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The Economic Impact of Sulfation Induced Electrical Resistance within the Industrial Battery Industry

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Introduction:

The Global Warehousing Industry is rapidly shifting their operational emphasis towards the conservation of resources, particularly the reduction of electrical inefficiencies and their "carbon footprint." Governmental pressures are increasing to reduce the consumption of electrical energy, many in fact moving to higher consumptive taxes, tax incentive programs, rebates, additional usage fees, Peak Load Reduction Programs and "Carbon Auctions and Trading Mechanisms." Government mandated carbon trading programs and the establishment of industrial battery charger efficiency standards, are further means by which government is trying increase electrical efficiencies within the Warehousing Industry. Local and national utility companies worldwide are pursuing energy conservation using Peak Reduction Programs, sponsoring energy efficiency innovations, products and processes, and other means to promote more effective use of electrical energy.

The warehousing industry is well aware of electrical conservation with regards to lighting, heating, and air conditioning inefficiencies. **Significant electrical savings in the motive/industrial battery re-charging processes are now available because of the recent technological innovation we refer to as, … Industrial Battery Optimization (IBO) implemented as a Daily Equalization Strategy (DES).** This new automated process delivered by the Model 6000 IBO/DES system, promises to significantly reduce the macro and microeconomic impact of charging industrial batteries, that include forklift and golf car batteries. While both battery types benefit from increased electrical efficiencies, for this discussion we are focusing on the recharging of "flat plate designed" forklift batteries used in the Warehousing Industry within California.

The Macroeconomics:

The macroeconomic impact of IBO/DES implementation within California would result from the continuously optimized state of forklift batteries on a daily basis, rather than the current Warehousing Industry's methodology of waiting until the battery is noticeably lower in electrical performance before restoring the lost efficiency. As an example, in 2010, California based industrial forklift truck battery chargers consumed approximately 3,600 GWH per year of electricity re-charging forklift batteries[1]. The implementation of the Patented and Patent Pending IBO/DES processes pioneered by Bravo Zulu International Ltd (BZI), **would save the California Warehousing Industry between 5% to 20% of this electrical consumption, or between 180 GWH and 720 GWH annually.** The financial impact of the electrical savings alone savings would be between 18 million and 72 million dollars per year, while the anticipated "One-Time" cost of implementation state-wide would be between 60 and 120 million dollars. **Carried forward 10 years, the savings to the California consumer are in the billions of dollars, while the California Power Generation Industry will conserve billions of kilowatt-hours of energy.**

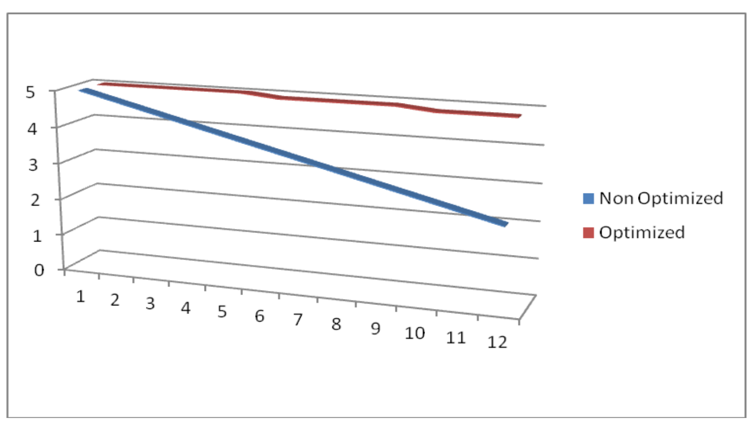
The Microeconomics:

The microeconomic impact of IBO/DES implementation to the warehousing operator would include the reduction in electrical consumption, the dramatic savings in periodic battery service costs and battery life extension.

The typical flat plate designed forklift battery will slowly increase it's internal electrical resistance during each charge and discharge cycle, caused by **Daily Excess Sulfation** deposits that remain and continue to accumulate after each successive cycle. Eventually, the internal lead plates become so obstructed with the increased resistive sulfation buildup, that the battery can no longer charge or discharge efficiently. In addition, when Daily Excess Sulfates are left to form into sulfate crystals, they become increasingly difficult if not impossible to restore, damaging the battery and shortening it's life expectancy.

Non Productive Compensation:

"Non Productive Compensation" is the use of additional charging cycles to perform the same amount of work, or Payload, compared to time. As the battery slowly sulfates, the useable runtime slowly diminishes causing the operator to use more charging cycles to accomplish the same payload over time, such as a week or a month. As the battery performance continues to diminish from sulfation, operators soon find themselves using as many as two battery charge/discharge cycles to accomplish the same payload, as they previously accomplished with one cycle.



A battery's life span is often rated by the number of charge and discharge cycles it can perform before it is considered "worn out." If a battery is rated to perform 1200 cycles in a lifetime, and 25% of those charge cycles are "**a non productive compensation"** caused by excess daily sulfation; then the battery will "cycle out" having wasted about 300 cycles combating the effects of sulfation, rather than performing some productive function such as moving pallets of goods. Non productive compensation is also a product of equalize charging a battery since equalization charging is a forced, unproductive additional charge. The implementation of daily battery optimization will not only slash electrical charging costs compared to payload, but extend the life of the battery by adding hundreds of productive life cycles.

As an example of a typical operational cycle, a battery that would initially operationally discharge for 5 hours on a 10KW charge consumption, after a period of 12 to 18 months may only discharge 2.5 hours for the same 10KW charge consumption. The typical industry practice is to then remove the battery from service and place it on a truck consuming many gallons of fuel transporting the battery to a local battery facility. Once at the facility, the battery is then alternated between a charger and discharging system to **aggressively cycle the battery in the attempt to de-sulfate the battery**, consuming tens of thousands of electrical watts and several finite battery life cycles. Once the battery has been charged excessively for many cycles and "de-sulfated," it is then returned to the operator again consuming numerous gallons of fuel.

From a marginal cost basis, the forklift battery operator will spend about $500 to $700 for this "sulfation service" process, 3 to 5 times during the battery's life expectancy. From a macroeconomic basis in California and assuming the batteries will be serviced for sulfation induced resistance only 3 times in their operational life, a conservative approach; then the cost to those operators could be averaged at about $300-$400 per year per battery, or about 45 to 100 million dollars per year. **The operational processes and expenses outlined in this paragraph would be significantly reduced or eliminated by the one-time integration of the IBO/DES system.**

Note: By contrast and when viewed as a restoration process, the BZI Model 4800 and Model 5000/6000 series of de-sulfation devices using only a few hundred watts of electricity, will typically further reduce the internal sulfation induced resistance even after the aforementioned restoration processes completed by the "Best of the Best" battery shops. When the leading shops deliver the battery to the forklift operator using the aforementioned system, it is still less than optimized when compared to a BZI Model 4800 or Model 5000/6000 manual process.

The Equalization Charge:

The marginal costs of operating the battery are also increased by the "Equalization Charging" of the battery cells. An equalization process is the intentional (forced) overcharging of the battery to balance the State of Charge (SOC) measured as the Electrolyte Specific Gravity of individual cells, in a series mounted array of cells. Specifically, the equalization charge is intended to reduce the **"Compounding Excess Daily Sulfation"** phenomenon that the conventional daily charging process is unable to overcome, and to "gas" the battery to mix the acid preventing **"Acid Stratification;"** or the phenomenon of the heavier acid settling within a column of water. **If IBO/DES is implemented after the normal charge cycle is completed, then the need to add an additional equalization charge for de-sulfation purposes is obviated.**

Secondly, if the BZI Patent Pending "real time" specific gravity sensor shown in the photo to the right, is used to measure the battery electrolyte during the re-charging process, then the need to extend the daily charge, or add an additional acid mixing equalization charge would be minimized or eliminated. Currently, conventional chargers cannot measure the specific gravity of the battery while under charge, therefore, any equalization strategy used to solely mix the acid is simply an educated guess, pre-programmed into the charger's operating profile. Volatile environmental factors that significantly affect the specific gravity of electrolyte, such as electrolyte temperature, sulfation and initial/intended electrolyte acidity levels, are unavailable to the conventional equalization charging methodology. **Therefore, charger profile designers simply overcharge to ensure that sulfation is reduced and the acid is mixed at the expense of electrical efficiency.**

Thus, conventional equalization overcharging raises the operating costs and demands upon the power grid, while reducing the battery life expectancy.

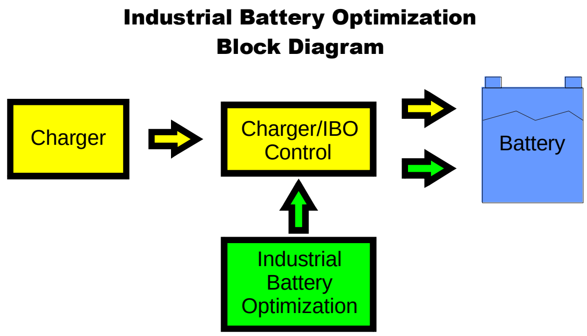
The Solution:

The ultimate solution is the automatic application of the Patented (US Patent 8,330,428) BattRecon **Industrial Battery Optimization/Daily Equalization Strategy (IBO/DES)** to optimize the battery on a daily basis. IBO is simply returning the battery's internal resistance to the lowest possible level after every charge cycle. The basic IBO system allows the battery charger to charge the battery without interference, after which the IBO takes over and applies a few minutes of the DES process to the battery. The result is a battery that is always scientifically optimized with respect to sulfation induced internal resistance.

The Model 6000 IBO/DES system can also be used to modify the charger's **"Native Charge Profile"** by interrupting the charger to battery connection by using pre-programmed modification instructions within the Model 6000's firmware. If your current charger is overcharging the battery on a daily basis, referred to as a high Charge Return Factor (CRF), the Model 6000 can be set to a lower the CRF by the modification of the interruption process using metrics such as; 1) Volts per cell, 2) Amp/hour charging rate, 3) Real Time Specific Gravity, 4) Battery Electrolyte Temperature, 5) Time, or 6) any derivative algorithm of the previous metrics.

The Model 6000 may also be used as an advanced charger control means to update older and obsolete charger designs such as the Ferro Resonant chargers, and convert them into a more modern high or low frequency pulse charger. The Model 6000 has an external charger control module, which can be integrated within any charger allowing the Model 6000 system to greatly improve the efficiency of an older, often considered obsolete charger.

The Model 6000 IBO/DES system may act as a "stand-alone" system as shown in the photo below, be seamlessly integrated into an existing charger chassis, or be incorporated within new production charging systems. When acting as a "Stand Alone" system, the Model 6000 is positioned between the client's existing forklift charger and the battery to be re-charged. The client may elect to keep the existing charger's "native" charge profile, or may elect to interrupt the native profile by pre-programming the Model 6000 system to discontinue the charge based upon the operator's desired parameters. Once the charger's native profile is complete, or the operator's Model 6000 modified charge return factor is achieved, then the Model 6000 automatically terminates the charger to battery connection and applies a brief period of our Patent Pending **"Eco Pulse"** process to the battery. It is this brief applied process that fully removes any Excess Daily Sulfation remaining after the re-charging process is completed.



The IBO/DES can be used to modify **any charger's Charge Return Factor**, or the daily degree of battery overcharging. The vast majority of today's industrial battery chargers have a daily overcharge ranging between 10 and 50%. This is due to the design of the charger and the need to overcharge daily to remove sulfates and mix the acid within the electrolyte. With IBO/DES, the battery's sulfation levels are minimized daily using only a few watts of electricity, replacing the previous high wattage daily overcharge used to remove excess daily sulfation.

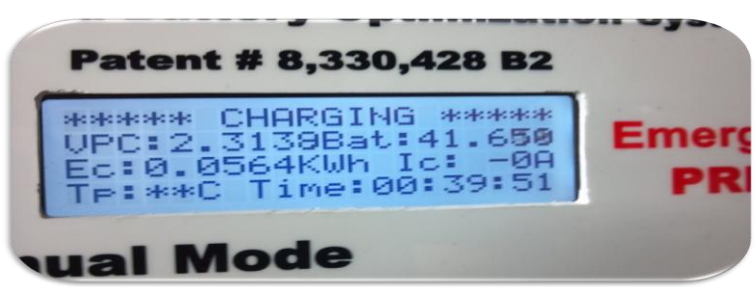
With the installation of the digital, real time, specific gravity probe into the battery, the Charge Return Factor can be further reduced. The IBO can interrupt the charger's connectivity to the battery when the measured specific gravity is at it's desired level, without wasteful overcharging simply to gas the electrolyte and mix the acid.

A Simple Test to Determine Forklift Battery Electrical Efficiency:

BZI has developed a portable, fully automatic service and data collection and testing system referred to as the Model 6048 for 24/36/48 volt batteries, The Model 6080 is for 24/36/48/80 volt batteries. The Model 6048/6080 can be used to optimize batteries as a service machine, or to perform scientific simulations for the field testing and evaluation of various types of industrial batteries, battery chargers, or any combination thereof.

As a simple field testing device, the system can be delivered and temporarily installed in the actual warehouse environment that the batteries operate within. Two Model 6000 systems would typically be used, secured to two selected batteries from the client's operating inventory referred to as Bank A and Bank B. The batteries should have the same approximate age and operating characteristics, identical chargers, the same battery manufacturer, voltage and amp/hour capacities. Bank A would be the "Control Battery,' cycled in simulation as the operator uses it in their current operation. Bank B would be cycled using the IBO/DES cycle simulation mode.

Establishing the Baseline:



Both batteries would be charged by the client's chargers as they "pass-through" the Model 6048. This charger pass-though capability allows the Model 6048 to control the charger Charge Return Profile, if desired, and measure the Energy Consumption in KWH shown in the photo to the right as the value EC. Both batteries would then be fully charged with the metrics recorded by the Model 6048.

The batteries would then be discharged and the runtime in amp/hours, minutes and KWH would be recorded. Both batteries would then be re-charged and the metrics again recorded, this would then be the baseline performance data. **Note: Since the KWH of both the charging and discharging cycle is measured, the client can for the first time accurately compare the electrical efficiencies of the batteries as a ratio of KWH in and out.**

The Differential Test:

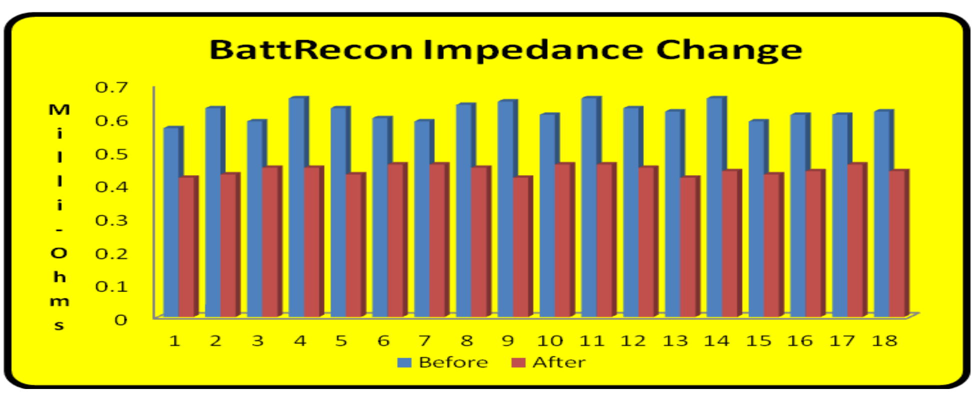
Once the baseline is established for both batteries, the Model 6048 would be programmed to sequentially cycle Battery Bank A in a manner consistent with the normal operating characteristics of the fleet including the equalization charge if used, while Battery Bank B is programmed to operate using the IBO/DES system without the equalization charge. At the end of a minimum of 6 operational cycles, the battery metrics can be compared and plotted on a spreadsheet for financial analysis.

It would be expected that the IBO/DES system would already have shown an advantage in the reduction of consumed wattage, while increasing the runtime during the discharge cycle testing. Further tests can be made and analyzed at the client's discretion by carrying the cycle parameters, until the battery electrical efficiency is fine tuned to the specific operation of the client.

The "BEST of the BEST" Case Study:

Detailed below is one of our many historical examples utilized a "Best of the Best" batteries operated by a Fortune 500 warehousing client within their facility. The equipment used was a high efficiency battery charging system provided by the client, an onboard battery monitoring system previously utilized by the client on the battery during its normal operation, the BattRecon Model 4800 de-sulfation system provided by BZI, and a discharge testing system also provided by BZI.

The test began with the determination of the age of the battery (approximately 1.8 years), the battery voltage (36 volts nominal), the battery capacity 765 amp/hours, and the time from the last major de-sulfation restoration service (approximately 3 months). The batteries were maintained by a nationally recognized battery service contractor under the supervision and authority of the battery manufacturer. It's important to note that in a little over 1.5 years of operation, the battery had already experienced enough of a loss of efficiency, that it had been removed from service for de-sulfation restoration.



The battery was represented as one of the best in the fleet of 800 and we decided to equalize charge the battery prior to beginning the test. This would ensure that the battery was in it's optimum field condition. The following day after equalization, each cell was checked for internal resistance (impedance) and the results varied from between .55 and .66 milli-ohms per each individual cell. The impedance values were tested by inserting a stainless steel screw into each corresponding cell terminal after which the Kelvin

Clamp of the impedance tester was clipped directly to the screw, rather than the battery terminal. This technique would ensure consistent readings for each successive impedance measurement.

The battery was then discharged using industry accepted standards of applying a fixed discharge rate while measuring the Volts per Cell (VPC). Once the VPC of any cell had reached 1.7 VPC, the test would then be discontinued and the elapsed time would be recorded. In this case, the battery was able to discharge until 4 hours and 15 minutes. The battery was then requested to be fully charged again and cooled, before testing continued.

The following day and after re-charging and cooling, the battery impedances were again checked and they again ranged from .55 to .66 milli-ohms. The BattRecon machine and process was applied to the battery for about 20 minutes, consuming about 300 watts of energy. The impedance values were again read at the same precise location as the previous measurements and they ranged from .42 to .45 milli-ohms.

We decided to begin the identical discharge test rather than return the battery to the charger for a few minutes, to maintain the same charge wattage consumption between the two tests. Other tests have shown that after de-sulfation with BattRecon, the battery will accept more amp/hours to the battery, which would lengthen the runtime during a discharge test. The “After BattRecon” discharge test was able to go 5 hours and 8 minutes before the first cell reached 1.7 VPC. The net gain in runtime minutes was 53, for the same applied charging wattage. Therefore, the increased runtime was about 53 minutes / 255 = .207, or a 21% improvement in runtime for the same exact charging wattage!

The forklift was therefore, capable of working longer at a faster rate after the applied BattRecon process, than before. This equates to about one free operational cycle for every 5 cycles of a non BattRecon processed battery. Another way of evaluating this change is that the client can produce the same workload using 20% less charging wattage energy when using the BattRecon Optimization processes, than without. This is essentially a 20% reduction in the battery charging consumption of energy. **These results are typical for a newer battery with exceptional maintenance, but consider the increased affect of Battery Optimization on older batteries with little or no maintenance program. They would be even more dramatic.**

The automated equalization charge methodology used by this client consisted of the battery mounted module communicating with the battery charger to apply an additional charge of 40 amps (for 3 hours) after every 5^{th} charging cycle, for 3 hours at approximately 43 volts. The result is that approximately 1,700 watts per hour are forced into the battery, or a total of 5,100 watt-hours every 5^{th} battery usage cycle. When calculating the affect of this equalization charge on the grid, one would need to either measure the wattage between the charger and the grid, or know the approximate charger efficiency. In this case, neither value was readily available, so it was assumed that the charger efficiency was 85% as a close approximation. This means that each equalization cycle consumes about 5,100 watt-hours / .85 = 6,000 watt-hours, or about 12KWH per week per battery.

As seen in this **“Best of the Best”** case study, the Patented BattRecon process significantly reduces the measured internal cell resistance, while correspondingly increasing the individual cell’s voltage and minimizing cell-to-cell differences (equalization). As shown in the example, the less efficient conventional equalization methodologies of forced overcharging consumed over 5000 watts per cycle, while BattRecon processed consumed only about 300 watts and produced significantly better results. Incidentally, this manual BattRecon process application would only be applied every 3 months or so to maintain the same relative efficiency, while the less capable equalization charging process would continue every 5 charging cycles.

A Summary of the Economic Advantages

The following is a brief summary of the microeconomic advantages for maintaining optimized forklift batteries in a warehousing environment. In the previous example, implementing DES/IBO may result in

1) Electrical savings of about 20% per day for the fleet of batteries.

2) The reduction or elimination of de-sulfation service intervals costing about $600 each, for 3-4 expected service actions during the life of the battery, or between $1,800 to $2,400 dollars.

3) The reduction or elimination of weekly equalization charging, saving about $60 per year, or about $300 for the lifetime of the battery.

4) An approximate 20% extension of the life expectancy of the battery reducing capital costs.

In conclusion, a charger based IBO/DES process microeconomic savings that accumulate to approximate the cost to **capitalize the purchase of the next replacement battery.** We call this phenomenon **"Capitalization Zero,"** which is the **permanent offset of motive battery capitalization costs** by applying the savings resulting from IBO/DES. The macroeconomic benefits to the State of California, for example, would be in the billions of dollars over ten years, while significantly reducing power grid consumption.

Please feel free to submit any comments or questions.

Cordially

Bruce Zeier

President

Bravo Zulu International Ltd.

References:

1) California Energy Commission, Titled: Proposed Title 20 California Efficiency Standards for Battery Charger Systems, Presented by Suzanne Foster Porter, Ecos.

