Primary Lithium Battery Safety and Handling Guidelines

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Introduction

POWER STABILITY Solutions Inc., a subsidiary of Greatbatch Ltd., manufactures a wide variety of lithium batteries in various sizes, temperature ranges, and rate capabilities. As a tested expert in design, manufacturing, assembly, and integration, we are synonymous with reliability and safety. For decades, the world's top research institutions, industry leading companies, and government agencies have chosen POWER STABILITY Solutions Inc. for the best in non-rechargeable and rechargeable power assurance. We are standard in critical applications such as oil and gas services, military communications, medical devices, oceanographic monitoring and more, ensuring power in places where others fall short.

The success of these systems is partially due to the fact that they contain more energy per unit weight than conventional batteries. However, the same properties which result in a high energy density also contribute to potential hazards if the energy is released at a fast, uncontrolled rate.
With proper use and handling, POWER STABILITY cells and batteries have demonstrated an excellent safety record. The cells and batteries manufactured by POWER STABILITY are used safely and successfully in many applications where safety and reliability are of the utmost importance.

Due to the recognition of hazards associated with high energy density systems, safety has been incorporated into the design and manufacture of all POWER STABILITY primary lithium cells and batteries. While we have designed our cells and batteries to be tolerant of adverse conditions, these very active chemical systems have limitations. Certain hazards are associated with exposure to heat and its subsequent effects on sealed cells. These hazards include the potential for cell venting, explosion, and/or fires. The initial source of heat can be external (welding, soldering, etc.) or internal such as heating caused by short circuiting, excessive running currents for prolonged periods of time, forced over-discharge, charging, or excessive mechanical abuse.

Specifically, mechanical abuse in the form of excessive shock or vibration can result in case deformation, crushing, and damage to the electrode materials.

Most primary lithium cells have a warning printed on the label that cautions against the following conditions:

- Short-circuit
- Charging
- Forced over-discharge
- Excessive heat or incineration
- Crush, puncture, or disassembly

Not guarding against these conditions may result in a hot cell or a battery pack that could vent or explode. With POWER STABILITY cells, the ensuing hazards associated with a hot cell typically will not occur the instant the cell is abused. Rather, the cell will heat up over a period of time. This can take place in a matter of seconds or hours. Subsequently, the end result has the potential to result in a cell vent or explosion once the critical temperature is reached. All POWER STABILITY primary cells and batteries are labeled with their maximum operating temperature, indicated in degrees Celsius. This temperature should not be exceeded.

Safe Handling Guidelines

The guidelines identified in this document should be incorporated into all areas of the facility as Best Management Practices and/or Safe Work Practices.

The intent of this section is to provide primary lithium cell and battery users with guidelines necessary for safe handling of cells and batteries under normal assembly and use conditions.
This document will address three principle areas:

1. Receiving, inspection, and storage of cells and batteries
2. Handling during product assembly
3. Packaging for shipment

Receiving, Inspection, and Storage

In general, the conditions that cause damage to cells and batteries and jeopardize the safety of personnel are summarized on the label of each cell. These conditions include:

- Short circuit
- Charging
- Forced over-discharge
- Excessive heating or incineration
- Crush, puncture, or disassembly
- Rough handling or excessive shock and vibration

The most frequent form of handling abuse during Receiving Inspection and Storage is inadvertent short circuiting. Control measures to protect against this form of abuse should be implemented throughout the workplace. It is POWER STABILITY's experience that inadvertent short circuits during handling are the largest single cause of field failures. More specifically, accidental short circuiting is a common occurrence in a receiving inspection environment due to frequent handling.

All POWER STABILITY high-rate cells are internally protected against the hazards associated with short circuits. This is accomplished by incorporating a fast-acting use under the terminal cap. While the fused cells are less likely to heat, vent, or explode under a direct short circuit condition, they will be rendered non-functional. Steps should be taken throughout the receiving and inspection processes to avoid short circuiting cells and batteries.

Issues associated with short circuiting, as well as other hazardous conditions, can be significantly reduced by observing the following guidelines:

- Cover all conductive work surfaces with an insulating material
- Work areas should be free of sharp objects that could puncture the insulating material
- Never disassemble a cell or battery pack or attempt to replace a blown fuse
- Conductive materials (jewelry, etc.) should not be worn by personnel handling cells and batteries
- Cells should be stored in their original packaging or by similar means
- Cells should be moved in trays using pushcarts to reduce the probability of dropping. Dropped cells or batteries should be treated as a potential Hot Cell
- All inspection tools should be non-conductive, or covered with a non-conductive material
- Cells should be inspected for physical damage
- Open-circuit-voltage (OCV) should be checked. The nominal OCV for each cell is printed on the label
- After a cell has been inspected, it should be returned to its storage container
- If leads or tabs need to be trimmed, cut only one at a time

Cell Storage

Storage of hazardous materials is generally regulated by Federal, State, and local regulations. These regulations will vary by region and it is up to each user to determine the appropriate regulations to comply with. Along with regulatory guidance, the following guidelines should be followed:

- Cells should be stored in their original containers or equivalent
- Cells should be stored in a dry, well ventilated area. Ideally, cells will be stored in a temperature controlled environment at 23°C or below.
- Cells should be segregated from other combustible or flammable materials
- Fresh cells should be isolated from depleted or used cells
- Appropriate fire extinguishing means should be available
- Storage areas should be equipped with sprinklers
- Appropriate personal protective equipment should be available
- Exercise caution when stacking boxes to prevent crushing of cells in lower boxes

Handling During Assembly

The guidelines identified in this document should be incorporated into all areas of the facility as Best Management Practices or Safe Work Practices. Additional precautionary measures should be observed in production areas to avoid more serious problems associated with heat, particularly around soldering and welding equipment or during routine performance testing at elevated temperatures. These guidelines include, but are not limited to:

- Written work and training instructions for each manufacturing procedure
- Transport cells in trays on pushcarts to reduce the probability of dropping
- Heat sensitive sheets can be placed on top of cells. These will change color when heated. Some heat sensitive sheets have life expectancy limitations.
- Never solder or use improper assembly techniques when attaching leads or conducting tabs to the cell case
- Heat sinks should be used when soldering to tabs. Contact should be limited to a few seconds
- Use caution when handling cells around solder pots. When tinning leads, only tin one at a time to prevent short circuiting. A cell dropped into a solder pot can short circuit and become a Hot Cell
- Cells should not be forced into housings as this can lead to deformation
- Excessive force should not be used to free a battery or cell from a housing
- Ovens or environmental chambers should be equipped with over temperature protection
- When loading cells and/or packs during short duration electrical tests, use caution not to exceed the current rating of the fusing
- When loading cells and/or packs during long duration performance tests, use caution not to exceed the maximum continuous current rating of the cells
- Cells subjected to continuous high current discharge may overheat, resulting in an unsafe condition. The risk of overheating is elevated when the cells are in an insulated environment

Packaging for Shipment

The regulations that govern the transportation of primary lithium batteries and cells include the International Civil Aviation Organization (ICAO), the International Air Transport Association (IATA) and the International Maritime Dangerous Goods Code (IMDG). In addition to international requirements, domestic regulations must be adhered to. The United States Department of Transportation (DOT) regulates the shipment of lithium cells and batteries domestically under part 49 of the Code of Federal Regulations (49 CFR).

All shipments of hazardous materials in must comply with current packaging regulations based on the United Nations Manual of Tests and Criteria. The packaging requirements require performance oriented packaging, meaning that a package must pass the following:

- Drop test
- Vibration test
- Leak proof test (where applicable)
- Internal pressure test (where applicable)
- Stacking test

These tests are performed by authorized independent testing organizations or by an authorized packaging supplier. Once a packaging system has been certified, the packaging is stamped with a UN marking. UN marked packaging may only be used to transport hazardous materials that have been used in the packaging tests. POWER STABILITY packaging may only be re-used when packaged in its original configuaration.

Lithium cells and batteries are classified as a hazardous materials in the United States unless the specific cell or battery meets an exemption in the 49 CFR. Consult current regulations to determine whether or not an exemption applies.

When transporting lithium cells and batteries by air, IATA Dangerous Goods Regulations must be adhered to. The provisions of the IATA DGR require cells and batteries to meet the requirements of the UN Manual of Tests and Criteria, Part III Subsection 38.3. POWER STABILITY Solutions can provide a Transport Certificate acknowledging that a specific lithium cell or battery meets the testing requirements. This certificate is maintained as long as no changes are made to the cell or pack as manufactured and transported from POWER STABILITY.

The United States DOT prohibits the transportation of primary lithium metal cells and batteries aboard passenger-carrying aircraft into, out of, or within the United States. Consult current regulations for details on exemptions and package weight restrictions associated with this prohibition.

Battery Pack Assembly

While POWER STABILITY cells possess a high power and energy density, many applications require even greater voltage, current, or capacity than a single cell can provide. The solution can be a battery pack of series and/or parallel configured cells. POWER STABILITY Solutions can provide this system or it may be designed and built by the users of POWER STABILITY cells. The following guidelines should be followed:

- Series fuses should be fitted external to the battery to allow for replacement
- Blocking diodes should be implemented wherever multiple cells are tied in parallel
- Thermal cutoff (TCO) or resettable polymeric positive temperature coefficient (PTC) devices can be used to prevent a battery pack from exceeding a safe operating temperature
- Both the surrounding environment and the heat output of a pack during operation should be evaluated to ensure a safe operating temperature is maintained

- Additional thermal management should be considered for large batteries or batteries intended to run at high rates
- Cells connected in series should not have a center voltage tap
- Batteries should not be encapsulated without first consulting with POWER STABILITY Solutions
- Battery compartments should be designed to allow for expansion of the battery pack
- All cells and batteries should be protected against excessive shock and vibration

Battery Fabrication

It is essential that engineering drawings and work instructions are reviewed and completed prior to the initial pack construction. The general handling procedures outlined in this document should also be observed. Safety procedures should be in place to prevent any hazards that may arise while assembling and handling battery packs.

Personnel assembling battery packs should adhere to the following recommendations:

- All jewelry should be removed to prevent short circuiting the battery
- Appropriate personal protective equipment should be worn
- Cells received from POWER STABILITY should remain in their original packaging until they are placed into the battery pack
- Work surfaces should be non-conductive
- Do not solder directly to the cell case
- Solder tabs extending from the cell should be insulated
- Avoid cutting or piercing the insulating shrink wrap on the cells
- Loose wires should not be stripped until they are ready for termination
- Wires should be trimmed one at a time
- All packs should be labeled with the appropriate warnings as they appear in the cell label
- Certain potting materials may be exothermic. Utilize thermal management techniques to remain within the safe temperature range of the cells - Never disassemble the cell

Handling Under Adverse Conditions

Abusive conditions discussed in this document must be avoided to ensure the safe operation of POWER STABILITY cells and batteries. Errors in pack design and assembly can result in emergency conditions that the user must be equipped to mitigate. The intent of this section is to provide a general knowledge of how to handle cells and batteries that have been subject to these adverse conditions. This document will focus on the following:

- Hot cells
- Leaking or venting cells
- Cells that have exploded
- Fires involving lithium batteries

The guidelines in this document are minimum recommendations. Each user shall determine the personal protective equipment needs, training, and emergency response procedures for cells and batteries that are involved in emergency conditions.

Only trained and equipped emergency responders shall be allowed to respond to a vented cell incident. Consult federal, state, and local regulations for emergency response regulations and training requirements.

Hot Cells

A hot cell is a condition that arises due to a short circuit of the cell or battery, either internal or external. The cell/battery temperature rises as the event continues which can lead to the cell reaching critical temperature and the potential to vent or explode.

The following are guidelines for a hot cell emergency response. A hot cell is a potentially dangerous situation and extreme caution needs to be exercised. Only properly trained and equipped emergency responders shall be allowed to respond to a hot cell incident. Consult federal, state, and local regulations for emergency response regulations and emergency responder training requirements.

As soon as a hot cell is detected, all personnel should be evacuated from the affected area. The area should then be secured to ensure no unauthorized personnel enter.

If the situation allows, prior to evacuating, the person that identified the hot cell should quickly determine if an external short circuit is present. After the short is removed, the cell temperature should start to fall. The area should remain evacuated until the cell has cooled to room temperature and has been removed from the area. If the hot cell situation persists, an emergency response may need to be implemented.

Equipment for responding to a hot cell emergency should include a non-contact means of temperature monitoring (thermal imager, thermometer, etc.); safety glasses and an impact resistant face shield; body, arm, and hand protection; and a means by which to move or pick up the battery or cell.

Response Procedure

- Evacuate and secure area as soon as hot cell is detected
- Monitor the temperature from a safe distance using a non-contact thermometer or thermal imager
- If temperature monitoring equipment is not available, keep the area evacuated and secure and do not handle the cell/battery for at least 24-hours

If the cell cools, continue to monitor until it reaches ambient temperature

Remove the cell from the area once it is cool

Dispose of the cell in accordance with waste or recycling protocols

Vented Cells

POWER STABILITY cells have a very high energy density. It is the combination of high voltage and capacity coupled with high reliability and lightweight construction that make POWER STABILITY cells attractive for many specialty applications. When a large amount of energy is contained in a small package, the results can be disastrous if the system is abused.

All POWER STABILITY lithium cells are hermetically sealed in a stainless steel case. A glass-to-metal seal is used as an insulator for the positive terminal. Under normal conditions, a cell will not leak or vent, however; cell leakage or venting can occur if the cell is overheated or the glass seal is compromised by excessive physical abuse.

The severity of a vent can range from a slight leak of electrolyte around the glass-to-metal seal to a violent expulsion of material through the seal or an explosion. In instances where the cell is unrestrained, this can lead to the cell becoming a projectile.

It is unlikely that any lithium battery would explode. These events are rare and are usually the result of an abusive condition or misuse that raises the cell temperature above its critical point. In the event of a lithium battery explosion, a room can quickly fill with a dense white smoke that can cause severe irritation to the respiratory tract, eyes, and skin. Precaution must be taken to limit exposure to these fumes.

The electrolyte contained in POWER STABILITY cells can cause severe irritation to the respiratory tract, mucous membranes, eyes, and skin. Electrolyte reacts with moisture to form Hydrogen Chloride (HCl) and Sulfur Dioxide (SO_2) gases. Some electrolytes can release Bromine (Br_2) and Chlorine (Cl_2) gases as well as HCl and SO_2.

Equipment for responding to a vented cell should include a non-contact means of temperature monitoring (thermal imager, thermometer, etc.); safety glasses and an impact resistant face shield; respiratory, head, body, arm, and hand protection; neutralizing agent (baking soda); individual, sealable plastic bags; and a means by which to move or pick up the battery or cell.

A leaking cell can be handled quickly by trained and equipped assemblers or an emergency response team. After ensuring that the cell is not hot, capture the cell, place it into a sealable plastic bag, fill the bag with baking soda and seal it. Place that bag into a second bag and seal it as well. This will neutralize any leaking electrolyte and stop the formation of fumes. Once the cell is captured, and in a safe place, ventilate the affected area. Ventilation should last as long as it takes for the odor to dissipate. The cell can then be disposed of in accordance with your hazardous waste disposal procedures.

Should a cell explode, ensure that all personnel are evacuated and accounted for from the affected area. Ventilation should be initiated and remain in place until the smoke is cleared and the odor is gone. Clean up of the affected area involves sweeping up any debris and containing it in a sealable plastic bag. The debris may consist of metallic pieces of the cell. Ensure that this debris is not in contact with any other cells, as this may lead to a hot cell. The affected area should be cleaned with a baking soda/water solution or a commercially available liquid acid neutralizer. After cleaning is complete, a second wipe down with a typical cleaning solution may be necessary.

The bag of debris can be disposed of in accordance with applicable hazardous waste disposal regulations. Contact your waste disposal coordinator for proper markings and packaging requirements.

Fires Involving Lithium Batteries

WARNING

The following statements are intended for guidance purposes only. Attempting to fight a lithium battery fire should only be attempted by trained and equipped responders. Consult federal, state, and local regulations for emergency response regulations, emergency responder training requirements, and fire brigade training and protective equipment requirements. Cells or batteries exposed to excessive heat beyond their recommended temperature range can explode. During thermal decomposition chlorine (Cl_2), hydrogen chloride (HCl), and sulfur dioxide (SO_2) can be formed.

In the unlikely event that primary lithium batteries are involved in or near a fire, the principle concern is personal safety. The area should immediately be evacuated and all personnel accounted for. Emergency response organizations, either internal or external, should be immediately notified. The secondary concern in the unlikely event of a fire involving lithium batteries is to prevent the spread of the fire and minimize cell venting. The most effective way of achieving these goals is through the use of large amounts of water. Lithium metal is a water reactive material; however in the unlikely event of a lithium fire, the lithium would be rapidly consumed thus minimizing the risk of a lithium-water reaction.

Flooding the area with water accomplishes two tasks. The water will cool surrounding cells and batteries and reduce the likelihood of additional cells venting. Flooding waters will also help to extinguish any secondary fires present in the area. In the event of a cell venting, a water fog pattern will help to reduce airborne concentrations of sulfur dioxide gas. The water will become a very weak sulfuric acid and is typically diluted by the large amounts of water used.

When attempting to fight a lithium battery fire, appropriate personal protective equipment should be worn. Respiratory protection should include self contained breathing apparatus and protective clothing should include firefighter turnout or bunker gear per local regulations.

Portable fire extinguishers should be considered a last resort for fighting a lithium battery fire as they require emergency responders to be in very close proximity to the fire. There are several types of portable extinguishers available commercially.

Class D fire extinguishers (copper based) have been developed for and proven successful for extinguishing lithium and lithium alloy fires. The compound acts as a smothering agent and also acts as a heat sink. Copper-based extinguishing media is able to cling to vertical surfaces. Care should be taken to ensure that Class D fire extinguishers are of the copper-type, and not sodium chloride. The sodium chloride extinguishing agent is not intended for the high heat of a lithium fire, nor will it cling to vertical surfaces.

Graphite-based extinguishing media are effective on smaller lithium metal fires. These work by smothering the fire. This material will not cling to vertical surfaces, but has been developed for high-heat metal fires such as magnesium and lithium.

First Aid Procedures for Electrolyte Exposure

Electrolyte composition will vary depending on the type of cell used, but the first aid procedures remain constant. Electrolyte will react with moisture to yield sulfur dioxide, hydrogen chloride, and chlorine depending on the electrolyte. Immediately refer to the Material Safety Data Sheets for additional information.

Eyes – flush with cool water for at least 15-minutes. Hold eyelids open and rinse thoroughly. Seek immediate medical attention

Skin – flush with cool water for at least 15-minutes. Remove contaminated clothing. Seek medical attention if necessary.

Inhalation – move to fresh air. If difficulty breathing, administer oxygen according to local protocols. If not breathing, begin artificial respirations and seek immediate medical attention.

Ingestion – DO NOT INDUCE VOMITTING. Drink copious amounts of water. Notify Poison Control or seek immediate medical attention. Never give anything to drink to a person that cannot swallow.

Cell/Battery Disposal

POWER STABILITY primary cells and batteries require special handling for disposal. Disposal requirements are region specific and many waste handlers have further requirements that need to be followed when disposing of cells or batteries. Primary cells and batteries can be recycled or disposed of as a hazardous waste.

General practices that should be followed when packaging a cell or battery for disposal or recycling include:

Secure terminals to prevent short circuiting

Package each cell or battery in a manner that prevents shorting with the container or another cell/battery

Package leaking cells/batteries in a manner that contains the leak (refer to Vented Cells)

Use packaging material that is in compliance with local regulations

Regulatory Considerations

Each region of the world has differing regulations that the end user of POWER STABILITY cells and batteries is responsible for complying with. Throughout this document, recommendations have been made on the safe and proper handling of lithium cells and batteries.
These recommendations do not take into consideration local requirements or regulations. It is the responsibility of each end user to establish their own internal policies and procedures while adhering to all applicable local regulations.

This document is not intended to provide all the information that you will need to be able to work safely. The guidelines are established to help facilitate site specific guidance in accordance with local regulations.

POWER STABILITY Solutions is a resource to our customers. If there are concerns around the safe handling of POWER STABILITY cells or batteries, we will help to address those concerns. Our goal is to provide all of our customers with safe and reliable portable power. Safety starts with those handling the cells or batteries.