R/V ENDEAVOR Lithium Battery Policy and Procedures

1. PURPOSE

This Procedure describes the safety requirements for lithium (primary) and lithium-ion (secondary) batteries that are used in battery packs. This Procedure covers normal and emergency conditions and applies to all personnel that use, store, and dispose of lithium battery packs aboard R/V Endeavor.

This Procedure is intended for science parties, marine technicians and ship's crew not acting as an emergency responder.

2. DEFINITIONS

Cell: A single primary or secondary battery.

Battery Pack: An assembly of cells that are connected in series or parallel. Each battery pack typically contains only one type of cell, primary or secondary.

Primary or non-rechargeable lithium cells: These cells have lithium metal or lithium compounds as the anode and are non-rechargeable. Many different primary cell chemistries are available. Lithium metal is water reactive and forms hydrogen and lithium hydroxide in aqueous solution. The lithium in primary cells is hermetically sealed to avoid this exothermic reaction. Lithium's melting point is 357°F.

Secondary or rechargeable lithium-ion cells: These cells do not contain metallic lithium and are rechargeable. Secondary cells contain lithium intercalation anode materials, where the lithium ion moves from the anode to the cathode during discharge and from the cathode to the anode when charging.

3. RESPONSIBILITIES

Research Vessel (R/V) Science Parties

- Obtain and understand the battery manufacturer's Material Safety Data Sheet (MSDS), Technical Specification sheet(s) and other available documentation prior to bringing batteries aboard. Understand and document the various failure modes and hazards associated with the proposed configuration(s) and type(s) and number of batteries used.
- Create and verify written standard operating procedures (SOPs) for lithium and lithium-ion powered research devices that reduce the chances of battery failures that can occur during: assembly, deployment, data acquisition, transportation, storage, disassembly and disposal.
- Use the cruise planning web site to notify the intent to bring lithium batteries and/or equipment containing batteries aboard. State if any batteries or equipment will require special handling or procedures.
- Upload SOPs, MSDSs and specification documents to the cruise planning web site.

- Provide paper copies of SOPs, MSDSs and specification documents to the marine technician when the batteries are brought aboard the ship.
- Understand when it is safe to provide initial response to lithium and lithium-ion battery emergencies. Notify bridge to initiate vessel emergency response procedures.

Technical Services Department

- Assist science party with the responsibilities detailed above in both pre cruise planning and aboard ship. Help align generic SOPs with realities of working aboard Endeavor.
- Assist science party in stowage of batteries aboard ship.
- Verify science party compliance with science party responsibilities.
- Provide initial response to lithium and lithium-ion battery emergencies when safe to do so. Notify bridge to initiate vessel emergency response procedures.

Marine Office and Ship's crew

- Respond to lithium battery and lithium-ion battery emergencies with vessel emergency response procedures.
- Include lithium and lithium-ion battery emergency response procedures in drills and training.

4. CELL HANDLING PROCEDURES

Battery manufacturers report that inadvertent short circuits caused by abuse during handling are the largest single source of field failures for both lithium and lithium-ion cells, especially during receipt, inspection, and storage of cells. Problems associated with shorting as well as other hazardous conditions can be reduced by observing the following guidelines:

- Cells should be transported in non-conductive carrying trays. This will reduce the chances of cells being dropped, causing shorting or other physical damage.
- If cells are removed from their original packages for inspection, they should be arranged to preclude shorting. Do not stack or scatter the cells. They should be placed in non-conductive carrying trays with individual compartments for each cell.
- Written work instructions or checklists should be generated for assembly and testing procedures. After a cell has been inspected it should be returned to its original container. All inspection tools (including calipers, rulers, etc.) should be made from, or covered with, a non-conductive material, when possible.
- Wear safety glasses whenever handling batteries. Remove jewelry items such as rings, wristwatches, pendants, etc., that could come in contact with the battery terminals. Jewelry has been accidently welded to lithium battery cells, causing serious burn injuries.
- All dented cells should be disposed. Denting of sides or ends increases the likelihood of developing an internal short circuit at a later time.
- Cover all metal work surfaces with an insulating material. Work areas should be clean and free of sharp objects that could puncture the insulating sleeve on cells.
- Measure the open-circuit-voltage (OCV) of the cell. The nominal OCV for each cell chemistry is printed on the cell label or in the manufacturer's data sheet. An open circuit voltage of 0.0 volts may be indicative of a blown fuse. However, if no fuses are present in the circuit, 0.0 volts could be a result of complete discharge.

- If leads or solder tabs need to be shortened, only cut one lead at a time. Cutting both leads at the same time can short the cell.
- Cells should not be forced into battery holders or other types of housings. Check for proper fit before inserting the cells into any type of housing. This could deform the bottom of the case causing an internal short circuit. Furthermore, the terminal cap could be crushed putting pressure on the glass- to-metal seal. This could result in a cell venting. Excessive force should not be used to free a cell or battery lodged inside the housing.
- Primary cells and/or batteries, should not be exposed to high voltage AC sources or other DC power supplies that could result in subjecting the cells to unanticipated charging or forced-discharging currents.
- Secondary cells should be charged only according to the cell or battery manufacturer's directions, particularly with respect to maximum applied voltage.

5. CELL STORAGE

Minimize the inventory of lithium batteries in storage by implementing a just-in-time inventory system in both storage and use areas.

Primary Lithium Batteries

- Do not leave packages or pallets of batteries unattended where they can be damaged by personnel or vehicles.
- Storage areas should be visually inspected on a routine basis. Documentation of inspections does not need to be maintained.
- Separate fresh and depleted cells.
- The presence of primary lithium batteries in a compartment shall be documented at the entrances of the compartment.
- Storage areas with more than 5 pounds of metallic lithium must be placarded with a NFPA 704 diamond that is at least 18" on each side with applicable information (e.g., Health 3, Flammability 2, Reactivity 2, and Special Hazard ~~W~~).

Secondary (lithium-ion) Batteries

- All applicable storage requirements for primary cells shall be followed. Minimize the inventory in storage.

6. EMERGENCY PROCEDURES

Only trained and properly equipped emergency response personnel should respond to lithium battery emergencies, including: leaking cell, vented cell, hot cell, and fires.

Hot Cells

A hot cell is a condition that arises due to an internal or external short circuit of the cell or battery. It the cell temperature continues to rise above the critical temperature, the hot cell could vent or explode.

As soon as it has been determined that a hot cell situation exists, evacuate all personnel from the area. The area should be secured to ensure that no unnecessary persons enter. Notify the bridge and initiate the vessel emergency response procedures.

If the situation allows, prior to evacuating, determine if an external short circuit is present. If safe to perform, quickly remove the short-circuit. The area should remain evacuated until the cell has cooled to room temperature.

Response Procedure for Emergency Responders:

- Ensure unauthorized personnel have evacuated the hot cell area.
- Monitor the temperature with a remote device such as a non-contact thermometer or thermal imager.
- If remote temperature monitoring device is not available, keep area evacuated/secured and do not handle battery for at least 24-hours.
- When the cell cools and is safe to handle, remove it from the area and dispose as universal waste.

Vented and Leaking Cells

Major manufacturers of primary lithium batteries report that it is unlikely that a cell will explode and that this rare event is usually the result of a condition that raises the cell temperature above its critical point. Depending upon the cell chemistry of the primary lithium batteries, an exploded or vented cell could fill a space with dense white smoke that can cause severe irritation to the respiratory track, eyes and skin. Depending upon the cell chemistry, the following chemical compounds could be released from an exploded or vented cell: hydrogen chloride, sulfur dioxide, bromine, and chlorine. Avoid exposure to these airborne contaminants.

- If a cell has vented, leaked or exploded, evacuate all personnel from the area. The area should be secured to ensure that no unnecessary persons enter.
- Notify the Bridge and initiate the vessel emergency response procedures.

Response Procedure for Emergency Responders:

- Ensure unauthorized personnel have evacuated the vented or exploded cell area.
- If necessary, ventilate the space where the cell vented or exploded until the smoke has cleared and the odor is gone.
- Monitor the temperature with a remote device such as a non-contact thermometer or thermal imager. When the cell cools and is safe to handle it can be neutralized with baking soda inside a sealed bag and disposed as universal waste.
- If remote temperature monitoring device is not available, keep area evacuated/secured and do not handle battery for at least 24-hours.
- Electrolyte spill areas and cell explosion debris should be neutralized with baking soda.

Electrolyte Exposures and First Aid

While the electrolyte composition will vary depending on the type of primary lithium battery cell, the general first aid procedures are the same for an exposure to the electrolyte. Electrolyte that is exposed to air at normal temperature and pressure can react with moisture to generate sulfur dioxide, hydrogen chloride, and chlorine. Refer to the specific material safety data sheet (MSDS) for detailed, cell-specific information. General first aid procedures are listed below.

- Notify the bridge and initiate the vessel emergency response procedures.
- EYES: Flush with water for at least 15 minutes and hold eyelids open to rinse thoroughly. Remove contaminated garments.
- SKIN: Flush with water for at least 15 minutes and remove contaminated garments.
- INHALATION: Move to fresh air. Monitor airway breathing and circulation. If necessary, implement appropriate first aid and/or CPR procedures.
- For significant exposures to electrolyte, get immediate medical attention. The applicable MSDS should be available when contacting medical help and sent with the patient to the hospital.

Primary Lithium Battery Fires

Only trained and properly equipped emergency responders should attempt to fight a primary lithium battery fire. Cells exposed to excessive heat beyond their recommended temperature range can explode. A cell fire within a battery pack can lead to the chain reaction that involves multiple cells. Note: metallic lithium melts at about 180°C (356°F). Depending on the cell chemistry, the thermal decomposition byproducts may include chlorine, hydrogen chloride, sulfur dioxide, and other compounds. A major battery manufacturer reports that portable fire extinguishers should be considered a last resort for fighting a primary lithium battery fire, as they require emergency responders to be in close proximity to the fire. Therefore, Class D (yellow) portable fire extinguishers are not recommended for use in any primary lithium battery storage or use areas.

During a lithium battery fire there are two main objectives: 1) life safety, and 2) preventing the spread of fire to other cells, preventing cell venting, and protecting the building/property. The most effective way to achieve these goals is through the use of large amounts of water. Lithium metal is contained in primary cells and is water reactive; however a major battery manufacturer reports that the relatively small amount of lithium in a cell would be rapidly consumed and thus minimizing the risk of a lithium-water reaction. Flooding the fire area with water will cool the surrounding cells and reduce the likelihood of additional cells venting. Flooding water also helps to extinguish secondary fires that could lead to a building structural fire.

In the event of a primary lithium battery fire: Evacuate the area and notify the bridge and initiate the vessel emergency response procedures.

Secondary Lithium-ion Battery Fire

Secondary lithium batteries contain an ionic form of lithium and do not contain metallic lithium. Therefore, the above precautions for primary lithium batteries do not apply to lithium-ion battery fires. The general fire procedures for secondary lithium batteries are listed below.

- Evacuate the area. Notify the Bridge and initiate the vessel emergency response procedures.

- Fight the fire if it is small (incipient stage), safe to do so, and you are adequately trained. Lithium-ion battery fires are considered an ordinary combustible fire; therefore a portable ABC fire extinguisher can be used.

7. WASTE MANAGEMENT

All waste management steps (collection, temporary storage, recycling, disposal, etc) for spent or waste lithium and lithium-ion batteries must conform to the University of Rhode Island Universal Waste Management Guideline, which is available on the URI Hazardous Waste web site: http://web.uri.edu/ehs/hazardous_waste/. The basic waste management procedures are described below.

- Isolate/secure all battery cell and pack leads and terminals to prevent short circuiting.
- Ensure the type of batteries is clearly written on the cell or pack.
- Gently place the spent cells and packs in the appropriate universal waste collection container. DO NOT throw the batteries into the collection container, as this can cause a short circuit. Spent lithium and lithium-ion batteries should go into the same universal waste container that is labeled 'lithium batteries.' Do not mix lithium batteries with other types of batteries, such as alkaline.
- Single cells of lithium-ion (secondary) batteries can go into the regular trash. However, spent lithium-ion battery packs must go into the lithium battery drum.
- Large quantities of spent lithium batteries (e.g., pallets) should be collected near the point of generation and do not need to be deposited in or near the universal waste drums.