	Alkaline Battery Pack Safety	12/27/2010 Rev.0

1.0 PURPOSE AND SCOPE

This procedure describes the safety requirements that apply to alkaline battery packs under normal and emergency conditions. This procedure applies to all WHOI personnel that design, use, store, and dispose alkaline battery packs.

2.0 GENERAL BATTERY PRECAUTIONS

- Never recharge primary cells. Primary (non-rechargeable) cells should not be exposed to external electrical power supplies that could cause unintentional charging or forced discharging current. This abusive condition could lead to excessive hydrogen off-gassing and an explosion.
- When in storage, cells should be stored in their original packaging from the manufacturer and within temperature range recommended by manufacturer.
- Cells that have been damaged or abused should be treated as if they are leaking. Place them in a plastic bag and contact EH&S for disposal (wastepickup@whoi.edu).

3.0 BATTERY PACK DESIGN, FABRICATION AND HANDLING

To increase the safety margin and decrease the failure rate of battery packs, the hazard analysis process should be conducted during the design phase of battery packs. Battery pack designers should refer to the Lithium Battery Safety Guideline for more detailed instructions on the hazard analysis process.

- Batteries should not be encapsulated in an air or watertight container without first consulting the manufacturer and observing the hydrogen gas precautions in section 4 below.
- Designers should choose batteries with the lowest power output needed to meet the application requirements.
- Before designing battery packs, review the battery manufacturer's technical specifications for the same type of cells that will be used in the battery packs.
- Do not solder directly to the cell case or outer sleeve. Solder only to solder tabs that are approved or recommended by the manufacturer. Cut one lead at a time to avoid a short circuit.
- Battery pack construction should consider the need for proper venting and heat transfer. Do not obstruct the cell's vent mechanism, which is designed to relive excessive pressure and protect against cell rupture.
- Always use the same size and type of cells in series and parallel connections.
- Partially discharged cells should not be mixed with fresh or fully charged cells in a battery pack. Always replace all batteries at the same time since batteries in series that are in different states of discharge may eventually drive the weakest battery into voltage reversal with progressive risk of leakage or rupture.

4.0 HYDROGEN GAS GENERATION FROM ALKALINE BATTERIES

During the normal use of alkaline batteries, hydrogen gas (H_2) is produced as a product of the corrosion or natural oxidation process of the zinc electrode in the aqueous electrolyte. Battery manufactures report that significant quantities of hydrogen gas can be generated from alkaline batteries under abusive conditions, including when batteries are discharged below a safe cut off voltage and when a reverse current is forced through batteries (charging). For example, Energizer® has reported the following hydrogen production for a D-size alkaline battery: 4.2 mL (normal use), 130 mL (deep discharge), and 21,800 mL (abusive charge).

Hydrogen gas is explosive at concentrations between 4% and 75% by volume in air at standard temperature and pressure. If alkaline battery packs are going to be used in air-tight or water-tight enclosures, the potential for hydrogen gas generation under normal and abusive conditions must be evaluated and safely controlled. The following lessons learned where identified during the investigation of a transponder sphere explosion and, where applicable, should be considered during design and use of alkaline battery packs in enclosed equipment and instruments:

- Determine the maximum possible hydrogen gas volume that can be accumulated in an enclosed space under normal and abusive conditions for battery packs that will be enclosed. Reduce the potential for an explosive atmosphere to be generated under all possible conditions. Some examples include: reduce the potential build-up of explosive hydrogen gas with enhanced absorbers or "getters", use batteries with less potential to generate hydrogen gas, use chemical catalyst to recombine hydrogen gas, and reduce the potential for shorting or deep discharge with engineering controls, e.g., conformal coating of electronic components, engineered cell cut off voltage, etc.
- Eliminate the potential for significant pressure build-up within the sphere (or other similar water-tight enclosure) and subsequent explosion. Some examples include modifying the design of the stainless steel fastening system to allow safe venting of the hemispheres (including elimination of the stainless-steel bands) and the use of rapid pressure relief devices.
- Eliminate the potential for ignition sources where the battery pack is enclosed. Some examples include: use of non-sparking "intrinsically safe" components, relocate sparking components and switches outside of the sphere, and locate power disconnect switches external to the sphere
- Reduce the oxygen content within the sphere by inerting the sphere with nitrogen (may not be effective during loss of vacuum or air infiltration into sphere or enclosure).
- Implement a method to rapidly identify potentially explosive or otherwise hazardous conditions, such as an indicator that is visible from outside the sphere that signals water intrusion or potentially explosive gas.
- Develop procedural steps to safely mitigate a potentially explosive sphere, such as a containment system, remote dismantlement, controlled destruction, etc.
- Coordinate with the vendor that designs and supplies the transponders to enhance the design and increase the safety margin of the transponder sphere system (or other enclosed instrumentation system). The vendor should be encouraged to review and, as feasible, implement the above recommendations related to design modifications.

5.0 EMERGENCY PROCEDURES

5.1 Hydrogen Gas in Enclosed Space

If hydrogen gas may have leaked from a battery pack and has accumulated in an enclosed space, the hydrogen gas must be safely vented and protected from ignition sources. As applicable and if safe to perform, the following steps should be considered for safely mitigating this condition:

- Do not inspect the device or vent the hydrogen gas near any potential ignition sources.
- Isolate the device/instrument from any external and internal electrical or signal connections.
- If safe to perform, vent the device in a well-ventilated location that is safely away from potential ignition sources.
- If the hydrogen gas cannot be safely vented, remote dismantlement or remote destruction of the device may need to be considered.
- Note: these steps should only be performed by personnel that are knowledgeable of the device/instrument in question and understand the associated hazards.

5.2 Leaking Cells

Damaged cells can leak electrolyte. For alkaline batteries, the electrolyte consists of a concentrated aqueous solution of potassium hydroxide to which zinc oxide is added to retard corrosion of the zinc. The electrolyte is alkaline (basic) and can cause severe irritation and damage to the skin and eyes. Note: cells may contain concentrated potassium hydroxide at a 35% concentration and the leakage volume of the electrolyte could be 2-20 mL per cell, depending on cell size.

- Skin contact with the electrolyte can cause caustic skin burns and should be avoided. Wear proper personnel protective equipment (gloves, safety glasses, lab coat) before neutralizing or cleaning up an electrolyte spill. If skin contact occurs, immediately flush with clean water.
- Spilled electrolyte should be neutralized before being cleaned up. Spilled electrolyte from alkaline batteries can be neutralized with an approved caustic neutralizer, such as Spill-X-C Caustic Neutralizer that is available in the green wall-mounted spill kits.
- Place all cleanup materials and damaged cells in a sealed plastic bag or sealed container and contact EH&S for disposal (x3347 or wastepickup@whoi.edu). Clean up materials that cannot be neutralized shall be managed as hazardous waste if the pH of the cleanup materials is greater than 12.5.

5.3 Alkaline Battery Fires

In the event of any fire (including an alkaline battery fire), activate the nearest fire alarm and call x2911 (508-289-2911 from cell phone) to report the fire.

After activating the evacuation alarm, fight the fire only if it is small, you are trained to use a portable fire extinguisher, and you follow these precautions:

- Do not attempt to put out a fire if it is between you and the exit.
- An ABC fire extinguisher can be used to extinguish a small fire, at the incipient stage that involves alkaline batteries and ordinary combustible materials, e.g., wood, paper, plastic, etc.
- If you need more than one extinguisher – the fire may be out of control – evacuate.
- Note: thermal degradation of alkaline cells may produce hazardous fumes of zinc and manganese, hydrogen gas, caustic vapors of potassium hydroxide and other toxic byproducts. Do not fight a fire if you will be exposed to significant smoke - evacuate.

6.0 WASTE MANAGEMENT AND TRANSPORTATION

Single cells of alkaline batteries that are spent and not leaking can be disposed as normal trash. Spent alkaline battery packs that are not leaking should be managed as universal waste by following these steps:

- Prior to disposal all electrical leads from the battery pack shall be safely isolated (taped).
- Spent battery packs must be gently placed in the proper Universal Waste drum that is labeled for alkaline batteries. Do not throw battery packs in the universal waste drum, which could cause cell leakage or rupture.
- Further details can be found in the WHOI Universal Waste Guideline on the EH&S website.

Spent alkaline battery cells and packs that are leaking should be safely neutralized before disposal – refer to section 5.2 above and contact the EH&S office for assistance (x3347 or wastepickup@whoi.edu).

Batteries should be transported in a manner that prevents short circuit or other abusive conditions. Contact the WHOI Distribution Manager for questions about properly shipping batteries.