Safe Charging and Storage of Lithium-Ion Batteries in the E-Bike Retail Environment
By Mike Fritz

The growth of the electric bicycle segment of the bicycle industry has been nothing short of remarkable. The pandemic, the environmental crisis, and soaring energy costs have all combined to highlight and magnify the importance of light electric vehicles in the transportation infrastructure.

Lithium-ion batteries represent the most significant technology breakthrough that has enabled the development and manufacture of practical electric vehicles, including e-bikes. The high gravimetric and volumetric energy density of lithium-ion batteries make them most suitable for use in transportation applications. These batteries store sufficient energy to power electric vehicles over meaningful distances. They can deliver the significant power required to accelerate heavy loads to useful speeds.

These batteries are the first viable alternative to gasoline as the energy supply of choice for practical, day-to-day electric transportation.

However, as is the case with gasoline, the storage of energy required by electric vehicles carries significant risk. The uncontrolled release of stored energy is dangerous and can have catastrophic consequences. One can imagine the unpleasant scenario resulting from tossing a lit match into a bucket of gasoline. There is a comparable analogy with lithium-ion batteries as it relates to the uncontrolled release of energy.

Certain attributes of lithium-ion batteries make them susceptible to catastrophic failure under certain predictable circumstances. Manufacturing defects, inadequate or improperly programmed battery management systems, service requirements that exceed battery design tolerances, improper charging protocols, physical damage, etc., lead to battery failures that can precipitate a fire. Due to the chemical composition of the liquid electrolyte used in a lithium-ion battery, such fires burn extremely hot, generate great quantities of toxic gasses and are very difficult to extinguish.

To date, incidents of catastrophic lithium-ion battery fires are relatively rare. But given the explosive growth of the eBike market in the U.S. and elsewhere, and the proliferation of low cost e-bikes likely equipped with substandard, uncertified battery packs, there is great concern that the frequency of these unfortunate events is going to increase. The potential for property damage, and the risks of personal injury and death, will also rise.

As advocates for the growth and commercial success of electric bicycles, we offer the following guidelines to e-bike dealers to ensure proper storage and charging of e-bike lithium-ion battery packs in their retail environments. These guidelines are intended to minimize the possibility of a battery pack failure, and to mitigate the danger and resulting damage that will occur in the event a failure does occur.

Lithium-Ion Battery Pack Storage in the E-bike Shop:

- Procure a fire-resistant cabinet. Appropriate cabinets are available at many industrial supply outlets (like McMaster-Carr, Grainger, etc.) or Amazon.com.
- Position the cabinet away from flammable materials (cardboard, boxed inventory, lubricants and/or chemicals) in your shop. Mount a smoke detector (preferably a networked smoke detector connected to the store's security system) in proximity to the cabinet. Mount a Class A, B, C fire extinguisher in proximity to the cabinet.
- Store all lithium-ion e-bike battery packs in the fire-resistant cabinet.
- Store new e-bike battery packs in their original cartons in the fire-resistant cabinet. **DO NOT** pre-charge battery packs. Only charge a new pack just prior to delivering a new e-bike to a customer.
- Store the battery pack from an e-bike brought in for service in the cabinet until such time as it's needed for testing the serviced e-bike, or the e-bike is being returned to the customer.
- Ensure all lithium-ion e-bike battery packs are stored in the cabinet whenever the store is closed or otherwise unattended.

Safe Charging of E-bike Battery Packs in the E-bike Shop:

- Procure a wire rack to use as a charging stand for e-bike battery packs. Suitable racks are available at many industrial supply outlets (like McMaster-Carr, Grainger, etc.) or Amazon.com. Preferably, procure a wire rack equipped with wheels for easy maneuvering. Procure a set of extreme heat-protection gloves and store them nearby the battery charging rack.
- Position the cabinet away from flammable materials (cardboard, boxed inventory, lubricants and/or chemicals), in proximity to the smoke detector and the fire extinguisher.
- If possible, position the battery charging rack near a door leading outside of the shop.
- Procure a 32-gallon industrial trash can. Position it near the charging rack. Fill it about 3/4 full of water.
- Procure additional battery chargers for the various battery packs supplied with e-bikes sold through the store. Fix these extra chargers on the wire rack (with zip ties or other means) and connect them to a switched power strip also attached to the rack. These extra chargers are to eliminate the need to use the new charger shipped with the e-bike.
- **ONLY USE CHARGERS INTENDED FOR THE SPECIFIC BATTERIES SOLD BY THE SHOP.** Never use a charger not supplied by the e-bike distributor or a DC power supply to charge e-bike batteries.
- Only charge batteries on the charging rack. Never charge a battery pack inside the fire-resistant cabinet.
- Charge e-bike battery packs just prior to the delivery of the new e-bike.
- **NEVER CHARGE A LITHIUM-ION BATTERY PACK UNATTENDED.** Lithium-ion batteries most often fail during charging. There are noticeable indications from a pack as it starts to fail. If there is an attendant present, actions can be immediately taken to deal with the pending failure.

- When the battery charger indicates that a battery pack is fully charged, turn off and then disconnect the charger from the battery pack. Return the battery pack to the cabinet until just prior to delivery.

IN CASE OF EMERGENCY:

- If a battery starts smoking, making noise or showing signs of melting plastic:
    - If it can be done safely, using the heat protection gloves, disconnect the failing battery pack from the charger and place it in the water-filled trash can. Otherwise, move the failing pack outside away from any flammable materials.
    - If the failing battery pack cannot be safely removed from the charging rack, disconnect the power strip from the electrical outlet and push the charging rack outside.
    - If it can be done safely, disconnect any other battery packs that are on the charging rack from their respective chargers, move them off the charging rack away from the failing pack, and return them to the fire-resistant cabinet.
- **Call 911 to summon the fire department.**
- Other than immersing the pack in water or moving it out of the shop to a safe place, do not try to extinguish the burning pack. You will not be able to do so. The recommended fire extinguisher is there to extinguish any secondary fires that may be ignited by the burning pack.
- Evacuate the store and wait for further instructions from the fire department.

Issues and Discussion:

- **Concern**: In a large store with many e-bikes in inventory, it may be deemed impractical to remove every battery from every bike box and store them in the fire-proof cabinet. Or there may be too many batteries in inventory to store in a single cabinet.
    - We understand. It's an inventory logistics problem. While it's highly unlikely, new lithium-ion batteries can fail spontaneously. It's always preferable to store all e-bike batteries in the fire-resistant cabinet. If necessary, procure additional cabinets to store as many batteries as possible.
    - Mitigating factors are that batteries packed with new e-bikes in their shipping cartons are obviously not being charged and are in a partially discharged condition. The likelihood of one failing under those conditions is low. However, new batteries in a partially charged condition have failed in transit, so there's no guaranty.
- **Concern**: What about e-bikes equipped with the battery housed in the down tube that is difficult and/or time consuming to remove?
    - Remember the Cardinal Rule: **NEVER charge batteries unattended.** Batteries usually fail while being charged. Charge those e-bikes with an attendant present in an open area away from flammable materials in the shop. If the pack sends signals that it's failing, wheel the e-bike out of the store to a place away from flammable materials and call the fire department.

    - When storing e-bikes with integrated batteries while the shop is closed, position those e-bikes **DISCONNECTED FROM THE CHARGER** in an open area away from flammable materials. This is when a networked smoke detector pays for itself.
- Why the water filled trash cans?
    - E-bike lithium-ion battery packs are comprised of a quantity of small (approximately AA-battery size) cells, wired in a configuration to yield the voltage and capacity requirements of the e-bike they are design to power. Depending on the voltage rating and capacity of the battery pack, there may be as many as 84 of these cells contained in the pack.
    - When an e-bike battery fails, it starts with a single cell. The cell enters a condition called thermal runaway resulting in boiling of the cell's liquid electrolyte which over-pressures the cell casing causing a relief valve to open. When the relief valve opens, the hot gas that results from the boiling electrolyte vents at high pressure and velocity.
    - This gas is very flammable and invariably catches fire as it's vented from the cell. The cell in effect becomes a mini-blow torch.
    - The failing cell then causes adjacent cells to overheat, resulting in a chain reaction as one cell after another overheats and vents the flammable gas.
    - The net result is an extremely hot fire that generates significant quantities of toxic smoke. The fire is virtually impossible to extinguish.
    - The reason we recommend submersing a failing pack in a trash can filled with water is to attempt to interrupt fire propagation by cooling the remaining cells in the pack thus preventing further propagation. A fire involving a few failed cells is significantly less dangerous than a fire involving 84 cells.
- The water immersion strategy to interrupt fire propagation has been called into question as an effective e-bike battery fire mitigation strategy. However, this method has been adopted by several European fire departments to control electric car battery fires. The fire department positions a car-size container of water near a burning car, and then uses a forklift or crane to immerse the car in the water. We are confident that this method will be effective in mitigating e-bike battery fires. Nevertheless, Human Powered Solutions is working with a battery pack manufacturer and an accredited testing laboratory to validate this method. We will advise the industry of our test results when available.
- This issue will not be with our industry forever. Solid state lithium-ion batteries are in development that will eliminate the potential for lithium-ion battery fires. It is expected that solid state lithium-ion batteries will be commercially available for use in electric bikes in the next three to five years. Solid state batteries offer the added benefit of higher energy density resulting in greater e-bike range and utility.
- Additional methods to reduce the possibility of e-bike battery fires rest with each e-bike retailer. Be proactive with your suppliers. Only buy electric bicycles from vendors that have (a) sourced high quality battery packs from reputable pack suppliers, and (b) supply copies of certification documentation proving that the packs supplied with the bikes you sell have been tested and comply with requirements promulgated by safety and regulatory agencies such as Underwriters Laboratories, the United Nations and various European safety agencies.

- Train your store personnel to familiarize them with these procedures.
- Do not offer to service cheap e-bikes purchased from unscrupulous Internet distributors. Substandard lithium-ion e-bike battery packs are much more likely to fail than those supplied by quality vendors.
- Do not buy no-name battery packs to replace packs that have reached the end of their service life. Given the high cost of replacement packs, it's tempting to buy a cheaper pack to make your customer happy. But there is a reason quality replacement packs are expensive. They are safer. Procure replacement packs from the distributor that sold you the e-bike in the first place.
- Follow the safety guidelines offered by the lithium-ion battery pack recycling firms that are opening. Companies like Call2Recycle will offer guidance and materials to ensure that you safely store and transport used battery packs at the end of their useful service life to an accredited recycling facility.

In closing, please know that the chances of a lithium-ion battery fire in an e-bike shop are miniscule. But the consequences of a battery fire are so significant that the relatively simple steps outlined in this advisory are more than justified.

About us: Human Powered Solutions, LLC, (HPS) exists to support individuals and businesses in the bicycle industry wanting to participate in the micromobility revolution currently underway in the world. We strive to offer advice and counsel related to commercial opportunities, product development, sourcing, distribution, and retail activities in the micromobility space. Our skill set entails expertise and experience in both the commercial and the technology sides of these industries. Please do not hesitate to contact us if you have any questions regarding the recommendations outlined above.

Mike Fritz
Chief Technology Officer
mike@humanpoweredsolutions.com