of a traditional lead metal plate. This surface area results in the significant increase in instantaneous power of Firefly's Oasis battery. So at cold temperature, instead of having to oversize a standard battery that only delivers roughly 20% of nameplate (measured at room temperature) capacity at -20°C in order to meet the power requirements, the Firefly battery effectively has a "super capacitor-like" capability designed into its electrode. So how does this help the trucking industry with the Group 31? Figure 2 below shows the comparisons of traditional lead acid batteries at -20°C as compared to discharge rates with C-Rate being the rate at which the battery delivers 60 minutes of runtime to 100% DOD. For the no-idle solution, most battery APUs shut down at a voltage of around 80% DOD. As can be seen in the figure, at a ten hour (C/10) discharge rate, a typical lead acid battery can only deliver 55% of its rated capacity as compared to 75% for Firefly. What this means is that to the same discharge voltage point, you will get upwards of 20% more cold temperature run time under the same load

The comparative test results show Firefly technology holding a 6 fold improvement in cold temperature performance at a one hour (1C-rate) discharge, retaining over 65% of rated capacity. What this means is significant power to the starter in cold weather. Low battery voltage while cranking for more than 15 seconds can cause serious damage to the starter in which the internal windings begin to melt. Truck alternators are designed to recharge a battery after starting the vehicle. They are NOT designed to recharge a battery from a completely discharged state. In recharging a completely depleted battery, the alternators operate at maximum current output much longer than they are designed to do, thus increasing wear on the alternator which can significantly shorten the component's life. Note, that the current Firefly G31 battery is a deep discharge (i.e. maximized run time) battery.



Note: Tested batteries were a high C-Rate design

Figure 2 - Cold Weather Performance

Life comparisons and analysis

“How long will my battery last?” “I don’t know, it depends...” If that sounds familiar, it’s because it actually is the truth. Battery life is directly correlated to how you use, handle and maintain your battery. There are two primary failure modes that end the life of a battery, **sulfation** and **positive grid corrosion**. Firefly’s engineers felt that if they could address the root causes of these two failure modes, they could make the battery significantly more tolerant of abusive conditions. This has significant monetary and reliability implications for the trucking industry. With a typical lead acid battery, if the hotel loads are left on and the battery is completely discharged, you will eliminate, at a minimum, 50% of the life of the battery. The older the battery, the higher that percentage becomes. Of course, there are limits to everything. Even the Firefly Oasis battery will leave you without power if the battery is run to 100% DOD. BUT, unlike a conventional lead acid battery, the Oasis battery can be recharged fully, with minimal impact to the life of the battery. To validate this claim, Firefly decided to perform life cycles tests, not at the SAE J-2185 spec which only discharges the battery to 80% DOD, but a life damaging, battery crippling 100% DOD at an aggressive one hour (C-Rate) discharge, followed by a full constant recharge immediately afterwards to a fixed

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voltage. The performance results are staggering. Figure 3 illustrates that the Firefly battery has achieved greater than 1100 of these ultra-deep cycles, while still capable of returning approximately 90% of the rated capacity. Keep in mind that the other batteries were tested to the manufacturers' requirements, which limit DOD to just 80%. It should be noted that these tests are being performed in a laboratory environment under controlled conditions. But the results are nonetheless astonishing. This is a direct result of the carbon foam architecture and its high resistance to performance-degrading sulfation.

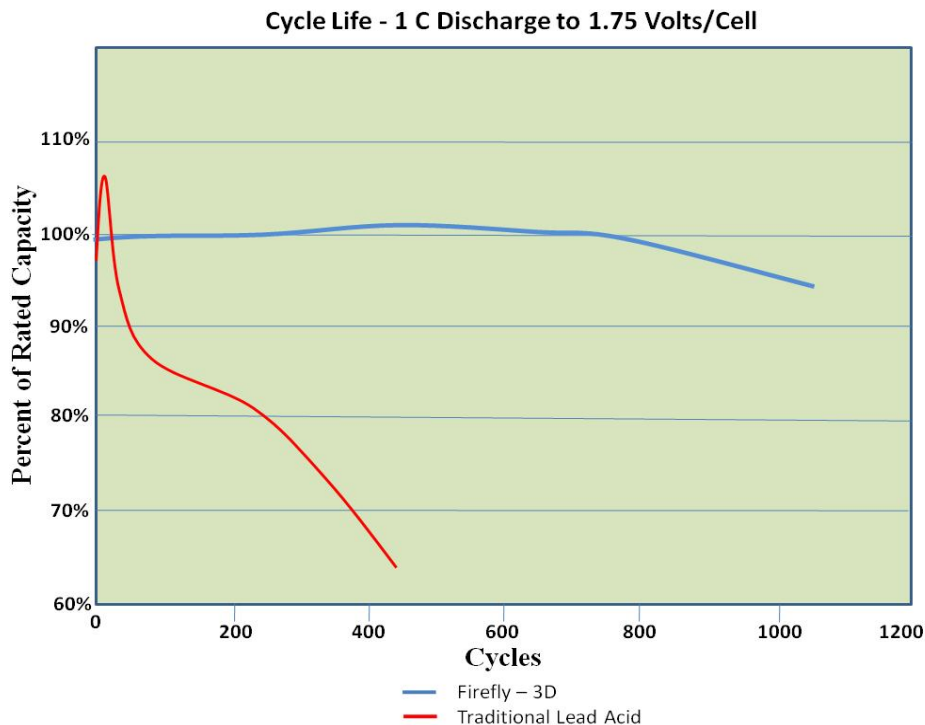


Figure 3 -Life Cycle Comparisons

Firefly's Oasis Group 31 battery replaces the negative lead metal electrode with carbon foam; the positive lead metal electrodes remain. While any lead acid battery's positive electrode is prone to corrosion, Firefly engineers were able to develop the means to make them more robust. This additional robustness of the positive electrode allows the Oasis battery to achieve dramatically increased life cycles before corrosion of the positive electrodes becomes an issue.

So, the answer to "How long will my Oasis batteries last", (considering an average truck's life before major overhaul or resale is 500K miles or 5 years), the answer could be "As long as you own your truck".

Reserve Capacity (RC)

So now let us level the playing field and define reserve capacity the values associated with the results as understood by the industry. Reserve capacity (or RC) is defined as the run time of any given battery at 25 amperes of constant current discharge until the voltage reaches 1.75 volts per cell (Vpc) at 25°C. However, taking advantage of the fact that there are minimal industry standards as to the exact definition and the tolerances associated with the testing, some manufacturers try to show more impressive results by testing at 27°C and discharging to 1.67 Vpc, resulting in better initial run time results. Now let's really understand what reserve capacity means and peel back the onion. What most people do not realize is this: The reserve capacity, or "RC" is the *first* discharge out of the battery, and it cannot be repeated with the same results because the battery has been discharged to 100% depth of discharge. As discussed in the aforementioned analysis, discharging a **typical lead acid battery to 100% DOD results in significant degradation of battery life**. Therefore, many manufacturers' claims of 200+ minutes of battery run time are correct, as Firefly found by running the tests on these products. However, some batteries were unable to deliver 80% of their rated capacity, AND were found to be non-recoverable in as few as 15 discharge cycles. Figure 4 shows the three leading batteries used in the trucking industry and the results of capacity fade or, in layman's terms, RC fade when discharged to the manufacturer's specification for run time values. As can clearly be seen, the RC of the batteries tested are for a one shot run and cannot be used as a basis for battery run capability to support hotel loads, nor for the design of an electrical battery-based truck APU. There are two exceptions: One, the spiral wound cell battery tested had fairly good capacity retention over 100% DOD cycles although very low run time minutes; and two, the Firefly Energy battery that has demonstrated over 1000 cycles in the laboratory with minimal capacity fade. The Oasis battery provides the trucking industry and truck battery APU industry with a high level of confidence that over time, the battery powered APU will continue to perform to expectations for years versus months, even if the cutout voltage is lowered to 10.5 volts versus the 11.2 volts now used for 80% DOD.

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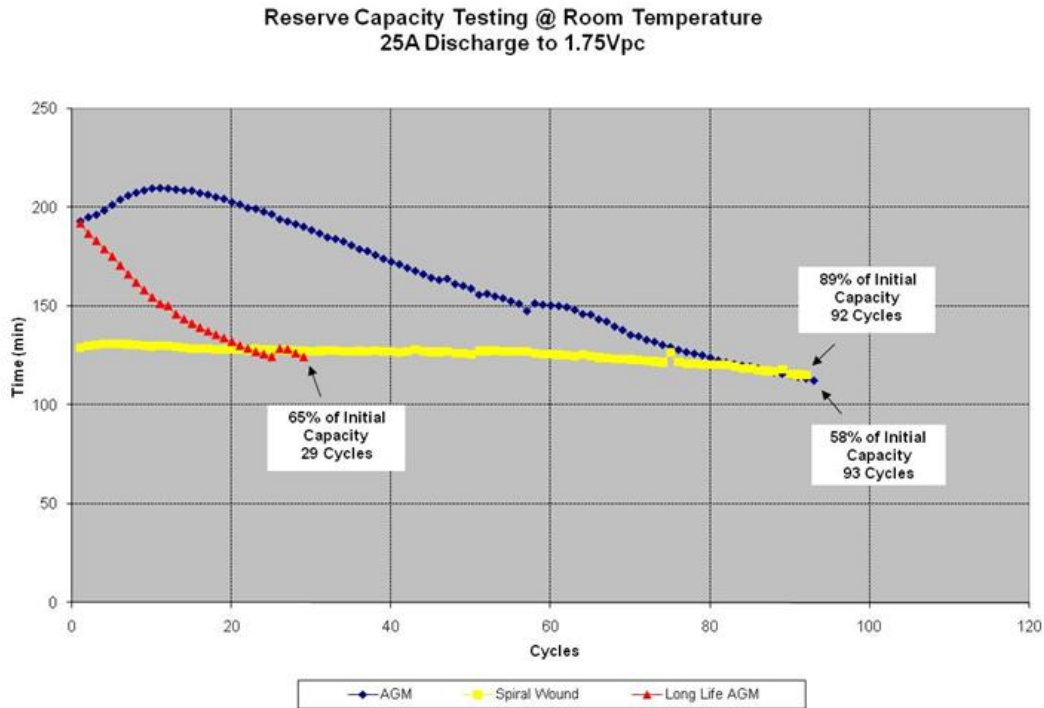


Figure 4 - Reserve Capacity Fade Effects from 100% DOD

Electrical Battery APU Analysis

Let's say that you own a class 8 truck or a fleet of class 8 trucks. So what does the correlation of cycle life, battery cost, and offset of fuel savings mean to you? According to Argonne National Laboratories, the average fleet truck spends about 300 days of the year on the road, and Federal regulations now require a minimum of ten hours of driver downtime for every 24 hours a truck is being operated. Couple this with the new California law specifying that a diesel over-the-road truck can only idle 5 minutes per hour and expel extremely low levels of NOx and particulates, and you have a very restricted operation of the main diesel engine on your truck. Many cities and states are watching the restrictions of California very closely and weighing similar legislation to reduce air pollution, dependence on foreign oil, and the trucking industry's contribution to elevated levels of greenhouse gasses.

Let's make some assumptions and run a typical scenario to calculate the benefits of a battery operated APU and, more importantly, what the Firefly Oasis battery can do to enhance that system. Although there are many factors and variations from fleet to fleet we will make some assumptions for a generic, top level analysis.

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Assumptions:

- 400 watt average AC load
- Classic lead acid battery run time to 80% DOD is 7 hours on average
- Firefly Energy battery's cycle life at industry standard 80% DOD is 1.71x what Firefly's battery cycle life attains at 100% DOD¹
- Diesel fuel \$3.25/gallon
- Idle fuel consumption is 0.8 g/hr at 800 rpm average.
- Idle hours 10/24 hours
- 300 days/year = 25 days/month for idle days
- 10 hours maximum APU run time
- 5 year analysis period equating to average fleet truck resale time frame
- 4 batteries per APU system
- Maintenance time to change out 4 batteries is 1 hour
- Avg. fully burdened labor rate at \$40/ hour
- Avg. battery APU system cost without batteries is \$7500
- Premium AGM battery price average \$200 from internet pricing research
- FFE battery price \$400 (Benchmark price for analysis only, and does not reflect MSRP pricing)

Let us now look at the total cost of ownership comparison of Oasis versus the best conventional premium lead acid battery. A summary of results is illustrated in Table 1 below.

¹ Since Oasis was tested at the more punishing 100% DOD level, and classic lead acid batteries cannot surpass 80% DOD due to severe limitation of cycle life, a ratio was created to compare Oasis at the industry-utilized 80% DOD level. For the purpose of this model a classic VRLA battery, when tested under load, ran approximately 7 hours @ 80% DOD, as compared to 12 hours @ a more challenging 100% DOD for the Firefly battery. To level the playing field - given that shallower depths of discharge lead to increased cycle life--a simple ratio of 12/7 or (1.71) was used as a multiplier. This ratio was used to reflect the increased number of cycles the Firefly battery could attain at the 80% DOD level.

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	Firefly Oasis	Standard VRLA G31
HVAC Run Time at 400 watts (hrs)	12	7
Cost / Battery	\$400	\$200
# Batteries Required	4	4
Cost / Battery String	\$1,600	\$800
Battery Cycle Life	1368	300
Battery Cycles / year	300	300
Battery Cycles / month	25	25
Replacement Frq (years)	4.56	1.00
Operational Life of Truck	5	5
# Batteries Rqd - Life of Truck	4.39	20
	4	20
Life Costs - Batteries	\$1,600	\$4,000
Number of Replacements	1	5
Time to Replace (hours)	1	1
Burdened labor Rate	\$40	\$40
Maintenance Costs	\$40	\$200
Total Cost of Replacements	\$1,640	\$4,200
Net FFE Savings or loss	\$2,560	
Cycles/dollar est.	\$0.29	\$0.67

Table 1 - Battery Cost Comparison

This analysis shows that even though a Firefly Oasis battery utilizing the new advanced material carbon foam has a higher initial price over the life of the vehicle, the overall system cost is roughly half at \$0.29 per cycle versus \$0.67 for one of the best premium conventional lead acid batteries on the market. What’s more, this does not include battery failures and replacements from leaving suite loads on for too long, or from the most “entrepreneurial” drivers who may bypass battery protection devices on their trucks, allowing the battery voltage to reach much lower voltage regimes.

For fleet operators, there are significant savings that can be recognized with use of battery powered APU’s, and further savings when operating the battery powered APU using Firefly Oasis batteries. In the following analysis, a generic fleet size of 20 vehicles was selected at random and fuel consumption values were based on the latest information from articles by Argonne National Laboratories and EPA SmartWay. This analysis is based solely on fuel cost offsets by running on battery power verses main engine idling. As previously stated, California mandates a maximum run time of 5 minutes per hour of idle time and Federal regulation requires 10 hours of driver downtime in a given 24 hour period. In addition, for the purpose of this analysis it is assumed that because of the additional three hours of needed power that a standard premium lead acid battery cannot provide, the truck will have to idle off the main engine to produce the power to keep the cab cool (providing pollution standards aren’t violated). Table 2 shows the analytical results based on a similar 5 year system analysis.

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As can be seen by the analysis, the costs associated with fuel consumption are significant, and that after a 14 month ROI for the APU costs, full cost savings for the fuel offset are realized. Now if one looks at the three additional hours of diesel consumption for operating the system for 10 hours of down time, one could expect additional fuel savings of over \$2000 per year per truck. When looking at the 5 year system analysis and a fleet of just 20 trucks, the savings potential could escalate to well over a quarter of a million dollars in fuel savings alone. Whereas it is understood that this is an analysis and each fleet must characterize how much A/C time and suite power are required per year, as well as what percentages of fuel consumption should be used as their average, the numbers will still result in significant cost avoidance.

Fuel Costs / Gallon	\$3.15
Idle Hours per day	10
Idle Days /month	25
Fuel (g) / hour	0.8
Maintenance Cost Avoidance/yr	\$300.00
Cost of APU - Electrical Sys	\$7,500
Approximate Months to ROI	14
Fuel Savings over eval. Period	\$30,480.00
Fuel Savings W/O Firefly battery savings	\$27,560.00
Fuel Cost Differential to 10h run time per year for Compliance (7hr to 10hr)	\$2,268
Total Fuel saving over eval. Period	\$11,340
Trucks/fleet	20
Fleet Savings No Idle - Std. LA	\$551,200.00
Fleet Savings With FFE	\$609,600.00
Fuel Savings with FFE Run time >10hrs	\$226,800
Differential	\$285,200.00

Table 2 - APU Fuel Consumption Offsets

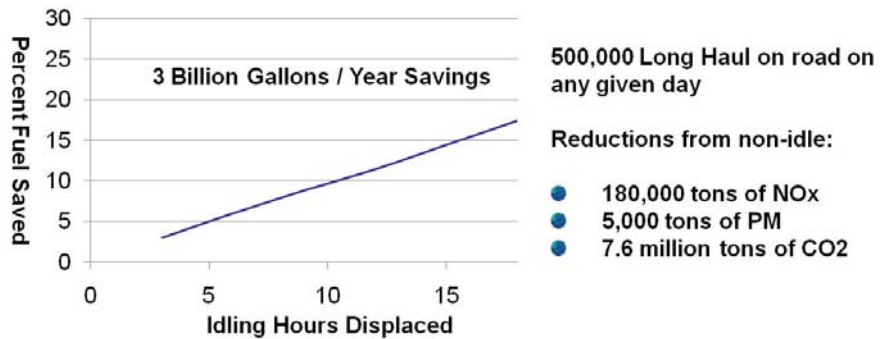
The “Green” Factor

In the previous section we discussed the cost savings made possible by using Firefly Oasis batteries in a battery powered APU. The driving force behind the California restrictions and the turn to “Green” power is all about the environment and pollution. Nitrous Oxides, Carbon Dioxides, particulate matter, noise, etc. will all be required to be significantly reduced to protect the environment in which we live. So how much reduction can be forecasted? The Firefly analysis above shows that, on average, a single truck could save as much as 2,400 gallons of diesel fuel per year. Add to that the

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savings to the environment in pollution by utilizing battery power instead of burning fossil fuels. To evaluate these environmental impact reductions, Firefly once again turned to published Argonne data. Figure 5 shows the significance in offsetting diesel fuel idle restrictions to the environment.

Projected Fuel Savings and Emission Reductions



Data provided by Argonne National Labs

Figure 5 - Fuel and Emission Reductions

Lead is the fifth most abundant metal in the world, and nearly 70% of all the lead produced is used to make lead acid batteries. Spent lead acid batteries are categorized as hazardous waste due to their corrosiveness, reactivity, and toxicity. Consequently, the lead acid battery industry has built up a strong infrastructure to ensure that as many of these batteries as possible are recovered and recycled. In the U.S., over 90% of all lead acid batteries are recycled.

As previously discussed, lead acid batteries are subject to corrosion and sulfation that shorten their useful lives, requiring more batteries to be produced and subsequently recycled. With Firefly Energy's patented carbon foam plate technology allowing significant cycle life and reduced lead content, a number of environmental advantages are realized.

Although the technology developed by Firefly Energy contains material other than lead, batteries containing Firefly's technology can be recycled through the existing lead acid recycling infrastructure. Carbon is already used to increase the temperature for the smelting of lead. Firefly's carbon foam plate material is simply burned away—and actually is a net fuel benefit for increasing smelting temperatures—and the remaining lead in the battery is recycled. Other “advanced technology” battery alternatives such

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as nickel metal hydride and lithium ion, do not have any recycling infrastructure; in fact, the battery owner must actually pay the recycler to take the battery.

When looking at the recycling reduction potential of Firefly batteries we must look at both quantity of recycled products and the amount of lead contained within the product. For this brief analysis we will concentrate on the Oasis Group 31 battery and its carbon negative electrode. As discussed earlier, the number of cycles achieved in the laboratory to 100% DOD is significant, but to put that into perspective as it relates to actual fielded batteries, we will de-rate the cycle life for the Firefly battery to 800 cycles at 80% DOD and use the average advertised premium lead acid battery cycle life as 300 cycles to 80% DOD. Using these estimates and using the quantity of batteries per APU at four, the impact on recycling per truck over a 5 year system cycle shows is illustrated in Figure 6. As this simple conservative analysis shows, not only is the quantity of batteries requiring recycling reduced by up to 300%, but the quantity of lead usage is reduced by as much as 1 ton per truck over a 5 year service life.

Recycle (5 year battery cycle at 80% DOD)

Battery	Cycle Life	cycles/year	Battery Qty	Years	# of batteries
Traditional Lead Acid	300	150	4	5	12
Firefly	800	150	4	5	4
Recycled Waste Reduction					300%

Battery Lead Content

Group 31 contains approximately 8% less lead content

Battery	Mass (kg)	% lead	Battery Qty	kg of Lead
Traditional Lead Acid	34.1	77%	12	315
Firefly	32	69%	4	88
Recycled Lead Reduction per truck				227

Figure 6 - Environmental Lead reduction

Everyone wants a cleaner environment for present and future generations. There is no better way for the battery industry and its customers to accomplish this than through the green technology developed by Firefly Energy.

Summary

In its vital and high-profile role as one of America's most important commercial transportation networks, the trucking industry is being required to shoulder a considerable burden in the critical areas of reducing both pollution and our nation's dependence on foreign petroleum. Diesel engine idling reduction is perhaps the most important element in this endeavor. The battery APU offers the cleanest and most "elegant" idling solution IF a battery can be found that is able to perform in the following areas:

Oasis Performance Features

"Key off" Run Times: Firefly's Oasis energy and power densities are substantially superior to conventional lead acid. (Figure 1)

Durability and Cycle Life: Firefly's Oasis is not only able to recover from a much lower depth of discharge than conventional lead acid batteries, but *has demonstrated an ability to surpass 1,000 of these cycles while maintaining some 90% of its rated capacity.*

Cold Weather Performance: Firefly's Oasis battery delivers upwards of 20% longer run time at -20° C than conventional lead acid batteries under an identical load. (Figure 2)

Reserve Capacity: While conventional lead acid batteries "self-destruct" under the rigors of repeated deep discharges, making them unsuitable for powering repetitive suite loads (Figure 3), Firefly's Oasis is able to perform this function over multi-year periods in demanding real world situations.

Oasis-Powered Battery APU Key Benefits

Cycles-per-Dollar Cost: It is estimated that over a five-year period, the cost-per-cycle of the Firefly Oasis battery will be roughly one half that of a conventional battery in a battery APU situation. (Table 1)

Fuel Savings Derived from APU Usage: By using an Oasis battery-powered APU rather than main engine idling, net fuel savings of over \$30,000 per vehicle, per year can be realized. Because of Oasis' ability to run longer, this is more than ten percent better than the savings obtained using conventional batteries in the same APU system. (

Table 2: Note that these are estimates based on average numbers and that actual results will vary.)

Environmental Benefits: Projected fuel savings brought about by "no idle" solutions if deployed to the entire 500,000 national long-haul truck fleet: 3 billion gallons per year. Nitrous Oxide emissions reduction: 180,000 tons. Particulate matter emissions

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reduction: 5,000 tons. CO² (greenhouse gas) emissions reduction: 7.8 million tons. Fewer batteries entering the recycling stream due to Oasis' significantly longer service life. Oasis batteries can be recycled through the existing industry infrastructure.

Summation: Firefly's Oasis Group 31 battery has been designed from the ground up for the requirements of battery-powered truck APUs. For this reason, and because of the benefits provided by its unique carbon foam cell architecture, no other Group 31 battery on the market can compare with it in terms of performance and cost-effectiveness.

Glossary of terms

APU	Auxiliary Power Unit
BCI	Battery Council International
Capacity	Amount of current that can be drawn from a battery over a given timeframe
C-Rate	Capacity rating of a battery set by the manufacturer indicating the amount of Capacity a battery can deliver in one hour. Example: 75 Ah battery C rate is 75 amperes, a C/10 would be 75/10 or 7.5 amperes
DOD	Depth of Discharge
Grid Corrosion	Deterioration of the lead grid on the positive electrode
L	Unit of measure (Liters)
Watt hour	The amount of power delivered in 1 hour measured in amperes x average voltage x time (in hours)
RC	Reserve Capacity – Standard discharge at 25 amperes
Sulfation	The formation of un-dissolvable lead sulfate crystals in and on the negative electrode, impeding recharge capability of the battery and life