



Transportation of Lithium Batteries

Focusing on international and U.S. air transportation of lithium batteries

Transportation of Lithium Batteries

There are numerous regulatory agencies that govern the transportation of lithium cells and batteries. For shipments by land, each State will have their own agency. In the United States it is the U.S. Department of Transportation's (DOT) Pipeline and Hazardous Safety Administration (PHSA). But who regulates over bodies of air and water between these States? Transportation by sea is regulated by the International Maritime Organization (IMO). By air it is either the International Civil Aviation Organization (ICAO) or the International Air Transport Association (IATA), both which provide very similar services. This document will focus primarily on international and U.S. air transportation of lithium batteries.

“Lithium is classified as Dangerous Goods not Hazardous Material”

It is important to understand that lithium is classified as Dangerous Goods rather than Hazardous Material. This provides for different definitions that depend exclusively on total amount of material present before it is regulated as opposed to mere presence in the product.

All international and most national regulations require all lithium batteries, regardless if they are rechargeable or not, to first meet section 2.9.4 of the United Nations' Recommendations on the Transportation of Dangerous Goods. In that document the UN recommends that all lithium batteries should be successfully evaluated to the applicable procedures outlined in section 38.3 of the UN Manual of Tests and Criteria. After a lithium battery has successfully passed UN 38.3 it may then be evaluated for the specific packing instruction regulations that apply to both

the size of the lithium battery and the mode of transportation.

These Packing Instructions can also be found in the UN Recommendations on the Transportation of Dangerous Goods. Each international and national regulatory agency may also add additional stipulations above the UN recommendations.



Lithium batteries, rechargeable or non-rechargeable, must meet section 2.9.4 of United Nations' Recommendations on Transportation of Dangerous Goods



Batteries must not leak, vent, disassemble, rupture or have fire

UN 38.3

Lithium batteries, whether rechargeable or not, must be comprised of cells that have already been subjected to the tests described in UN 38.3 before the batteries can be evaluated. Once successfully evaluated, that evaluation is authorized as long as designers do not change the mass of the electrodes or electrolyte, the rated energy or the nominal voltage of the battery by more than 20%.

- 01** Batteries must not leak, vent, disassemble, rupture or have fire
- 02** Batteries must have an open circuit voltage that is $\geq 90\%$ initial
- 03** Batteries must not exceed 170°C skin temperature

THE TESTS



T.1 Altitude Simulations

Batteries are stored at a pressure of 11.6 kPa or less for at least six hours at room temperature ($20^{\circ}\text{C} \pm 5^{\circ}\text{C}$). This results in an atmosphere that is at an altitude of 50,000 feet and $+76.5^{\circ}\text{C}$ above ISA, equating to a significantly lower density altitude.



T.2 Thermal Test

Batteries are to be stored for at least six hours at $72^{\circ}\text{C} \pm 2^{\circ}\text{C}$ followed by storage for at least six hours at $-40^{\circ}\text{C} \pm 2^{\circ}\text{C}$ with a maximum time interval between those extremes of 30 minutes. This procedure is repeated ten times at which point the batteries are stored for 24 hours at room temperature ($20^{\circ}\text{C} \pm 5^{\circ}\text{C}$).



T.3 Vibration

Batteries are firmly secured to a platform and vibrated using a sinusoidal waveform with a logarithmic sweep between 7Hz and 200Hz and back to 7Hz in 15 minutes. This cycle is repeated 12 times for a total of three hours for each of three mutually perpendicular mounting positions of the battery.

For small batteries, a peak acceleration of 1g is maintained until 18Hz is reached, at which point the amplitude is maintained at 0.8mm and the frequency is increased until a peak acceleration of 8g occurs. A peak acceleration of 8g is maintained until the frequency is increased to 200Hz. For large batteries, a peak acceleration is 2g is maintained instead of 8g.



T.4 Shock

Batteries are firmly secured to a mount and subjected to a half-sine wave shock. For small batteries, that shock will generate a peak acceleration of 150g and pulse duration of six milliseconds. For large batteries, that shock will generate 50g and a pulse duration of 11ms.



T.5 External Short Circuit

Batteries are temperature stabilized to $57^{\circ}\text{C} \pm 4^{\circ}\text{C}$ and subjected to a short circuit condition of the power contacts using an external resistance that is less than 100 milliohms. The short circuit condition is continued for at least an hour after the battery's external case temperature has returned to $57^{\circ}\text{C} \pm 4^{\circ}\text{C}$, or in the case of large batteries, has decreased by half of the maximum rise observed.



T.7 Overcharge

This test evaluates the ability of a rechargeable battery to withstand an overcharge condition. Rechargeable batteries are charged using a charge current that is twice the manufacturers specified maximum continuous charge current and using a minimum voltage that is lesser than twice the maximum charge voltage specified by the manufacturer or 22V. If the manufacturer's maximum specified charge voltage is greater than 18V, the minimum voltage of the test shall be 1.2 times the maximum charge voltage specified.

The Regulations

Air, Land & Sea

LITHIUM METAL = NON-RECHARGEABLE = PRIMARY
 LITHIUM ION = RECHARGEABLE = SECONDARY

International Air Transport Association (IATA)
 Dangerous Goods Regulations (DGR)



U.S. Hazardous Material Regulations 49 CFR 100-177 (HMR)
 European Dangerous Goods by Road (DGR)



International Maritime Organization (IMO)
 Dangerous Goods Code (IMDGC)



The above regulations provide for more than just packing instructions. In many cases they describe additional precautions that must be taken to ensure a safe shipment of the batteries. Requirements such as outer labels and markings, inadvertent activation of equipment, inner containers, prototype batteries, etc.

All Dangerous Goods regulations are primarily concerned with the total amount of lithium present in a shipment of batteries as lithium is the primary source of energy in the event of a catastrophe or other hazard. The regulatory agencies have followed the UN Recommendations and control the different types of lithium-based batteries by either the aggregate lithium content if primary, if the rated energy of the battery is rechargeable. Shipments of lithium batteries without equipment present are not allowed on passenger aircraft as cargo. As of April 2016, all shipments of lithium ion batteries without equipment present must also be shipped with less than 30% of their full charge capacity available.





“All shipments of lithium ion batteries without equipment present must be shipped with less than 30% SOC”

Airlines have also followed this method of regulation when developing Operator Variations (published in the IATA DGR regarding the carrying-on board or checking-in baggage of lithium batteries by air traveling passengers:

AIR TRAVEL	≤2g or 100Wh	>2g or 100Wh
Carried on	YES	YES
Checked in	NO	NO
Spares Allowed	Unlimited	1 or 2
Limitations	None	<8g or 160Wh

Packing Instructions

Lithium Metal

LOOSELY PACKED	PACKAGED WITH EQUIPMENT	CONTAINED IN EQUIPMENT
> 2g of lithium per battery *		
<p>UN3090 Packing Instruction 968 Section IA Class 9 Dangerous Goods</p> <p>Net weight per package: Passenger aircraft = 0kg Cargo aircraft ≤ 35kg</p>	<p>UN3091 Packing Instruction 969 Section I Class 9 Dangerous Goods</p> <p>Net weight per package: Passenger aircraft ≤ 5kg Cargo aircraft ≤ 35kg</p>	<p>UN3091 Packing Instruction 970 Section I Class 9 Dangerous Goods</p> <p>Net weight per package: Passenger aircraft ≤ 5kg Cargo aircraft ≤ 35kg</p>
≤ 2g of lithium per battery *		
<p>UN3090 Packing Instruction 968 Section IB Class 9 Dangerous Goods</p> <p>Net weight per package: Passenger aircraft = 0kg Cargo aircraft ≤ 2.5kg</p>	<p>UN3091 Packing Instruction 969 Section II Excepted Dangerous Goods</p> <p>Net weight per package: Passenger aircraft ≤ 5kg Cargo aircraft ≤ 5kg</p>	<p>UN3091 Packing Instruction 970 Section II Excepted Dangerous Goods</p> <p>Net weight per package: Passenger aircraft ≤ 5kg Cargo aircraft ≤ 5kg</p>
<p>If battery has ≤ 2g of lithium AND no more than two batteries and one package is being shipped,</p> <p style="text-align: center;">-OR-</p> <p>If battery has ≤ 0.3g of lithium, then it is: Section II Excepted Dangerous Goods</p> <p>Net weight per package: Passenger aircraft = 0kg Cargo aircraft ≤ 2.5kg</p>	<div style="display: flex; align-items: center; justify-content: space-between;"> <div data-bbox="581 1369 711 1411" style="border: 1px solid black; padding: 2px;">* 1g for cells</div> <div style="text-align: center;">  </div> <div data-bbox="1166 1381 1432 1621" style="border: 2px dashed red; padding: 5px;"> <p style="text-align: center; margin: 0;">CAUTION!</p>  <p style="text-align: center; margin: 0;">* DO NOT LOAD OR TRANSPORT PACKAGE IF DAMAGED</p> <p style="text-align: center; margin: 0; font-size: small;">For more information, call xxx.xxx.xxx</p> </div> </div> <div style="text-align: center; margin-top: 20px;">  </div> <div style="text-align: center; margin-top: 20px;">  <p style="color: red; font-weight: bold; margin-top: 10px;">Stop.Think.Check.</p> </div>	

Packing Instructions

Lithium Ion

LOOSELY PACKED	PACKAGED WITH EQUIPMENT	CONTAINED IN EQUIPMENT
> 100Wh of energy per battery		
<p style="text-align: center;">UN3480 Packing Instruction 965 Section IA Class 9 Dangerous Goods</p> <p>Net weight per package: Passenger aircraft = 0kg Cargo aircraft ≤ 35kg</p>	<p style="text-align: center;">UN3481 Packing Instruction 966 Section I Class 9 Dangerous Goods</p> <p>Net weight per package: Passenger aircraft ≤ 5kg Cargo aircraft ≤ 35kg</p>	<p style="text-align: center;">UN3481 Packing Instruction 967 Section I Class 9 Dangerous Goods</p> <p>Net weight per package: Passenger aircraft ≤ 5kg Cargo aircraft ≤ 35kg</p>
≤ 100Wh of energy per battery		
<p style="text-align: center;">UN3480 Packing Instruction 965 Section IB Class 9 Dangerous Goods</p> <p>Net weight per package: Passenger aircraft = 0kg Cargo aircraft ≤ 10kg</p>	<p style="text-align: center;">UN3481 Packing Instruction 966 Section II Excepted Dangerous Goods</p> <p>Net weight per package: Passenger aircraft ≤ 5kg Cargo aircraft ≤ 5kg</p>	<p style="text-align: center;">UN3481 Packing Instruction 967 Section II Excepted Dangerous Goods</p> <p>Net weight per package: Passenger aircraft ≤ 5kg Cargo aircraft ≤ 5kg</p>
<p>If battery has ≤ 100Wh of energy AND no more than two batteries and one package is being shipped,</p> <p style="text-align: center;">-OR-</p> <p>If battery has ≤ 2.7Wh of energy, then it is: Section II Excepted Dangerous Goods</p> <p>Net weight per package: Passenger aircraft = 0kg Cargo aircraft ≤ 2.5kg</p>	 <p style="text-align: center;">THE U.S. DOT DETERMINED IN 2012 THAT BATTERIES THAT HAVE TWO OR MORE INTERNAL, ISOLATED BATTERIES WITHIN A SINGLE ENCLOSURE SHOULD BE TREATED AS MULTIPLE SINGLE BATTERIES IN TERMS OF DANGEROUS GOODS CLASSIFICATION.</p> <p style="text-align: right;"><i>Portable Rechargeable Battery Association</i></p>	

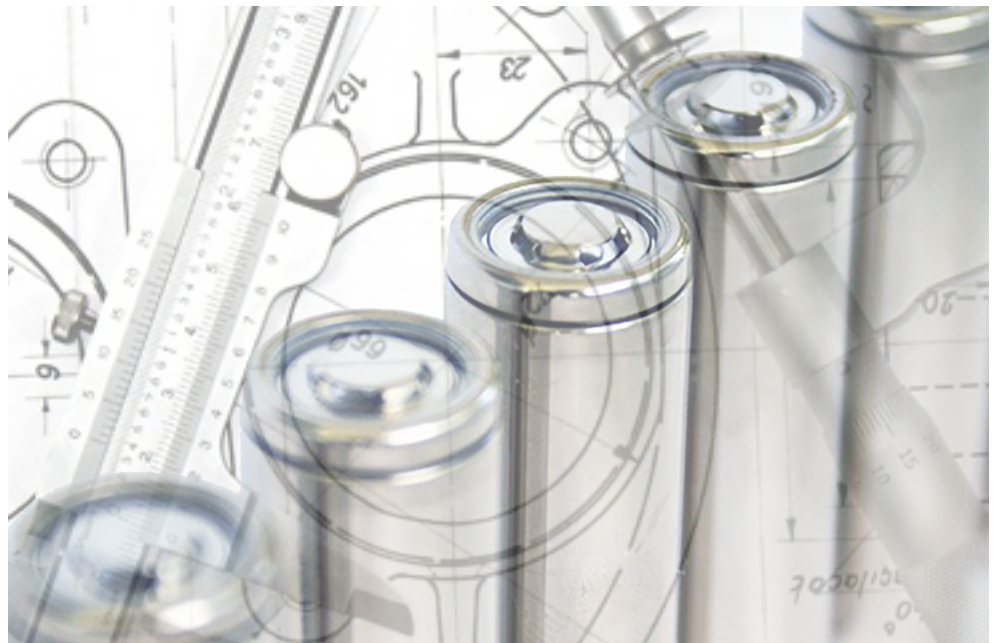
Prototypes

In accordance with UN Recommendations on the Transport of Dangerous Goods, special provision 310, battery manufacturers should be allowed to ship loosely packed lithium ion and metal batteries that have not first been successfully evaluated to UN 38.3 under Packing Instruction 910 for either of the following two reasons:

- 1. Annual production runs consisting of not more than 100 loosely packed batteries.***
- 2. Pre-production prototypes of loosely packed batteries when these prototypes are transported for testing purposes.***

The low volume production quantity limit of 100 batteries and the term “prototype” are mutually exclusive. The above terminology is similarly repeated across the numerous regulatory agencies when looking specifically at “pre-production prototype” batteries. Agencies such as the U.S. Dept of Transportation (DOT), the Pipeline and Hazardous Materials Safety Administration, the International Air Transport Association (IATA) and the International Maritime Organization (IMO) all recognize and dictate when and how “pre-production prototype” batteries can be shipped.

Domestic shipments in the United States of “pre-production prototype” cells and batteries can be shipped by ground as long as each battery is individually packed in an inner packaging, surrounded by cushioning material that is non-



Manufacturers may ship samples to test labs for safety evaluation or for characterization by prospective customers without first passing UN 38.3 transportation testing.

combustible and non-conductive and is transported as Class 9 Dangerous Goods, regardless of the battery’s energy rating or lithium content. Domestic shipments may also be shipped by air or by sea vessel if special permission is obtained from the Pipeline and Hazardous Materials Safety Administration – the compliance authority for the United States. This involves obtaining an approval number and is generally issued in the form of a letter to the battery manufacturer. Domestic air or sea shipments of “pre-production prototype” cells or batteries in the U.S. must be shipped in the same manner as international shipments would (see below) with the additional requirement that shipping papers include the notation “Transport in accordance with §173.185(e)” and the packages are plainly marked with the issued approval number.

Per the IATA Dangerous Goods Regulations and IMO Dangerous Goods Code, which have jurisdiction over international shipments as they require the use of air or sea vessels, prototypes must be packaged according to the UN recommended Packing Instructions for prototypes (910).

This is summarized as:

Packaging

Each battery is individually packed in a non-metallic inner packaging, inside an outer packaging, and is surrounded by cushioning material that is non-combustible and non-conductive or contained in equipment. If contained in equipment, then the equipment must be constructed or packaged in a manner as to prevent accidental operation during transport. Appropriate measures must be taken to minimize the effects of vibration and shocks and prevent movement of the batteries within the package that may lead to damage or a dangerous condition during transport. Cushioning material that is non-combustible and non-conductive may be used to meet this requirement. The inner packaging or equipment is placed in outer packaging that meets the requirements of Packing Group I performance level if by air and Packing Group II performance level if by sea.

Quantities

The total gross mass of the package, including equipment of different sizes, shapes or masses, must not exceed the gross mass for which the package design type has been tested.

- A battery with a net mass of more than 30 kg is limited to one battery per outer packaging.
- For batteries with a Watt-hour rating equal to or less than 312.5Wh, no more than 12 batteries per package is allowed.
- For batteries with Watt-hour rating greater than 312.5Wh, no more than six batteries per package is allowed.
- No single package may contain greater than 6,250Wh.
- The gross weight of a package may not exceed 45 kg.

All prototype or low volume production lithium batteries that have not successfully passed UN 38.3 must be shipped in cargo-only aircraft and sea vessels (no passengers aboard).

"Prototypes must be packaged according to UN Packing Instruction 910"

Testing

If the battery is comprised of individual cells that have not been evaluated for compliance with UN 38.3, then one battery must first be stored at $55^{\circ}\text{C} \pm 2^{\circ}\text{C}$ for at least 48 hours followed by a short circuit test (connecting a conductor across the positive and negative terminals) and maintaining this short circuit for at least

1 hour after the case temperature has returned to $55^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

If the battery is comprised of individual cells that have successfully demonstrated compliance with UN 38.3 through testing, then one battery must be subjected to a similar short circuit test for at least 1 hour at room temperature (approximately 23°C).

Batteries are considered safe to transport by air or sea if the batteries show no disassembly or fire during or after these tests have been completed.

"All prototype or low volume production lithium batteries must be shipped in cargo-only aircraft and sea vessels"



ULTRALIFE®

ULTRALIFE BATTERY & ENERGY PRODUCTS

2000 Technology Parkway
Newark
New York 14513
United States

TEL 800-332-5000 (USA & Canada)
TEL +1-315-332-7100
EMAIL sales@ultralifecorp.com
WEB www.ultralifecorp.com

Readers should be advised that this document is merely a summary of the relevant regulations and is not to be considered an official source of information. All information contained herein is accurate as of the date this document was published. Ultralife assumes no liability for the application of this information by the reader and directs readers to consult with official publications. More information can be obtained via the **IATA Lithium Battery Shipping Guidelines** document available online