Session 781

Lithium Batteries: What Every SH&E Manager Must Know

Scott C. Dunsmore, CET
Vice President
Lion Technology Inc.
Lafayette, NJ

Introduction

Beginning in the latter portion of the 20th Century and continuing into this century, our society has witnessed the growth in the production and use of portable electronic devices. This includes equipment and tools that are used within the workplace (e.g., cordless tools, cell phones, tablet/slate computers, e-readers, and more). The demand for these portable devices continues to grow. This demand triggers the need for the batteries powering these devices to be more powerful, longer lasting, and able to work in more environments.

Lithium batteries have quickly become the battery of choice for just about every type of portable electronic device. Lithium batteries have become the most common battery type to fulfill these demands. This, in part, is due to the unique characteristics of this battery type's chemistry. Lithium batteries have the highest energy level (i.e. energy/unit weight and energy/unit volume). Also, due to the absence of water, the batteries have a fairly large operating temperature range (e.g., ≥-55°C and ≤ 150°C).

Like other batteries, there are similar hazards that must be addressed from a SHE perspective. However, due to their unique properties, lithium batteries are subject to hazardous materials transportation, environmental, and workplace safety regulations. This adds to the challenge of proper management-use/handling, storage, disposal, and transportation.

Whether a company ships a finished product or component that contains a lithium cell or battery or employees use or travel with equipment containing lithium batteries, there are specific regulations that apply to their use, handling, transportation, and disposal. In all of these situations, safety, health and environment (SH&E) managers are on the front line. They must assess each activity and assure each is done in compliance with the latest requirements.

What's more, technology is changing quicker than our regulations can keep up. As more is learned about the risks, new or revised regulations seem to come out monthly. The SH&E manager must be aware of pending changes and assist their organization commit resources to meet new obligations without unnecessary delay or cost.

Battery Basics

In everyday terms, a battery is a device that converts stored chemical energy into usable electrical energy. A battery is essentially a box in which there is an electrochemical reaction which produces electrons. It is the movement of the electrons from one pole to another that is the electrical current. To be a battery, there must be three components-an anode, a cathode, and an electrolyte.

However, technical sources, including certain regulatory programs, may be necessary to separate vernacular terminology from some of the more technically correct terminology. One of the distinctions is in the use of the terms “cell” and “battery.” Technically, a cell is the device capable of receiving, storing, and producing an electric charge, consisting of the anode, cathode, and electrolyte. A battery is a series of two or more cells. So, the button cell battery that one places in a wrist watch is technically a cell. The device in a person's laptop computer, which contains typically six to nine cells connected together, would be considered a battery.

The basics of what a battery is and how it works are essentially the same as when the first battery was invented in 1800 by Alessandro Volta. However, the specific chemistry, and materials have undergone an incredible evolution. Rechargeable batteries, such as lead-acid, lithium ion and nickel-metal hydride, have the capability of reversing the reaction by applying a current to the battery (i.e., driving the electrons back to the negative pole).

Lithium Battery Types

Lithium batteries can be divided into two basic categories: primary and secondary. The difference between the two types of batteries is based on the “form” of the lithium that they contain. A primary lithium battery is a battery that has lithium metal or lithium compounds as the anode. Primary lithium batteries are sometimes referred to as “non-rechargeable” or “disposable” batteries. Primary lithium batteries are also known as lithium metal batteries or “Li-Metal batteries.”

A secondary lithium battery is a battery that contains lithium ions that move from the negative electrode to the positive electrode during discharge, and back again when charging. Secondary lithium batteries are sometimes referred to as “rechargeable” batteries. Secondary lithium batteries are also known as lithium ion batteries or “Li-Ion batteries.”

Since their introduction in 1991, lithium ion batteries have become popular because of the electrochemical properties. These batteries typically have a graphite anode, a cathode made of lithium ion phosphate, lithium cobalt oxide, or lithium manganese oxide, and a solid lithium salt in an organic solvent as the electrolyte. Lithium batteries have the highest specific energy and energy density of any battery type. That coupled with the ability to hold a high energy level until depletion, makes the batteries not only more powerful, but more effective between charges.

Lithium Battery Hazards

Perhaps all this capability comes at some cost. What is it about the lithium batteries that create this increased risk? Prior to the lithium ion battery, lithium metal batteries had been developed in the early 1970's. There are inherently unstable properties of metallic lithium. This was observed primarily during recharging. The lithium metal would undergo a thermal runaway reaction. The temperature would rise quickly to the melting point of metallic lithium, resulting in a violent reaction.

Manufacturers started using a lithium ion in place of lithium metal. While not carrying as high an energy density, they were still very powerful batteries. The growth of portable electronics and tools drove the demand for more power. Manufacturers were able to pack more active

material into each cell. Since the early 2000s, the number of incidents involving fires of lithium batteries has been steadily increases. In 2006, the Consumer Product Safety Commission (CPSC) announced large-scale recalls of several major brands of rechargeable lithium computer batteries when it was determined that the batteries could possibly overheat, which could in turn catch fire or explode. Commonly in a lithium ion battery there is a coil of metal and flammable, lithium-containing liquid. As a result of the manufacturing process, there are tiny pieces of metal contained in the liquid. It is impossible to completely remove these tiny particles. The lithium ion cells also contain very thin films (20-25 microns) that act as separators-keeping the anodes and cathodes apart. If the battery gets hot, the tiny pieces can move around. This activity can cause the metal to puncture the separator and cause a short circuit. Results of a short-circuit can include:

- Causing sparks to ignite the flammable liquid and cause a fire,
- Causing a thermal runaway reaction (i.e., the temperature and pressure inside rise rapidly resulting in an explosion),
- Causing a slower rise in temperature resulting in the melting of the casing and release of the contents.

In the event of a thermal runaway, the heat from the one cell can propagate to adjacent cells. The timing of the chain reaction will vary. In some cases a battery (multiple cells) can disintegrate in seconds, while others can linger for hours.

Common triggers for lithium battery thermal runaway reactions are:

- Exposure of the battery to heat or fire
- Short-circuit (internal or external)
- Recharging
- Crushing
- High recharge rates

Manufacturers have been building in safeguards and the risk is rare. However, static electricity has been demonstrated to damage the battery's internal circuit guards. This essentially leaves the battery in a permanent “on” position, increasing the risk of a thermal runaway.

Another risk to creating thermal runaway reactions is in cold charging. Charging a lithium ion battery at freezing temperatures ($\leq 0°C$) causes lithium metal to permanently plate the anode. The battery becomes increasingly susceptible to failure when subject to shock (i.e., impact or crushing) or rapid charging.

Workplace Safety Concerns

Based on the properties of lithium metal and the lithium ion compounds in the battery, it is reasonable to presume that these batteries would meet the criteria for a hazardous chemical under OSHA's hazard communication (hazcom) standard [29 CFR 1910.1200(c)]. However, a battery would meet the definition of an article [29 CFR 1910.1200(c)]. With the exception of workplaces that might manufacture, recycle, or dismantle the lithium battery, these batteries would not be subject to the hazcom standard [29 CFR 1910.1200(b)(6)(v)]. However, there are still several workplace safety issues that all employers will have to consider, under either a specific standard or the Occupational Safety and Health Act general duty clause [OSH Act §5(a)]. The following are some of the more common possibilities.

Material Handling

Most employers are not likely to have large stores of lithium batteries. However, due to the potential hazards associated, the employer needs to address the locations for storage of spare

lithium batteries as well as the locations and practices for charging/recharging lithium batteries. OSHA's material handling requirements have a general rule for housekeeping that applies in all workplaces. The requirement at 29 CFR 1910.176(c) may often be read to assure that there are no tripping hazards. However, the standard also requires that care be taken to store materials so as to minimize the risks of fire or explosion. Thermal runaway is more likely to occur in conditions of heat or stress to the battery. Storage batteries and equipment of batteries should be locations that are not exposed to prolonged higher temperatures.

The workplace needs to assure that the batteries are handled in a manner to minimize shock and stress. This should include the handling of the batteries themselves. However, the employer must also consider high traffic areas where material handling activities may increase the risk of shock to stored lithium batteries (e.g., powered industrial truck movement crashing into stored lithium batteries or dropping other material on top of stored batteries).

Fire Fighting

While the risk is still small, the consequences of a lithium battery fire on board an aircraft yield high consequences. Therefore, the Federal Aviation Administration (FAA) has conducted extensive studies on the causes of lithium battery fires and the means to best extinguish the batteries once a thermal runaway reaction has begun. In dealing with a thermal runaway within a lithium battery, there are two objectives:

1. Extinguishing the fire, and
2. Cooling the reaction

Therefore, the techniques to extinguish lithium battery fires are somewhat counter-intuitive to the normal techniques for fighting fires, especially electrical-type fires. The FAA has identified the most effective means as follows (best to least):

1. Water extinguisher – while it is not common to use water for Class B fires, water is the best means of fighting lithium battery fires. The water extinguishes the fire and simultaneously cools the reaction down.
2. Halon (or other extinguishing media) *and* water – the non-water extinguisher will only extinguish the fire. Without cooling the battery, the reaction will continue. This often results in the battery flaring up and subsequent cells exploding. Once the fire is extinguished, copious amounts of water still need to be applied in order to cool the reactions down.
3. Halon (or other) extinguisher alone – this will only extinguish the current fire. The runaway reaction is still occurring and will likely flare up again. This will require the continual use of the extinguisher. This technique merely contains the extent of damage. The battery will continue on its path at disintegration until the reaction is completed (i.e., all cells have reacted).

The FAA advises against the use of pouring ice or other smother agents over the battery fire. While extinguishing the fire, it actually serves as an insulator to the thermal reaction, increasing the risk of battery cell explosion.

OSHA does have workplace safety requirements for the placement, use, and maintenance or portable fire extinguishers [29 CFR 1910.157]. The SH&E manager will need to review the placement of portable fire extinguishers used to fight lithium battery fires to assure that they are adequate for the type of fire and are located so that they are *readily* accessible [29 CFR 1910.157(c) and (d)]. SH&E managers must also assure that these portable extinguishers are inspected and tested per the requirements at 29 CFR 1910.157(e) and (f). Employees that will be assigned responsibilities for using portable fire extinguishers must complete an education and

training program specific to the type or types of fire extinguishers used [29 CFR 1910.157(g)]. The training portion must be repeated annually.

For larger quantities, the employer will need to consider other factors. For example, the use of water may produce hydrogen gas. If the fire is located in a confined, poorly vented area, this may complicate both the firefighting measures and necessary personal protective equipment.

The SH&E manager will also need to consider any personal protective equipment (PPE) that might be necessary in situations for fighting lithium battery fires [29 CFR 1910.132]. The specific type(s) of PPE may depend on the type of lithium batteries and quantities that might be involved in a reasonable fire or thermal runaway situation. This assessment must be documented consistent with the general provisions of the personal protective equipment standard at 29 CFR 1910, Subpart I.

Waste Concerns

As with other discarded materials, the Environmental Protection Agency's (EPA) hazardous waste regulations require the generator to determine whether the discarded material is a hazardous waste [40 CFR 262.11]. The EPA defines hazardous wastes as any solid waste that is either described on a list at 40 CFR 261, Subpart D, or exhibits one or more characteristics defined at 40 CFR 261, Subpart C [40 CFR 261.3]. The EPA does not specifically list discarded batteries (including lithium batteries), so it boils down to the characteristics.

Based on the properties of lithium, it is very likely that the battery may meet the reactivity criteria at 40 CFR 261.23. For example, certain lithium batteries will form potentially explosive hy7drogen gas when mixed with water. This condition satisfied the reactivity criteria at 40 CFR 261.23(a)(3). Some lithium batteries may be capable of violent rupture or reaction if subjected to a strong initiating source or if heated under confinement. This condition would satisfy the criteria at 40 CFR 261.23(a)(6).

There are no standardized tests for the reactivity characteristic. Each generator must consider the specific properties of the lithium battery being discarded. The SH&E manager should speak to each lithium battery manufacture in their workplace to get first-hand knowledge of that battery's chemical and physical properties.

Typically, if a waste meets the definition of hazardous waste, it is subject to the full cradle-to-grave hazardous waste management requirements at 40 CFR 260-270. However, the EPA has established lesser stringent standards for storing and transporting certain hazardous wastes that meet the definition of being a universal waste [40 CFR 273]. Batteries are included in the EPA's definition of universal waste [40 CFR 273.9].

The universal waste regulations provide an alternative set of management standards that operate in lieu of 40 CFR Parts 260 through 272. These regulations are designed to make the on-site management of universal waste simpler for generators.

The universal waste rules identify two groups of persons-"large quantity handlers" and "small quantity handlers." While the management for both is relatively the same, there are some distinctions, so it is important for the SH&E manager to know which designation applies to his or her site. A large quantity handler is a universal waste handler who accumulates ≥ 5,000 kilograms of universal waste (i.e., batteries, pesticides, mercury-containing equipment, or lamps, calculated collectively) at any time. A small quantity handler is a universal waste handler who accumulates < 5,000 kilograms of universal waste at any time [40 CFR 273.9].

Prohibitions

All universal waste handlers are prohibited from disposing, diluting, or treating universal waste [40 CFR 273.11 and 273.31]. They are also prohibited from managing any way that prevents releases to the environment [40 CFR 273.13 and 273.33].

Management

Under the universal waste rules generators may accumulate their lithium batteries for up to one year [40 CFR 273.15 and 273.35]. If the generator needs more time to accumulate sufficient quantities to facilitate proper recovery, treatment, or disposal, he or she must be able to prove the need to exceed the one-year limit.

Universal waste handlers are provided several options to document how long they have been accumulating their universal waste. These options include:

- Marking each item with the date it was initially accumulated,
- Marking the container holding the waste with the date the material was initially accumulated, or
- Using an inventory tracking system.

The waste batteries must be stored in a container that is closed, structurally sound, compatible with the contents, and lacks evidence of leakage, spillage, or damage. The containers must be marked with either:

- "Universal Waste Batteries"
- "Waste Batteries"
- "Used Batteries"

[40 CFR 273.14 and 273.34]

The universal waste rules allow the following activities as long as the casing of each battery remains intact and closed:

- Sorting batteries by type
- Mixing of battery types in one container
- Discharging to remove electric charge
- Regenerating used batteries
- Disassembling batteries or battery packs into individual batteries or cells
- Removing batteries from consumer products
- Removing electrolytes from batteries

If there is a release from the storage of a waste battery, the facility must immediately contain the releases and residues, then determine whether the material resulting from the release is a hazardous waste. If it meets the definition of a hazardous waste, then it must be managed according to the applicable regulations from 40 CFR Parts 262–272.

Small quantity handlers must be "informed" about proper waste handling and emergency procedures appropriate to the type of waste they are handling [40 CFR 273.16]. Large quantity handlers must ensure that employees are "thoroughly familiar" with proper waste handling and emergency procedures [40 CFR 273.36].

Shipments of universal waste lithium batteries are not subject to the normal hazardous waste manifesting requirements. However, the facility must assure that the batteries are transported to:

- Another universal waste handler,

- A destination facility, or
- A foreign destination.

A large quantity handler of universal waste must track the shipment. However, they are not required to use a Uniform Hazardous Waste Manifest. All DOT requirements still apply, including the use of some form of shipping paper.

Additional Requirements for Large Quantity Handlers

Large quantity handlers must receive (or already have) an EPA identification number before meeting the 5,000 kg storage limit. Large quantity handlers must keep a record of all universal waste shipments they receive or ship off site. This record may be a log, invoice, manifest, bill of lading, or other shipping document.

Shipping Concerns

When shipped, batteries present several potential dangers. For example, batteries that contain corrosive liquids could spill or leak during transport, damaging equipment and property and injuring people. All batteries have the potential to give off sparks or excessive heat due to short circuits across the terminals. Lithium batteries in particular pose special risks of causing fires because they have "extra high" energy densities, making it difficult to extinguish the fires that they cause.

All shipping regulations on offering and transporting batteries (new or wastes) are intended to prevent these dangers. Essentially, all shipments of lithium batteries are regulated by the U.S. Department of Transportation's (DOT) hazardous materials transportation regulations at 49 CFR 171-180. However, the DOT allows the use of certain international standards in lieu of the DOT regulations [49 CFR 171.22]. This includes the use of the International Civil Aviation Organization Technical Instructions for the Safe Transport of Dangerous Goods by Air (ICAO TI). The International Air Transport Association (IATA) is a member organization of air carriers. IATA has adopted the IACO TI into its own working regulations, IATA Dangerous Goods Regulations (IATA DGR). The IATA DGR incorporates carrier-specific restrictions that are more stringent than the ICAO TI. The DOT allows shipments of lithium batteries by aircraft to be prepared under the IATA DGR, provided the conditions at 49 CFR 171, Subpart C are followed.

The SH&E manager must know two sets of rules for transporting lithium batteries-DOT for ground shipments (i.e., road and rail) and IATA for air transportation. The remainder of this paper discusses the requirements under DOT and IATA for lithium battery shipments.

UN Tests

With very limited exceptions, all lithium batteries, no matter how they are shipped, must pass specific standards in the UN Manual of Tests and Criteria, Part III, Subsection 38.3 [49 CFR 173.185(a)(1)]. More information on the UN Manual of Tests and Criteria can be found at http://www.unece.org/trans/danger/publi/manual/manual_e.html.

Forbidden Shipments

In addition to specific regulations for shipping batteries, the "Forbidden Materials" requirements at 49 CFR 173.21(c) absolutely prohibit offering or transporting electrical devices, such as batteries and battery-powered devices that "are likely to create sparks or generate dangerous amounts of heat, unless packaged in a manner which precludes such an occurrence." The DOT is especially concerned about sparks and excessive heat in carriage by aircraft as the consequences of a fire on board an aircraft are the most severe.

This rule means is that, at a minimum, batteries must always be packaged in a way that prevents sparks or heat from being generated during transport (i.e., the terminals must be securely covered or insulated in some way).

Lithium Batteries Size Matters

The shipping requirements for lithium batteries are based on the "size" of the battery, which in turn is based on the lithium content of the cell or battery. There are three sizes or categories of lithium batteries: small, medium, and "normal." Small batteries can be excepted from the majority of hazardous materials/dangerous goods regulations under DOT and IATA. Medium batteries are a designation solely in the DOT regulations. Medium batteries can be excepted from the majority of the DOT hazardous material (hazmat) regulations.

"Normal" batteries under the DOT rules are those that do not meet the criteria for small or medium batteries. Since the IATA DGR does not recognize medium batteries, "normal" batteries under the IATA DGR are all lithium batteries that do not meet the criteria for small batteries. Normal batteries are subject to the full DOT and IATA regulations.

Table 1, below, lists the maximum lithium content that a battery can contain to fall into the small and medium categories. Batteries containing lithium contents higher than these levels would be considered "normal" batteries.

Size	Type	Li-Metal (Primary)	Li-Ion (Secondary)
Small	Cell	1.0 g	1.5 g (20 Wh**)
	Battery	2.0 g	8.0 g (100 Wh**)
Medium	Cell	5 g	5 g
	Battery	25 g	25 g
* Lithium content in lithium ion batteries is measured as the "equivalent" lithium content			ELC = 0.3 × amp-hours
** IMDG and IATA measure the size of secondary lithium batteries in watt-hours (Wh)			Ah × V = Wh

Table 1. Criteria for Small and Medium Batteries

Determining Lithium Content

Since lithium ion cells and batteries do not contain actual metallic lithium, their size is based on their "equivalent" lithium content. The equivalent lithium content (ELC) for a lithium ion cell is the product of the rated capacity (in ampere-hours) of a lithium ion cell multiplied by 0.3.

ELC = 0.3 x (amp-hours)

The total equivalent lithium content is expressed in grams. The equivalent lithium content of a battery is the sum of the grams of equivalent lithium content contained in each of the component cells of the battery.

Calculating Equivalent Lithium Content

A lithium ion cell in a laptop battery pack has a rated capacity of 2.2 ampere-hours. Multiplying this by the conversion factor of 0.3, a battery pack with nine of these cells contains 5.94 grams of equivalent lithium content.

2.2 x 0.3 x9 = 5.94 grams of ELC

There is no "calculation" available to determine the lithium content of a primary (lithium metal) lithium battery. Instead, you need to contact the manufacturer to determine the lithium content in the battery.

Hazard Classification of Lithium Batteries

Lithium metal reacts violently with water to give off flammable hydrogen gas and corrosive dust. As such, it is classified as a Division 4.3 (Dangerous When Wet) material when it is shipped [49 CFR 173.124(c), IATA DGR 3.4.3]. Because they contain lithium, lithium batteries have the potential to pose a similar hazard. However, when transported they are actually assigned to Miscellaneous Hazard Class 9 [49 CFR 173.140, IATA DGR 3.9].

The proper shipping name is used to describe the material and to identify the packaging requirements. Table 2 identifies the proper shipping names authorized under the DOT and IATA regulations. While IATA uses the internationally recognized shipping names, the DOT does allow the use of the international proper shipping names when shipping lithium batteries domestically under the requirements of 49 CFR [74 FR 42952, August 25, 2009].

Proper Shipping Name	Identification Number
DOT	
Lithium battery	UN 3090
Lithium batteries, contained in equipment	UN 3091
Lithium batteries, packed with equipment	UN 3091
IATA	
Lithium ion batteries	UN 3480
Lithium ion batteries, contained in equipment	UN 3481
Lithium ion batteries, packed with equipment	UN 3481
Lithium metal batteries	UN 3090
Lithium metal batteries, contained in equipment	UN 3091
Lithium metal batteries, packed with equipment	UN 3091

Table 2. Permissible proper shipping names by regulation and type

Packaging Fully-Regulated Lithium Batteries (DOT)

Lithium batteries that will be shipped as "fully regulated" batteries under the DOT regulations must meet all of the following requirements:

- Meet the requirements of each test in the UN Manual of Tests and Criteria.
- Be equipped with mechanisms to prevent:
- Reverse current flow (e.g., diodes, fuses),
- Short circuits, and
- Violent rupture (e.g., safety venting device).
- Be packaged in UN specification, combination packaging that meets at least Packing Group II levels of performance.
  [49 CFR 173.185(a)]

The following UN-specification outer packagings may be used to ship lithium batteries: 4A, 4B, 4C1, 4C2, 4D, 4F, 4G, 4H2, 1G, 1A2, 1B2, 1D, 3H2, 3A2, or 3B2. Hazardous materials are typically placed into one of three packing groups, I, II, and III, representing the severity of the

hazard. The letters "X," Y," and "Z" are used to indicate the packing group performance level for which the package has been tested (X = I, Y = II, and Z = III).

Cells and batteries containing sulfur dioxide, sulfuric chloride, or thionyl chloride may only be shipped for disposal (by motor vehicle) if they have been discharged.

Packaging Fully-Regulated Lithium Batteries (IATA)

Fully regulated packages of lithium batteries that are shipped by air under the IATA requirements must meet the same requirements as fully regulated packages that are shipped by the DOT with a few additional requirements [IATA DGR 5.9, PI 965–970, Section I].

- Lithium metal (primary) batteries on passenger aircraft must be packed in either a rigid metal intermediate or a metal outer packaging.
- Lithium metal batteries on passenger aircraft must be surrounded by cushioning material that is non-combustible and non-conductive.
- Packages of lithium ion batteries may have a maximum gross weight of 5 kg on passenger aircraft.
- Packages of lithium ion and metal batteries shipped on cargo aircraft may have a gross weight up to 35 kg.

The U.S. DOT generally prohibits lithium metal batteries being shipped on passenger aircraft. Lithium metal batteries that are packed in or with equipment ARE allowed on passenger aircraft in the U.S., as long as all of the following conditions are met:

- Each cell contains £ 5 g of lithium.
- Each battery contains £ 25 g lithium.
- The net weight of the batteries is £ 5 kg (11 lbs.).
- The package contains no more than the minimum number of batteries needed to power the equipment.

Packaging Requirements-Batteries with Equipment

In order to ship fully regulated lithium batteries with equipment, the DOT requires that the batteries must meet all the packaging requirements necessary to ship them "separately" found at 49 CFR 173.185(a). The batteries and equipment must be placed together in a strong outer packaging as an "overpack."

Packages of fully regulated lithium batteries with equipment shipped under the IATA requirements must meet all the requirements for shipping them by the DOT. The packages are limited to a maximum weight of 5 kg on passenger aircraft and 35 kg on cargo aircraft. In addition lithium metal (primary) batteries on passenger aircraft must be packed in either a rigid metal intermediate or a metal outer packaging and the lithium metal batteries must be surrounded by cushioning material that is non-combustible and non-conductive. [IATA DGR 5.9, PI 966 and 969, Section I]

Packaging Requirements-Batteries in Equipment

When a fully-regulated lithium battery is shipped in equipment, the DOT requires the following:

- The batteries must meet all the packaging requirements necessary to ship them "separately" found at 49 CFR 173.185(a) EXCEPT that the batteries do not need to be placed in combination packagings.
- The equipment must be placed in a strong outer packaging.
- The equipment, liner, or package must be waterproof.

- The equipment, batteries, and cells must be:
- Secured within the outer packaging

[49 CFR 173.185(c)]

Packages of fully regulated lithium batteries in equipment shipped under the IATA requirements must meet all the requirements for shipping them by the DOT. The amount of lithium metal in any equipment cannot exceed 12 g/cell or 500 g/battery. The packages are limited to a maximum weight of 5 kg on passenger aircraft and 35 kg on cargo aircraft. Weight refers to the quantity (net weight) of the lithium cells and batteries per of equipment. [IATA DGR 5.9, PI 967 and 970, Section I]

Marking and Labeling Requirements [49 CFR 172, Subpart D and E; IATA DGR 7.1.5 and 7.2]

Fully regulated packages of lithium batteries, including those packed in or with equipment, must be marked with all of the proper shipping name, UN identification number and the shipper's and/or consignee's name and address. The packages must also have a Miscellaneous Hazard Class 9 label affixed on the surface of the package, near the marking information.

If the packages will be shipped by air under the IATA rules, the following additional requirements the net or gross weight of lithium batteries or cells, as appropriate, must be marked on the package. If gross weight is used the marking must include the letter "G." IATA requires BOTH the shipper's AND the consignee's names and addresses must be marked on the package. If the package can only be shipped by cargo aircraft, the package will also need a "Cargo Aircraft Only" label.

Shipping Paper and Placarding Requirements [49 CFR 172, Subpart C; IATA DGR Section 8]

Shipping papers must be filled out when sending fully regulated packages of lithium batteries. When using IATA rules, a "Shipper's Declaration for Dangerous Goods" must be used [IATA DGR 8.0.2]. Otherwise, any format is legal as long as the document contains all required information.

Elements required on a shipping paper include, but are not limited to a basic description (UN number, Proper Shipping Name, hazard class, packing group), the total quantity being shipped, the number and type of packages, and the shipper's certification and signature.

Fully regulated shipments of lithium batteries must have emergency response information either on or attached to the shipping papers. The emergency response information must provide potential emergency responders with detailed information regarding the procedures that can be used to respond to an incident involving the batteries and must also contain specific safety information.

Packaging Requirements for Small Lithium Batteries

The DOT hazmat regulations except shipments of small lithium cells or batteries (including those shipped in or with equipment) from the majority of the hazmat and dangerous goods shipping rules (including specification packaging requirements), provided they pass the required UN Tests and meet a few additional requirements [49 CFR 172.102, SP 188].

To be eligible for relief, the cells and batteries must be packed in a strong outer packaging or contained in equipment. Except when the cells or batteries are contained in equipment, in order to qualify for the small battery relief under DOT rules, a package containing more than 24 cells or 12 batteries must also be able to withstand a drop test of 1.2 m, and not exceed 30 kg (66 lbs.) gross weight [IATA DGR 5.9, PI 965-970, Section II].

Packages of small lithium cells and batteries that will be shipped by air under the IATA requirements must meet the same requirements as packages of small batteries that will be shipped by the DOT. In addition, the IATA DGR requires that inner packagings must "completely enclose" the batteries (e.g., blister packs). Packages must be able to withstand a 1.2 m drop test and cannot exceed the maximum gross weight of 2.5 kg (5.5 lbs.) for lithium metal (primary) cells and batteries, or 10 kg (22 lbs.) for lithium ion (secondary) cells and batteries.

If lithium batteries are shipped with equipment, the package may contain no more than the minimum number of batteries necessary to power the equipment plus two spares.

Marking and Labeling Small Lithium Batteries

The DOT requires packages containing small primary (metal) lithium batteries must be marked with the following statement:

PRIMARY LITHIUM BATTERIES - FORBIDDEN FOR TRANSPORT ABOARD PASSENGER AIRCRAFT
[49 CFR 172.102, SP 188]

This statement is NOT required if the batteries are contained in or with equipment, there are no more batteries present than are necessary to operate the equipment, and there is less than 5 kg net weight of batteries in the package.

If a package of small lithium batteries contains more than 24 cells or 12 batteries, it must be marked to indicate that it contains lithium batteries, and special precautions must be taken if the package is damaged. It is not necessary to specify the specific procedures that must be followed in the event of damage to the package, but simply indicate that special precautions will need to be taken.

Packages containing small lithium batteries must be labeled with a special label [IATA DGR 5.9, PI 965–970, Section II and IATA DGR 7.4.2]. The label must indicate "Lithium metal batteries" or "Lithium ion batteries," as applicable, on the middle line of the label. If both types of batteries are present in the same package, then the label must show "Lithium metal and ion batteries."

IATA does not require the small lithium battery label for packages containing equipment installed with four or fewer cells and two or fewer batteries. In addition, the label is not required when lithium button cell batteries are installed in equipment.

Markings for Primary (Metal) Lithium Batteries

Packages containing small primary (metal) lithium batteries must be marked with the following statement:

PRIMARY LITHIUM BATTERIES - FORBIDDEN FOR TRANSPORT ABOARD PASSENGER AIRCRAFT

This statement is NOT required if the batteries are contained in or with equipment, there are no more batteries present than are necessary to operate the equipment, and there is less than 5 kg net weight of batteries in the package.

Additional Markings for Air Shipments [IATA DGR 7.1.4.2]

If multiple overpacks are being shipped in a single shipment, then each overpack must be marked with a unique alpha-numeric ID (e.g., AA001, BB002, etc., or #F2345m #G4567, #H6789) and the total quantity of dangerous goods in the overpack, as indicated in the Shipper's Declaration.

Shipping Papers

Shipping papers meeting the requirements of 49 CFR 172, Subpart C are NOT required for shipments of small batteries. If a package contains more than 24 cells or 12 batteries, then the shipper is required to include a document with the shipment that indicates that the package contains lithium batteries, and special precautions must be taken if the package is damaged. This document is not required if the cells or batteries are contained in equipment.

The IATA DGR requires a "hazard document" to accompany packages containing "small" lithium batteries. The document must indicate that the package contains lithium (ion or metal) cells and/or batteries, the package must be handled with care, a flammability hazard exists if the package is damaged, and special procedures should be followed in the event the package is damaged, to include inspection and repacking if necessary.

Furthermore, the document must include a telephone number that can be called for additional information regarding the shipment. This telephone number is not considered an "emergency response" telephone number, but can simply be the office number of the shipper.

IATA does not require a hazard document is not required for packages that do not have the "Lithium Battery" label (i.e., packages containing no more than four cells or two batteries or button cells in equipment).

When an air waybill is used for a shipment of small batteries, the following words (as appropriate) must be included in the Additional Handling Information:

Batteries Shipped Alone (i.e., No Equipment Present)

- "Lithium ion batteries," "not restricted," and "PI 965"
- "Lithium metal batteries," "not restricted," and "PI 968"

Batteries Shipped With Equipment

- "Lithium ion batteries," "not restricted," and "PI 966"
- "Lithium metal batteries," "not restricted," and "PI 969"

Batteries Shipped In Equipment

- "Lithium ion batteries," "not restricted," and "PI 967"
- "Lithium metal batteries," "not restricted," and "PI 970"

Medium Lithium Cells and Batteries

Shipments of medium lithium cells or batteries (including those shipped in or with equipment) sent by ground are excepted from the majority of the DOT hazmat shipping rules (including specification packaging), provided they pass the required UN Tests and meet a few additional requirements.

To be eligible for relief, the cells and batteries must be separated to prevent short circuits, and packed in a strong outer packaging or contained in equipment. Except when the cells or batteries are contained in equipment, in order to qualify for the medium battery relief, a package containing more than 24 cells or 12 batteries must also be able to withstand a drop test of 1.2 m, and not exceed 30 kg (66 lbs.) gross weight.

Packages containing medium lithium batteries must be marked with the following statement, "LITHIUM BATTERIES - FORBIDDEN FOR TRANSPORT ABOARD AIRCRAFT AND VESSEL." Except for when the cells or batteries are contained in equipment, if a package of medium lithium batteries contains more than 24 cells or 12 batteries, it must be marked to indicate that it contains lithium batteries, and special precautions must be taken if the package is damaged. It is not necessary to specify the specific procedures that must be followed in the event of damage to the package, but simply that special precautions will need to be taken.

Shipping papers meeting the requirements of 49 CFR 172, Subpart C are NOT required for shipments of medium batteries. If a package contains more than 24 cells or 12 batteries, then the shipper is required to include a document with the shipment that indicates that the package contains lithium batteries, and special precautions must be taken if the package is damaged. This document is not required if the cells or batteries are contained in equipment.

For Disposal and Recycling [49 CFR 173.185(d)]

Batteries being shipped by motor vehicle for disposal or recycling do not need to pass the standards in the UN Manual of Tests and Criteria or be placed in specification packaging as long as they are in strong outer packaging and packed to prevent short-circuiting. In August 2009, IATA released a guidance document regarding the following issue:

Question: "Can I ship recalled, damaged, or non-conforming cells or batteries?"

Response: Lithium batteries, identified by the manufacturer as being defective for safety reasons, or that have been damaged, that have the potential of producing a dangerous evolution of heat, fire, or short circuit are forbidden for transport (e.g., those being returned to the manufacturer for safety reasons). The U.S. DOT has developed guidance for consumers and manufacturers for shipping recalled batteries: http://safetravel.dot.gov/Battery_Recall_Guidance.pdf

Incident and Emergency Reporting [49 CFR 171.15(b)(6) and 171.16(a)(5)]

The person "in possession" of the shipment during the cycle of transportation is required to make a written report for ALL battery incidents (even excepted packages). If a battery-related incident occurs while being shipped by air, a telephone report must also be submitted to the National Response Center (1-800-424-8802). Generally, shippers are not responsible for reporting battery incidents and emergencies, because carriers would usually be "in possession" at the time of a transportation-related incident.

Bibliography

29 CFR Part 1910, U. S. Government Printing Office, July 1, 2010.

40 CFR Parts 260 through 270, U. S. Government Printing Office, July 1, 2010.

49 CFR Parts 171 through 180, U. S. Government Printing Office, October 1, 2010.

Dangerous Goods Regulations, 52nd Edition, International Air Transport Association, Montreal, Quebec, September 2010

Hazardous Materials Accident Brief, Accident No. DCA04MZ001, National Transportation Safety Board, August 7, 2004

Isidor Buchman. Cadex Electronics. February 2007 *Lithium ion Safety Concerns* (retrieved March 3, 2011) (batteryuniversity.com/partone-5B.htm)

Kay Miranda. *What Are the Dangers of Lithium Batteries?* (retrieved February 28, 2011) (www.ehow.com/facts_4962571_what-dangers-lithium-batteries.html)

Lion Technology Inc. *Advanced Hazardous Waste Management: The Compliance Reference.* Lafayette, NJ, 2011.

Lion Technology Inc. *Hazardous Materials Transportation: Compliance Reference*. Lafayette, NJ, 2011.

Lion Technology Inc. *Managing OSHA Compliance*. Lafayette, NJ, 2011.

Marshal Brain and Charles W. Bryant. *How Batteries Work* (retrieved March 1, 2011) (electronics.howstuffworks.com/battery.htm/printable)

Mike Budmir. March 6, 2003. *Lithium Battery Basics* (retrieved February 28, 2011) (machinedesign.com/article/lithium-battery-basics-0306)

Safety Recommendation A-99-80 through -84, National Transportation Safety Board, November 16, 1999

Tracy V. Wilson. *What Causes Laptop Batteries to Overheat?* (retrieved March 1, 2011) (computer.howstuffworks.com/dell-battery-fire.htm/printable)