A Thought-Starter Conversation

Understanding the challenges associated with DIY electric-assist bicycle battery and system “Right To Repair” legislation

Let’s face it, if there were a legitimate resource of battery cell-based electrical/chemical/material engineers available, we would have far more cell production companies here in North America. The reality is that we don’t have the technical manpower with the expertise needed to fully understand everything from the actual formulation of new cell chemistry to the adaptability of reverse engineering of cell and pack technology to identify and repair existing battery packs built into electric vehicles.

Those who claim to have basic electrical engineering skills and somehow assume that these skills automatically adapt to advanced lithium cell technology, are kidding themselves. When the US walked away from lithium rechargeable battery production back in the 1980s under the pretext that these cells would be too expensive for consumer use, it left the Japanese and Koreans to pick up the slack. Following their continued government-based investments in Li advancements and the inclusion of these new rechargeable technologies into consumer products produced there, the Japanese and Korean markets got a huge jump start. The Chinese, realizing they had access to the bulk of the rare earth materials needed, eventually saw an opportunity to commoditize this energy resource and its manufacturing.

As the Asian manufacturing markets witnessed the transition from Nickel Metal Hydride (NiMH) and NiCd batteries as packs, migrating to the more consistent output of Lithium-based cells, premium consumer products saw a dramatic increase in the length of time between charges as well as a consistent power output. John Goodenough, a materials scientist, solid-state physicist, and a Nobel laureate in chemistry, discovered $LiCoO_2$ in 1980 and as a result, SONY commercialized Lithium Ion cells in 1991.

Globally, numerous companies produce both pieces and parts, as well as finished individual cells, along with assembled battery packs that make up the current generation of Lithium Ion makers. Everything from raw material mining to the refining of rare earth elements, aluminum foils, activation chemicals, and the management circuitry, reaches virtually every corner of the planet.

Because verifying the quality and density of each material is extremely precise, there are entire groups of firms that measure, evaluate, and separate the different grades which are then sent to the cell manufacturers. Additionally, because the chemistry is so precise, often an intermediate external step is introduced that blends these elements and attempts to balance the mix into a specific consistency before it is turned into a paste-like slurry coating. This external business exists simply because the expertise to separate, weigh, and blend is not typically available at mid-level producers.

Additional components include the metal substrate on which the slurry coating is applied and dried. This is most often an aluminum film-like or copper roll. The slurry coating is applied to both sides of this substrate and dried, and then slit into dimensioned bands. Besides the unique blend, application thickness is also an important factor. A separator element is rolled (or cut and layered in the case of pouch or prismatic cells). There are single and multiple separator layers and the makeup usually is polyolefins or polymer blends. The purpose of the separator is to create a physical barrier to prevent electronic contact between the two electrodes. The separator also holds the reservoir of the liquid electrolyte.

For this discussion, the purpose of all this detail is to note that each cell producer has developed their blend of chemical slurry, determined the material makeup of the separator, and the chemical composition of the injected electrolyte activator. This means that cell chemistry has unique characteristics in terms of energy, capacity, volatility, discharge rate, and overall cycle life. The assumption that all cylindrical 18650 cells are identical is patently false. Understanding this means that mixing different chemistries, from different sources can enhance the dangers of pack damage and possible thermal runaway (fire).

Another important fact that does not get commonly publicized is the grade of cells. We talk about bad cells being a major part of the problem, but how do they end up in the items we buy?

Because there are so many potential variables in the blending of refined raw materials, the quality of the substrate, and the consistency of the electrolyte chemistry all determine the final grade of the individual cell. In mid-sized, to large-scale Chinese factories, there can be as many as 4500 workers who are part of the manual assembly process. So many hands involved.

The testing of each cell is done after the post-assembly activation and rest period, whereupon they are placed into electrical racks for repeated testing in a semi-isolated facility. These racks can monitor the status of each cell during the charge and discharge process. They are often pushed to a maximum capacity limit to determine their performance as well as SoC. In the course of the 24 to 48 hours of the repeated process, the cells ultimately get divided up into three grades, A, B, and C.

The A cells are at the top of the line and are labeled as the house brand. The B cells typically do not meet the top standards so they are sold to the brokers primarily for domestic consumption. This is done at a discount. The C-quality cells are also sold to local brokers who go so far as to completely rebrand the cells and are presented at a substantial discount. From a consumer point of view, these are all Lithium Ion rechargeable cells.

While it is not often publicized outside of China, there have been multiple massive factory explosions where the cell testing facility has suffered significant damage from bad cell thermal runaway.

In Southern China alone, there are roughly 50 actual cell producers, yet there are more than 200 cell brokers in Shenzhen alone. These brokers source their “Special Incentive” cells from

the core manufacturers, which are marketed at significant price reductions and then they are sold to local consumer electronics producers. While these goods are primarily for the domestic Asian market, a fair amount of them make their way onto the sales channels of foreign e-commerce websites.

With rechargeable batteries often making up the most expensive component within any given electronic product, the low-quality rechargeable batteries being marketed are typically how we get the questionable electric-powered bicycles and scooters sold into the US under the de minimus pricing limit for US customs. The cells are sold at rates as much as 60% below traditional wholesale market value.

The Making Of A Battery Pack

There is a good deal of discussion in the “Right To Repair” marketplace, where cell phones are the leading example used. The major difference is that in all but a few of the latest foldable models, a cell phone only has a single cell (typically a pouch or prismatic) powering the device. An official replacement cell will have a simple two-tab configuration where the replacement process can be handled by a trained assembly tech. The charge, discharge, and status management are controlled by circuitry embedded into the main IC board within the phone.

For the electric-assist bicycle and scooter products, their batteries are packs made up of dozens of individual cells inside a plastic or metal case. They can be cylindrical (18650) or 21700-dimensional cells. Some packs are made up of multiple pouches or prismatic cells (never a mixture). All of the cells are connected to a BMS (Battery Management System) IC. This is the board that controls the charge and discharge rates as well as monitors the health of the cells and the overall SoC.

Again, there are hundreds of different BMS designs based on a combination of the functionality of the final device, the environment that the pack will be used in, and how sensitive the product designer wants to track the safety of the finished pack. Packs can be a combined makeup of both serial and parallel cell groupings, and often, to get the maximum discharge rate, cells are tested and matched into pairs to improve the balance of the charge level. Temperature monitoring can be done as cheaply as a single circuit on the BMS that passively monitors the overall temperature within the single pack. More advanced packs can monitor groups of cells fed to dedicated circuits. The most expensive and safest option is to actively monitor each cell within a pack and, when necessary, automatically disable a cell when it exceeds the SoC and/or temperature limits.

When packs have dozens of compatible cells, some circuits divide up groupings to better manage the State of Charge and balance the load to keep the energy capacity equal throughout. This is a more expensive feature that well-designed BMS ICs offer but is often skipped over due to cost constraints. In some cases, advanced chip technology incorporated into the BMS comes from suppliers who do not distribute in China, and/or if by chance the product makes its way into Asia, is sealed and coated to challenge reverse engineering.

An attempted repair of a pack without exact knowledge of the makeup and access to the actual OEM parts can completely change the functionality of the SoC system. The balance, performance, temperature monitoring, and overall lifecycle of the pack are at risk. Furthermore, some battery/motor/controller relationships communicate via custom firmware. Changes to the system could disable this handshake.

Technically, repairs are not as simple as using a soldering iron to heat a tab connection, sticking another generic cell in its place, and using a solder gun to reconnect. The heat from an iron can potentially damage the cell. Often, top pack producers use everything from lasers to ultrasonic devices to avoid heat damage and secure individual cells to build a pack.

Legally, every battery cell and pack that is transported into North America from overseas and/or overland in a commercial truck or cargo plane must have a certificate indicating that these class 9 hazardous material goods have met the UNDOT 38.3 regulations. Even in China, where a legal transport certificate is not required to move cells and packs around, to be transported out of the country, these goods must go through the 8-step process. Here are the steps:

1. **Altitude Simulation**: This is low-pressure testing that simulates unpressurized airplane space (cargo area) at 49 thousand feet in altitude for more than 6 hours.
2. **Thermal Test:** This test covers changes in temperature extremes from -40 F to +165 F. Batteries are stored for 6 hours at -40C (12 hours for large cells/batteries), then 6 hours at +75C (12 hours for large cells/batteries), for a total of 10 cycles. Testing may be performed in a single chamber or thermal shock chamber, but less than 30-minute transitions shall be used.
3. **Vibration:** This test simulates vibration during transportation. The test is a Sine Sweep: 7 Hz–200 Hz–7 Hz in 15 Minutes; 12 Sweeps (3 hours); 3 mutually perpendicular axes.
4. **Shock:** This test also simulates vibration during transportation. The test is a Half-Sine pulse: 150 G/6 ms for small cells/batteries; 50 G/11 ms for large cells/batteries; 3 pulses per direction; 6 directions (+/-z, +/-x, +/-y).
5. **External Short Circuit:** This test simulates an external short to the terminals of the cell or battery. At a temperature of +55 °C, apply a short circuit (0.1 ohm) across terminals. Maintain it for at least an hour after the sample temperature returns to +170 °C. Pass criteria are: the case temperature does not exceed +338 F, and there is no disassembly, rupture, or fire within 6 hours of the test. Fuse, current-limiting circuit, and venting mechanism activation are allowable.
6. **Impact:** This test is only applicable to primary and secondary cells. For cylindrical cells >20mm in diameter, it simulates impact to the case of the cell. For cylindrical cells <20mm in diameter and all other cell constructions, it simulates the crushing of a cell. Pass criteria for any type are: Case temperature does not exceed +170 °C; no disassembly or fire within 6 hours of the test;
7. **Overcharge:** This test is for secondary or rechargeable batteries only. It simulates an overcharge condition on a rechargeable battery: 2x the manufacturer's recommended charge current for 24 hours. Then the battery shall be monitored for 7 days for fire or disassembly.

8. **Forced Discharge:** This testing simulates a forced discharge condition for primary and secondary cells only.

While there have been debates over the required testing and certification (primarily based on who picks up the cost), in reality, many of the situations tested are common to the activity of riding an e-bike, such as vibration and shock.

Controversy With This Certification

The DOT and US Customs have indicated that while this certificate covers both the individual cells used as well as the complete battery pack and is mandatory for goods shipped to North America via ocean or air cargo, it seems as if they don't require an actual official copy of these certificates to be included in the packing materials for review. It states that they must be on file, and unless the vendor is called out to validate this, no one knows if the certificate is valid and/or current. Often, it has been determined that the B and C-quality cells don't pass the 38.3 tests.

> **"Any modifications to a certified UNDOT 38.3 battery pack will automatically void the certificate, and transport of these packs through public commercial cargo services could carry a fine that reaches into the thousands if caught."**

For a while, copies of the certificate were provided with shipments. With the pressure on Asian cell sales channels, there were opportunities for brokers and exporters to illegally duplicate certificates, and often customs inspections didn't confirm that the cells were the exact size or density and would let them through.

In other cases, EU certification misinformation led buyers to believe they could circumvent the 38.3 certificate by submitting EN 60086-4 or EN 61960 certificates. Simply having the CE identifier on the shipping box does not ensure safe transport into North America. For CE, the Declaration of Conformity is a primary document that is often requested by other authorities, retailers, or marketplaces.

Getting Back To The Issue At Hand

Those attempting to repair battery packs with replacement cells often purchase them through online Asian e-commerce sites. The generic nature of the cells provides little, if any, testing documentation to determine capacity, density, or discharge output. In other cases, generic class B or C cells have been wrapped in labels with marketing designations indicating that the cell meets and/or exceeds performance criteria. We have even seen knockoffs of leading brands.

The Challenge Of Charging Battery Packs

For the longest time, battery charger producers who originally built products for NiCd and similar batteries attempted to shift to the multi-phase charge process of Lithium Ion cells, but the complexity of the different chemistries and the measurement and monitoring capabilities of the BMS IC created conflicts. Developing new technology chargers was costly, and in the early days, the demand to support lithium-ion-powered products exported from China didn't warrant it.

Today, the charging industry has several levels of offerings. The least expensive chargers are often the ones associated with the battery issues found in NYC and elsewhere. They don't properly take into account the taper charge process when the cells reach a certain level of capacity. Additionally, many of the chargers don't meet the latest California standards, which are designed to shut down at a certain level during the trickle charge and maintenance process. This integrated sequence terminates all activity from the charger, which would help eliminate the overnight overcharge process.

However building chargers that interact with the BMS circuitry and controller IC requires investment and engineering to create the handshake. Often, these low-end bikes include the least expensive charger. Additional issues occur when the charge connector is either proprietary or wired uniquely. There is a reason for that. Quality chargers are often paired with specific bikes or scooters. In NYC, unknowledgeable riders often splice different chargers together, changing the connector ends, and try to charge multiple packs at once.

Again, allowing someone to attempt to repair or replace any component within the charger-battery-controller chain is setting the product's owner up for warranty failure and potential system and surrounding environmental damage.

Often, the goal of the DIY rebuilder is to replace components with the motivation of improving the performance of the bike. Replacing cells with higher energy density ratings, updating the BMS circuitry, or tweaking the controller on the motor to eke out a bit more power are all reasons not to allow self-repair.

Even authorized distributors find it almost impossible to store replacement parts, let alone individual, independent DIYers, or small service centers. Because of this, untrained pack assemblers attempt to use generic parts or pieces from other brands.

While most consumers don't see themselves shipping their products via commercial carriers, the moment a pack is modified or a cell is replaced, the UNDOT 38.3 certification becomes null and void. Whether it's a DIY project or through a local bike shop, it doesn't matter.

UL Certification and Product Liability

At present, there are no full e-bike drive kit manufacturers producing complete systems here in the US. Virtually every part of the bicycle is imported, along with the motors, controllers, battery packs, and chargers. Even the system displays (unless they incorporate your cell phone) all come from outside the country.

Once assembled, the finished bike becomes a product. Often, the exporters make slight tweaks to the component list, and individual finished products are similar but can be associated with multiple brands. Because the product suppliers are offshore and have virtually no North American presence, every importer who establishes a business entity to bring in and sell these bikes should have product liability insurance. This is to protect themselves against

manufacturing defects and/or failures. With the volume of fire incidents, rider accidents, and even deaths being reported, operating a business without this coverage is foolish.

Getting an insurance carrier to provide the importer with coverage frequently requires them to become the “Manufacturer of Record”, which means they are on the hook for the components used to build the bike instead of the Asian manufacturer.

Assuming that the importer or distributor has secured this liability coverage, it does not automatically mean that the local dealer (if they sell through dealers) or the repair facility that takes on the task of fixing the bike is covered or indemnified under the importer’s policy should an issue arise after they work on the product. Once a product is serviced outside of the manufacturer/importer/distributor loop, the consumer is stuck.

The ability to certify an entire electric-assist bicycle system has now become a requirement to sell and ride an eBike in New York’s five boroughs. The New York City Council passed Initiative 663-A, mandating e-bikes, e-scooters, e-mobility devices, and light electric vehicle (EV) battery packs to be third-party certified. On March 20, 2023, New York City Mayor Eric Adams signed this into law. With this new law, any company selling, leasing, or distributing micro-mobility devices, such as e-bikes or e-scooters, has until September 16, 2023, to obtain certification from UL Solutions or another nationally Recognized Testing Laboratory.

What is important to note is that a UL certification on one bike that includes a foreign-made component paid for by an individual importer does not automatically indemnify that foreign brand for all other importers using a similar product. Only manufacturers of full systems who have completed the certification of their solution may indemnify an authorized distributor to claim proper certification. An example would be Bosch and Panasonic.

One benefit of the full UL certification is that it also includes the UNDOT 38.3 transport certificate.

Creating A Unified Standard

There are numerous discussions about the need to create a standard of batteries and chargers where cross-compatibility would allow a common exchange between electric-assist bikes. But with no actual manufacturing of electric-assist bicycle drive systems here in North America, there is little opportunity to initiate a concerted effort to establish standardization. Furthermore, the volume of e-bikes imported into the US market is a minor figure when compared to annual sales in specific countries in the EU.

Technically, each of the quality-built bundled drive solutions has created a more integrated relationship between the battery, the motor controller, and the display, and attempting to make their battery packs compatible with the low-end products doesn’t work with their business models. Additionally, many of the performance brands have integrated their batteries into the frame to the point that they would not be compatible with the external mounts on the low-cost imported bikes.

A Final Analysis

The discussion surrounding the "Right To Repair" for electric-assist bicycles encompasses both a valid business case and crucial safety considerations. This debate is particularly pronounced due to the clear distinction between reputable, high-end brands and the more budget-oriented, generic Chinese bicycles that raise concerns about their quality and reliability.

The challenge is twofold: ensuring the quality of components and seamlessly integrating the technology that governs the interaction between the electric drive and performance sensors. A prime example of this distinction lies in the sophisticated onboard systems capable of learning a rider's individual traits, skills, and usual terrain, thereby tailoring the bike's features accordingly. Beyond this, an array of other intricate elements, including torque sensors, ABS brake systems, and electronic shifting, further contribute to the intricate web of complexities.

Consumers who unknowingly acquire subpar or inadequately vetted electric-assist bikes or scooters, which manage to evade official safety standards, frequently find these items being employed in dubious contexts. Notably, these include instances involving children below 16 years old, commercial delivery services, and unconventional commuter vehicles modified for speeds surpassing recognized class limits. These scenarios often take center stage in the ongoing debate.

A recurring theme involves bicycles triggering building and house fires due to lithium battery pack malfunctions, commonly during the charging process. Furthermore, the potential for severe injuries is heightened by excessive speeds or deficient braking capabilities. Compounding these issues, cases of underage riders neglecting established traffic regulations add another layer of concern.

Prominent industry leaders express apprehension regarding potential tangential ties to liability cases, wherein their products are utilized in questionable contexts. Furthermore, they are troubled by instances where components originally designed exclusively for their high-quality offerings find their way into substandard bicycles in unintended ways.

To put it plainly, these companies have made substantial investments in crafting top-tier products and establishing their brand presence. Their driving force lies in upholding performance and safety benchmarks for the entire industry.

Short-term investors and importers, driven by the prospect of tapping into the market with budget-friendly, yet inferior offerings, prioritize swift returns on investment and aim to minimize liabilities. Consequently, the emphasis on providing extended warranty services takes a backseat. Frequently, these entities adopt a marketing strategy centered on complete product replacement upon failure, given the considerably lower initial cost of the item.

A potential solution involves a well-regarded industry association devising a balanced training program to cater to fundamental repairs and a certain extent of warranty service. This program would be made available to specific shops willing to invest in it. While the training and necessary equipment for this endeavor come at a cost, there exists a viable business opportunity within this framework.

The predicament confronting many shops lies in the cost of product recertification and the daunting challenge of sourcing genuine OEM parts. In numerous instances, traditional bike shops exhibit reluctance to engage in servicing and repairing products they haven't sold, while a lingering stigma attached to electric-assist cycling persists within premium cycling establishments.

In the view of the author, it's high time for a bold industry association to take the reins in addressing problematic imports. This can be achieved through fostering enhanced customs procedures, encouraging domestic onshore manufacturing, enforcing mandatory safety certifications, and imposing more severe penalties for deliberate evasion of regulations. Additionally, a nationwide marketing campaign akin to the RV market could be developed to promote the safe and legal aspects of electric-assist cycling to the general public.

Companies committed to obtaining comprehensive safety certifications for their products should promote this as a clear distinguishing factor between them and those who opt not to vouch for secure products. Empowering consumers with a thorough understanding of their purchases, encompassing the inherent risks of cycling and the potential repercussions linked to poorly manufactured goods, is pivotal.