Lithium Battery Safety Procedures

The purpose of this document is to describe the procedures implemented aboard the R/V F. G. Walton Smith to ensure the safe handling of lithium-metal and lithium-ion batteries and mitigate their inherent risk of fire and explosion. It is intended to be comprehensive and cover everything from Cruise-Planning information gathering to spent battery disposal, firefighting, and first aid. It was developed in response to UNOLS Research Vessel Safety Standards mandate for such a document, described in the Lithium Battery Handling and Storage section of Chapter 9.

BACKGROUND

Lithium-ion batteries have become ubiquitous. They are found in many small electronic devices, such as cell phones, iPads, laptop computers, etc. However, not all lithium batteries in small electronics are lithium-ion batteries. Cameras often have small lithium-metal batteries in them. Lithium-metal batteries are also used extensively in oceanographic research equipment. Their relatively long life makes them ideal for use in equipment deployed for extended periods.

Lithium batteries are affordable, lightweight, and pack a high density of energy. However, they also present unique fire and explosion hazards. Precisely because of their high energy density, cells are quick to overheat in the presence of an electric short circuit, physical damage, overcharging, or other circumstances outside their designed tolerance. This cell overheating can start a chain reaction, with the heat emanating from one cell causing the adjacent cell to also overheat. This process leads to venting or explosion, spilling electrolyte or spewing molten lithium.

From a fire-fighting perspective, lithium batteries can be classified into two distinct, mutually exclusive categories:

- Those that can safely be extinguished with water and water based products, and

- Those that are water-reactive and can be explosive when in contact with water or moist air.

Relevant characteristics of lithium-ion batteries are:[2]

- Contain flammable liquid electrolyte that may vent, ignite and produce sparks when subjected to high temperatures (> 150°C/302°F), damaged or abused (e.g., mechanical damage or electrical overcharging).
- May burn rapidly with flare-burning effect.
- May ignite other batteries in close proximity.

Relevant characteristics of lithium-metal are:[1]

- Produce flammable gases on contact with water.
- May ignite on contact with water or moist air.
- React vigorously or explosively on contact with water.
- May be ignited by heat, sparks or flames.
- May re-ignite after fire is extinguished.

To further complicate matters, fires started by lithium batteries can quickly evolve into multi-class fires (those burning more than one type of fuel). This makes the choice of extinguishing agent even more difficult.

This information should not lead us to be in mortal fear of having lithium batteries onboard. Rather, the purpose of these procedures is to use this information to mitigate the risks, focusing on fire planning, prevention, and early intervention, and thus enhance our emergency preparedness.

CRUISE PLANNING

During the cruise planning process, the Chief Scientist is required to submit complete information on any lithium batteries to be brought onboard with the science equipment. This information includes battery type, quantities, Safety Data Sheets, Technical Specification Data Sheets, and any other relevant manufacturer information available. Preferably, the batteries will remain installed inside the equipment while onboard. If they need to be removed, or they need to be charged while onboard, prior notification and arrangements will need to be made.

PRE-CRUISE SAFETY BRIEFING

A Pre-Cruise Safety Briefing is conducted with the science team prior to each cruise. The briefing includes an explanation of lithium batteries' inherent risk of fire and explosion, and precautions to take when working with lithium batteries. The presentation also covers what to look out for when monitoring the charging process. Science team members are encouraged to take extra precautions with their personal devices, such as not using damaged batteries, and only using the charger that came with the device to recharge the batteries.

FIRE PLANNING

For fire planning purposes, it is important to note that the risk of fire and explosion is much increased by:

- using a battery that is physically damaged,
- improper storage,
- exposure to heat sources, and
- improper charging.

Also, because of the mutually exclusive fire-fighting requirements, it is of utmost importance that fire-fighting teams know exactly, and without a doubt, which type of battery is on fire. To that end, the following procedures address this need and are intended to prevent any potential confusion.

When a fire is in its incipient stage, it might be easy to determine what object originated the fire. However, once engulfed in flames, it will be much more difficult, if not impossible, to determine the cause at first glance. Therefore, there has to be a procedure in place such that the culprit of the fire can be readily known from the location of the fire. This requirement is met by designating, for each individual mission, a well-defined area where each type of battery, or equipment with that type of battery, will be kept at all times.

As mentioned above, the risk of fire and explosion is even higher during the charging process. Therefore, it is very important to choose the charging location keeping that risk in mind. It is also important to ensure batteries are never left to charge unattended, and to stop the charging process as soon as the batteries are sufficiently charged.

When a mission includes science equipment with lithium batteries, a meeting will be required with the Chief Scientist, Captain, Chief Mate (fire team scene leader), Chief Engineer, and Marine Technology Group (MTG) technician. The purpose of the meeting is to review the information about the specific lithium batteries, and devise a **Lithium Fire Risk Management Plan** to mitigate the risks. It will be necessary to determine the best area to stow the equipment, the location and schedule for any needed charging, and who will be responsible for monitoring the charging process. These decisions, along with other related information, will be documented in the Lithium Fire Risk Management Plan (blank forms are kept with this document). The completed form will be posted in the designated location in the Dry Lab, as well as on the Bridge. Each person at the meeting will then be responsible for disseminating the information to their team, so that every person on the vessel understands what is expected, and is prepared to implement and monitor the devised plan. If anyone observes any deviation from the plan, it must be reported to the Officer of the Watch immediately.

Several factors will need to be considered to determine the safest place on the vessel for equipment with lithium batteries - size, temperature requirements, weight, transportability, need for access, availability of means to secure while underway, etc. In addition, location of fire-fighting equipment and staging areas are important factors to consider. Specifically, for lithium or any other metal firefighting, accessibility to the Wet Lab area is crucial. This area houses the vessel's only Class D fire extinguisher, as well as the container of Lith-X extinguishing powder. The fire-fighting gear cabinet is also in the Wet Lab. As such, this area is used by crew for dressing out. Therefore, lithium batteries should be kept out of the Wet Lab as much as possible. In the event that it is absolutely necessary for them to be there, it should be for the shortest amount of time possible, and in any case should never be left there unattended.

Also to be considered are the following storage recommendations for Lithium-metal batteries:[2]

- Away from direct sunlight,
- between 40-80°F, and
- away from water sources.

When equipment with lithium batteries is to be kept in the Dry Lab, it should be secured in the Port Aft corner, leaving fire escape routes as unencumbered as

possible. The fact that this location is above the PORT fuel oil tank was taken into consideration in arriving at this recommendation. While it is not ideal, there is approximately 18" of space between the top of the tank and the underside of the main deck. In addition, Standard Operating Procedure requires that enough ullage to be left in the tanks to allow for heat expansion of fuel oil without risking overflow. However, this and all vessel arrangements should be kept in mind during any fire situation.

Batteries NOT in equipment:

It is the policy of the vessel that batteries be kept installed in equipment, whenever possible. However, for "mooring turnarounds" and other operations where this is not possible, the following precautions must be observed:

- Batteries should be kept in original manufacturer packaging. Whenever that is not the case, steps must be taken to ensure batteries are always electrically isolated from one another.
- Because this situation presents the highest density of lithium per unit of volume (many batteries in a container as opposed to spread out over many pieces of equipment), the danger is significantly increased. Therefore, special attention must be paid to the choice of stowage location. A nine-foot wide swath, longitudinally concentric with the Dry Lab (and the vessel) spans the open space between the twin hulls. If not otherwise contra-indicated, this is likely the safest area to stow these batteries.
- Wherever they are stored, always handle with care. Do not **throw** into a container. Batteries should NEVER be airborne. Place them gently and carefully in their place.

READY ACCESS:
In any case, lithium-ion or lithium-metal batteries, contained or not contained in equipment, should always be located and stowed such that they are readily accessible to extinguish in the event of a fire. Every effort should be made to clearly label containers and keep access unobstructed at all times.

CHARGING BATTERIES

Given the increased risk of fire and explosion during the charging process of lithium-ION cells, it is the policy of the vessel that secondary batteries arrive at the vessel having been already charged. If there is a need to charge batteries while onboard, special arrangements will have to be made. During the Lithium Fire Risk Management meeting, a safe location will have to be chosen for charging the batteries. In addition, a charging schedule will have to be planned, with human resources allocated to monitor the process. This information will be entered in the Lithium Fire Risk Management Plan, which will be prominently posted in the Dry Lab and the Bridge.

The charging station must be set up in such a way that the person in charge of monitoring the charging process can quickly de-energize it, from a safe distance, in the event of a fire, explosion, or a hot or venting cell. This may be accomplished by a long extension cord, of adequate gauge for the charging load, safely installed so as not to pose a tripping hazard. Both, battery charger and extension cord (or other means of remotely de-energizing) must be provided by the science team. If the remote manner of de-energizing is not obvious, a sign must be posted clearly indicating where and how to de-energize.

The charging batteries must never be left unattended. While it is not necessary to allocate a person to monitor the process exclusively, the monitor must be close enough to the charging station to be able to quickly notice any problems and take appropriate corrective action. The charging process must be stopped immediately if any of the following anomalies is noticed:

- Unusual noise, hissing
- Smell of smoke, burning
- Abnormal heat
- Visible smoke, darkening, melting, bulging, deforming, venting

The vessel is equipped with an infrared non-contact thermometer that may be used to monitor the temperature of the charging batteries.
Any problems, or even the suspicion of any problems, must be immediately reported to the Bridge so that emergency procedures can be activated and the problem can be addressed before it escalates.

FIRE FIGHTING

Training:

- Crew has fire-fighting training as required by STCW.
- All crew have read and understand this document.
- Fire drills are conducted on a regular basis, including both types of Lithium-fire simulations.

Equipment and Supplies:

The vessel is equipped with the following extinguishers:

- Several Dry Chemical and CO_2 (carbon dioxide) fire extinguishers, mounted at various locations throughout the vessel (see Safety Plan for locations).
- One Ansul Class D, Model LX-30-G fire extinguisher, located in the Wet Lab, STBD Fwd. It is filled with Lith-X extinguishing agent. It is cartridge-operated and uses CO_2 as the expellant gas, therefore has a very cold discharge. It weighs 51.5 lbs. when fully charged, and has a discharge time of 30 seconds. Specification sheet is kept with this document.
- A 45-lb. container of Lith-X fire extinguishing powder, which is especially formulated for lithium-metal fires. It is stowed in the Wet Lab under FWD sink. Safety Data Sheet is kept with this document.

The latter two suppress fire by excluding air and conducting heat away from the burning mass.

A 12 lb. bag of sodium bicarbonate (baking soda) is kept on hand to neutralize spilled electrolyte and exploded battery shrapnel. It is stowed on top of the container of Lith-X extinguishing powder.

The vessel is also equipped with a Raytek Raynger ST infrared non-contact thermometer. It has a distance range of 6" to 6', and a temperature range of -25°F to 750°F. It can be used for monitoring the temperature of a hot cell or a cooling fire.

Methods:

The following guidelines take into consideration the specific layout of the vessel, as well as the type, number and location of fire-fighting resources onboard.

It is difficult to determine definitively the best approach to the two types of lithium battery fires. Reading the literature in the sources listed at the bottom of this document (and searching the internet for related information), vague, confusing, and even contradictory information can be found. According to Ed Hayes, COSTHA[9] (Council On Safe Transportation of Hazardous Articles) member, the reason for this is that the science is evolving rapidly, and the industry is relatively new and has yet to reach consensus. Ron Butler, partner with LithFire-X expresses the same opinion in his article "Managing the lithium (ion) battery fire risk" in the Industrial Fire Journal.[10]

In Woods Hole Oceanographic Institution Lithium Battery Safety Procedure, Section 8.4 Primary Lithium Battery Fires, they recommend "the use of large amounts of water." Oregon State University Lithium Fire Prevention Safety Instruction, however, indicates that "Only Class D fire extinguishers that contain a copper powder are approved for combating a lithium fire." They go on to specifically contra-indicate the use of water as an extinguishing agent in lithium metal fires. Tadiran Batteries, a leading provider of lithium-metal batteries for Oceanographic Research applications, recommends Lith-X as the **only** effective means of extinguishing a fire involving a few lithium batteries. They also go on to specifically contra-indicate the user of water, sand, CO_2, Halon, and dry powder or soda ash extinguishers when the cells are directly involved in the fire. NFPA 485 Standard for the Storage, Handling, Processing, and Use of Lithium Metal, paragraph A-6-2.4(a) reads "The application of water in any form on lithium releases considerable amounts of hydrogen gas, steam, and heat and is not recommended on lithium." The Emergency Response Guidebook offers similar advice. To summarize, even though there is conflicting information, the preponderance of the available information clearly indicates water is extremely dangerous as an extinguishing agent in the presence of lithium and should be avoided.

Also, the nature of battery fires is such that they quickly become multi-class fires (other types of fuel around batteries also catch fire). For these reasons, it is practically impossible to make specific recommendations. As a result, the guidelines presented in this document are to be considered a recommended, rather than emphatic protocol. A quick but complete evaluation of the circumstances of each case, combined with situational awareness upon approach,

will play a significant role in making decisions as to how best to proceed. As the industry comes up with better guidelines, this document will be updated to reflect better or more definitive methods.

Jettison

If it is possible to quickly and safely jettison a heating or burning cell or piece of equipment, that may well be the best way to proceed. The problem with the jettison approach, as a pre-planned strategy, is that a burning object is quite difficult to pick up and launch overboard. If the burning object were located on the 01 Deck, it would have to be lifted above the rails and launched with enough force to clear the Main Deck, which extends three feet (3') beyond the 01 Deck on either side. On the Main Deck, the object would have to be raised above the level of the gunwale to jettison over the bulwarks. Prior arrangements to facilitate this procedure using cranes or other devices are not realistically feasible.
If a viable jettison plan is devised, its feasibility should be carefully evaluated *while standing at the proposed location*, so that any problems that may have been overlooked can be more easily identified.

Hot cell:

As soon as a cell appears to be over-heating, do a quick check for an external short circuit. If found, quickly remove the short circuit. If charging, stop immediately. If not charging and no short circuit is found, immediately evacuate the area and cool the battery with a shot from a CO_2 fire extinguisher (if cell catches fire, immediately stop CO_2 application and proceed with the appropriate firefighting method listed below).

Using the Raytek Raynger non-contact thermometer, monitor the cell's temperature to ensure it is not re-heating. Keep in mind that thermal run-away can be a slow process. Lithium batteries have been known to re-ignite a full five days after having been extinguished.

Vented and Leaking Cells:

This situation should be treated as a fire. Protocol should be the same as a fire emergency, including fire alarm.

Area should be immediately evacuated and de-energized. Due to propensity for ignition and explosion, firefighting crew must don full firefighting gear. Because fumes from vented and leaking cells are toxic and corrosive, SCBA is required. Taking cover behind a solid object, a CO2 fire extinguisher should be used to cool the battery. Due to danger of explosion, battery should not be handled while it is actively venting. If the battery explodes and a fire ensues, proceed to fight the fire according to the appropriate protocol. Once venting and leaking have stopped and/or fire extinguished, sodium bicarbonate (baking soda) should be used to neutralize spilled electrolyte and/or exploded battery shrapnel. Avoid stepping in spilled electrolyte.
Leaking batteries and contaminated absorbent material should be placed in metal containers.[2]

FIRE:

Call for help:
Make the call early. It is better to call for assistance and not need it, than to call when it is too late. Local assistance may be available when near a port. Assistance may also be available from the U. S. Coast Guard, and/or other vessels in the vicinity. When far away from any such assistance, professional guidance may be available over radio or telephone.

Lithium-ION Battery Fire:

- Don full fire-fighting gear, including SCBA.
- Small lithium-ion fires can be safely extinguished with a Dry Chemical fire extinguisher.
- Larger lithium-ion fires that have evolved to a multi-class fire should be fought using the standard fire-fighting protocol, always being extremely cautious of a potential lithium reaction.
- Given that most people do not know exactly what type of batteries power their small electronic devices, if a fire appears to have possibly been started by one such device, a dry chemical fire extinguisher should be used to put it out.

Lithium-METAL Battery Fire:

As mentioned earlier, Tadiran Batteries recommends Lith-X as the **only** effective means of extinguishing a fire involving a few lithium batteries. They specifically contra-indicate the user of water, sand, CO_2, Halon, and dry powder or soda ash extinguishers when the cells are directly involved in the fire. However, if the fire is in an area near the cells, and the cells are not actively on fire, the fire should be fought based on fueling material. Copious amounts of cold water, if not otherwise contra-indicated, would be effective in keeping the cells cool while extinguishing the nearby fire. CO_2 would also have a similar cooling effect.

Categorize the fire according to the amount of lithium metal involved:

- Small – e.g., a tag with less than 1g of lithium in its battery
- Medium – e.g., a CPIES (Current and Pressure recording Inverted Echo Sounder) with 240 grams total lithium in its battery pack
- Large – e.g., a container with enough batteries for 12 CPIES mooring turnarounds (3kg of lithium metal)

The choice of initial extinguishing agent will be based on the following factors:

- Safety Data Sheet (SDS)
- Battery Manufacturer's recommendations
- Amount of lithium metal
- Stage of fire
- Other types of fuel involved (multi-class fire)

If the amount of lithium metal is relatively small, and the fire has advanced to a **multi-class fire** (it has spread to other types of fuel), it is likely that the small amount of lithium will have already been consumed by the fire, thereby reducing the risk of a lithium-water reaction. Obviously, this evaluation will have to be made in real-time based on the factors listed above. Even if the lithium were not totally consumed, if other types of fuel are significant contributors to the fire, Lith-X might not be an effective extinguishing agent. In this case, depending on the size of the fire, dry chemical or water would be the next best choices of extinguishing agent. If the fire is still relatively small, dry chemical is the best choice to be sure to avoid a lithium-water reaction. However, if the fire is larger, water may be the safer choice because it can be applied from a longer distance. If water is the choice, keep in mind the very real possibility that the lithium may NOT have been consumed, in which case it might be molten. Molten lithium is very fluid, easily spread, and highly reactive, which makes it extremely hazardous.

When molten lithium reacts with water, it can be ejected for a considerable distance. One of the greatest dangers to firefighters is the splattering effect of burning lithium.[8] Furthermore, tests have demonstrated that the effect of water on lithium fires is the formation of hydrogen gas. In some cases, hydrogen will burn and intensify the fire; in other cases, hydrogen results in rapid heat rise with an explosive-like effect.[8] Even when the probability of this happening is relatively low, this situation calls for extreme caution. Approach from a safe distance, taking cover behind a solid object, if possible. Be prepared for a quick retreat and change of plans if there are any signs of a lithium-water reaction.

If the amount of lithium is considerable, such as in a container with 3kg of batteries NOT in equipment, water or water-based products should definitely NOT be used. The Class D fire extinguisher and Lith-X extinguishing powder would be the only possible choices, given the high likelihood of a lithium-water reaction. Due to the possibility of explosion, the Class D fire extinguisher would be the preferred initial choice over the Lith-X extinguishing powder because it can be applied from a longer distance. This extinguisher has a maximum effective range of eight feet. Proceed with extreme caution but no hesitation, taking cover behind a solid object if possible. Once extinguisher is expended (discharge time is 30 seconds), proceed with Lith-X extinguishing powder to make sure fire is completely smothered. Lith-X forms a crust over the fuel, but due to molten lithium's fluid properties, lithium tends to "burn-throughs."

Summary points:

- Lithium-METAL fires should be extinguished with the Ansul Class D fire extinguisher. <u>DO NOT USE WATER OR FOAM</u>.
- Given the risk of explosion, try to take cover behind a substantial object when approaching the fire.
- While a lithium fire is being fought, every effort shall be made to avoid splattering the burning lithium.[8]
- Initial approach to fire should be with Class D fire extinguisher, starting from 8' away, taking cover as much as possible.
- Once it is safe to approach closer, you may use Lith-X powder to make sure all burning metal is completely covered.
- Lithium fires burn hot. While water can be used for boundary cooling, extreme care must be taken not to allow water to come in contact with fire, or hot remains of fire, as this would produce flammable gases and create a

highly explosive atmosphere. Contact with water may also produce harmful corrosive solutions.

- Given the characteristics of a lithium-metal fire and the health hazards they present, crew will need to don full fire-fighting gear, including SCBA, prior to approaching the fire.

Overhaul:

We have learned several lessons about lithium-ion battery fires from the recent and much-publicized TESLA car fire incidents. But the over-riding theme seems to be the propensity for RE-ignition, surprisingly much later after the original fire was extinguished. In one incident, the battery pack re-ignited twice despite firefighters dousing it with copious amounts of water and foam. It first reignited when crews were removing the car from the crash scene, and again when it arrived at a storage yard. On another occasion, the battery pack re-ignited five days after the vehicle was left in an impound lot.
Even though the amount of lithium we encounter is often much less than the 63kg of lithium in a TESLA battery pack, the chemistry and fire dynamics apply all the same. Therefore, we must take the concern over re-ignition very seriously. Whereas an initial spontaneous fire is very unpredictable, once there has been a fire, we must be on high alert and prepared for a possible, and probable, re-ignition. For this reason, it is imperative that a fire watch be constantly maintained after either kind of lithium fire. This fire watch must be maintained until the end of the mission, or until the fire site is cleaned and overhauled by professional crews.

Other points to keep in mind during overhaul:

- Fire site should be cordoned off and all non-essential personnel kept away.
- Runoff from fire control may cause pollution. Care should be taken to contain the burned residue and extinguishing agents.
- Ventilate the area before re-entry.
- Once the fire is extinguished and a crust is formed, the crust shall not be disturbed until the residues have cooled to room temperature.[8]
- Even after a lithium fire has been extinguished, lithium may still be present in sufficient quantity to create adverse reactions and exhibit the burning characteristics of lithium. Lithium fire residues can include other reactive

components. Residues can be coated with water-free mineral oil to exclude water and reduce the potential for reaction.[8]

- A fire-watch should be implemented and maintained until the end of the mission, even after the fire residue has completely cooled down.
- Once completely cooled, fire remains should be covered with a tarp to protect it from seawater spray, rain, or any other water sources.
- DO NOT CLEAN UP OR DISPOSE OF, EXCEPT UNDER SUPERVISION OF A SPECIALIST.[1]

When all has failed

If all appropriate vessel resources have been expended and the fire could not be put out, it does not necessarily mean all is lost. Before making the decision to abandon ship, consider the possibility of letting the fire burn out. Depending on the fire, it might be possible to move the fire to an area where it would be safe to allow it to burn out.

Keeping in mind that a disabled, half-burned ship is still a safer place to await rescue than a life raft, abandoning ship should be an absolute last resort. However, when all efforts have failed and it is determined there is no way to save the ship or it is no longer safe to be on the ship, the Master of the vessel will make the decision to Abandon ship and sound the alarm. All focus and effort should then shift to enacting the Abandon Ship protocol.

FIRST AID[1,2]

Health-related characteristics specific to Lithium-ION batteries:

- Fire will produce irritating, corrosive and/or toxic gases.
- Electrolyte may be irritating to skin, eyes and mucous membranes.
- Burning batteries may produce toxic hydrogen fluoride gas.
- Fumes may cause dizziness or suffocation.

Health-related characteristics specific to Lithium-METAL batteries:

- Fire will produce irritating, corrosive and/or toxic gases.
- May also produce corrosive solutions in contact with water.
- Inhalation or contact with vapors, substance or decomposition products may cause severe injury or death.

If exposed to any of the above:

- Move victim to fresh air.
- Call 911 or emergency medical service.
- Give artificial respiration if victim is not breathing.
- Administer oxygen if breathing is difficult (located in Mess Hall, under ladder).
- Remove and isolate contaminated clothing and shoes.
- In case of contact with corrosive solution, wipe from skin immediately; flush skin or eyes with running water for at least 20 minutes.
- Keep victim warm and quiet.
- Inform medical personnel of the material(s) involved.

DISPOSAL

This section pertains to disposal of spent batteries, NOT to disposal of fire remains (this is covered in Overhaul Section).
If lithium batteries need to be removed from science equipment and discarded onboard, a special container must be provided for the spent batteries until the ship returns to homeport for proper disposal. It is the responsibility of the science team to provide an adequate container for this purpose. The leads of each battery must be cut off and the terminals carefully taped with electrical tape, or other insulating tape, to prevent them from accidentally discharging further and increasing the risk of fire or explosion. The disposal container shall be labeled according to what type of batteries it contains – lithium-metal or lithium-ion. If both types are being discarded, two separate containers must be provided. The placement of the containers will be decided based on the same criteria as for *batteries NOT in equipment* in the Fire Planning section above, taking care to keep lithium-metal containers well enough apart from lithium-ion containers, as well as keeping lithium-metal containers protected from any source of water or water spray.

Even though lithium metal is not listed or characterized as a toxic hazardous waste, significant amounts of spent cells and batteries that are untreated and not fully discharged are considered as reactive hazardous waste[7]. Therefore, spent batteries need to be neutralized prior to disposal. Neutralization and disposal should be performed by an authorized, professional disposal company having knowledge of all federal, state and local regulations regarding material,

transportation and waste disposal[7]. Arranging for proper disposal, and corresponding expense, is the responsibility of the science team.

SHIPPING

The science team is responsible for any shipping of lithium batteries to and from the vessel. Instruction on how to comply with transport regulations is beyond the scope of this document. However, the following links may provide a place to start researching the applicable requirements:

- https://www.phmsa.dot.gov/lithiumbatteries
- https://www.ecfr.gov/current/title-49/subtitle-B/chapter-I/subchapter-C/part-173/subpart-E/section-173.185

Sources:

[1]2016 Emergency Response Guidebook, Guide 138
[2]2016 Emergency Response Guidebook, Guide 147
[3]Oregon State University Environmental Health and Safety Lithium Fire Prevention Safety Instruction Fact Sheet
[4]Woods Hole Oceanographic Institute Lithium Battery Safety Procedure, 23 Feb 2011
[5]UNOLS Research Vessel Safety Standards, 10th Edition, July 2015, Chapter 9, Scientific and Shipboard Hazardous Materials
[6]UNOLS Safety Circular regarding Lithium Battery Safety Information, 10 May 2012
[7]Tadiran Batteries, Ltd., Lithium Technical Notice LTN0111
[8]NFPA (National Fire Protection Association) 485 Standard for the Storage, Handling, Processing, and Use of Lithium Metal
[9]COSTHA – Council On Safe Transportation of Hazardous Articles
[10]Industrial Fire Journal – Fire & Rescue – Hemming Group Ltd: Managing the lithium (ion) battery fire risk, 23 July 2013