Lithium Battery Testing Under UN/DOT 38.3

8 tests required according to the United Nations Manual of Tests and Criteria

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White paper

Abstract

Lithium batteries provide a reliable and cost-effective power source for a wide range of electrical and electronic products. However, safety concerns still exist, especially in instances where battery inventories are transported via aircraft. These concerns have led to increased attention to the potential dangers of transporting lithium batteries, and new requirements for manufacturers of lithium batteries and devices powered by lithium batteries. This white paper reviews the testing required under UN/DOT 38.3, as well as other requirements applicable to the transportation of lithium batteries.

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Introduction

Lithium batteries provide a reliable and cost-effective power source for a wide range of electrical and electronic products, from consumer-friendly smartphones and tablets to advanced medical diagnostic devices and even the current generation of electric vehicles. Driven in large part by the growing demand for wireless electronic devices, the worldwide market for lithium batteries is projected to reach $33 billion by 2019, up from just $12 billion in 2012.[1] Indeed, access to reliable and safe lithium batteries is a significant contributing factor in the global expansion of portable and wireless electronic devices for every conceivable application.

However, while the overall failure rates associated with lithium batteries is low, safety concerns still exist, especially in instances where battery inventories are transported via aircraft. A 2010 crash of a United Parcel Services jet near Dubai International Airport which killed two pilots was linked to a fire in one of the plane's cargo holds containing large quantities of lithium batteries and electronic equipment. The Dubai crash, along with other reports of fires in airplane cargo holds containing lithium batteries, has led to increased attention to the potential dangers of transporting lithium batteries, and new requirements for manufacturers of lithium batteries and devices powered by lithium batteries.

This white paper discusses the testing now required of all lithium batteries according to Section 38.3 of the United Nations Manual of Tests and Criteria: Lithium Battery Testing Requirements, commonly referred to as UN/DOT 38.3. Following a brief review of lithium battery design and the risks associated with the transportation of lithium batteries by air, the paper reviews each of the eight specific tests required by UN/DOT 38.3, as well as other requirements affecting lithium battery manufacturers. The white paper is intended for manufacturers of both lithium batteries and devices powered by lithium batteries, especially design engineers and regulatory compliance professionals.

"However, while the overall failure rates associated with lithium batteries is low, safety concerns still exist, especially in instances where battery inventories are transported via aircraft."

Lithium Battery Design

The term "lithium battery" is used to refer to a range of batteries utilising different components and chemistries. Lithium metal batteries are primary, rechargeable or non-rechargeable batteries used to power watches, calculators, cameras and other small electronic devices. Lithium-ion batteries are secondary, rechargeable batteries used in consumer electronic products, such as mobile telephones and laptop computers, and larger applications such as hybrid and electric vehicles.

A lithium battery produces electrical power as a result of the movement of lithium ions through an electrolyte from a negative electrode (the anode) to the positive electrode (the cathode). Typically, the electrolyte in a lithium battery is mixture of non-aqueous organic carbonates that contain lithium ions, which are more stable than pure lithium. Different lithium chemistries and materials choices can be used to achieve specified battery performance characteristics.

To ensure safe operation, battery components are encased in a sealed container that prevents water from contacting reactive materials. Passive safeguards may also be integrated into the design of the battery to prevent or mitigate some types of failures. Nonetheless, the thermal stability of a battery's active materials presents specific challenges, especially when the battery is operating at high temperatures. In addition, impurities in the electrolyte material can compromise the safety of the battery.

Defective or damaged lithium batteries can lead to significant safety consequences. For example, electrolyte impurities can produce an internal short circuit. In other instances, a short circuit can occur when battery terminals come in contact with other batteries, metal objects or conductive surfaces. A short circuit can also result from puncturing or denting the battery casing, or other types of external damage.

A battery short circuit can lead to a condition known as thermal runaway, in which the internal temperature of a battery rapidly escalates. Under such conditions, lithium-ion batteries can vent, explode or catch fire, producing temperatures over 1200°F, a level sufficient to melt aluminum structural members and materials within the cargo hold of an aircraft (lithium-metal batteries burn at even higher temperatures). Even without inflicting significant structural damage, smoke generated by a lithium battery fire can impair the ability of aircraft personnel to safely land an aircraft.

UN Manual of Tests and Criteria and Section 38.3

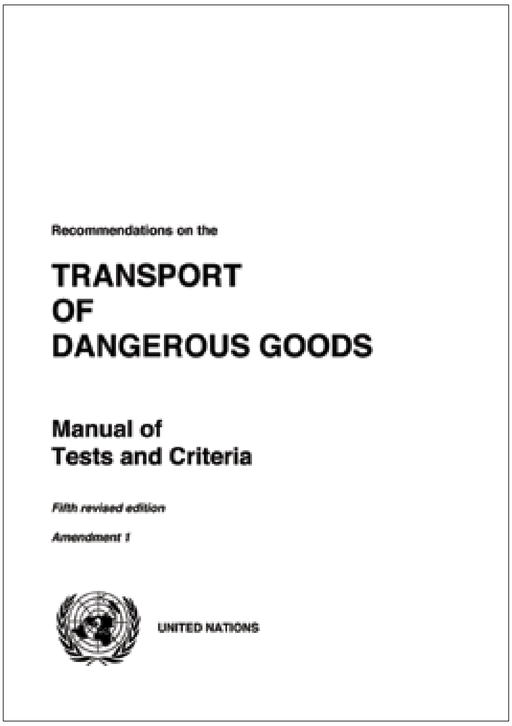
The UN Manual of Tests and Criteria contains criteria, test methods and procedures to be used for the classification of dangerous goods that may be transported, according to the United Nations Recommendations on the Transport of Dangerous Goods, Model Regulations. The Manual also includes a list of chemicals that present physical hazards according to the Globally Harmonized System (GHS) of Classification and Labeling of Chemicals. The tests and procedures specified in the Manual are intended to supplement national and international regulations and standards regarding the transportation of potentially dangerous goods.

Originally developed by the UN's Economic and Social Council's Committee of Experts on the Transport of Dangerous Goods, the first version of the Manual was adopted in 1984, and has been updated and amended every two years since. The fifth revised edition of the Manual was published in 2009, and amended by the Committee in 2010, 2012 and 2014. The sixth revised edition of the Manual, which incorporates all of the amendments to the fifth edition, was published in 2015.

Part 3, Section 38.3, of the UN Manual addresses those requirements that apply to lithium cells and batteries.

The Section outlines classification procedures consistent with the structure defined in the Manual. Most important, Section 38.3 includes detailed information on the specific tests applicable to lithium cells and batteries, the number of samples required for testing, and the minimum acceptable testing results. As a result of changes in the amended fifth revised edition of the Manual, the testing requirements in Section 38.3 are now applicable to all lithium cells and batteries, including batteries consisting of cells that have been previously tested.

"The tests and procedures specified in the Manual are intended to supplement national and international regulations and standards regarding the transportation of potentially dangerous goods"



Source: http://www.unece.org/?id=27472

Required Tests According to UN/DOT 38.3

According to the requirements of UN/DOT 38.3, lithium cells and batteries are subject to as many as eight separate tests designed to assess their ability to withstand the anticipated rigors incurred during transport. The eight tests evaluate samples for risks from electrical, mechanical and environmental conditions, as follows:

REQUIRED TESTS	TEST DESCRIPTION
Test 1: Altitude Simulation	Also known as the low-pressure test, the altitude simulation test simulates the transportation of cells and batteries under low pressure conditions, such as those experienced in an aircraft cargo hold, or in an aircraft cabin that experiences a sudden loss of pressure. During the test, a sample is stored at a specified pressure and at ambient temperature for at least six hours. To pass this test, the sample must not leak, vent, disassemble, rupture or ignite. In addition, the open circuit voltage of the tested sample must be at least 90% of the sample's voltage as measured before the test.
Test 2: Thermal Test	The thermal test assesses the seal integrity and internal electrical connections of a cell or battery after exposure to rapid and extreme temperature variations. During the test, a sample is cycled 10 times through extended periods of exposure to extreme heat and cold conditions, after which it is stored for 24 hours at ambient temperature. To pass this test, the sample must not leak, vent, disassemble, rupture or ignite. In addition, the open circuit voltage of the tested sample must be at least 90% of the sample's voltage as measured before the test.
Test 3: Vibration Test	The vibration test (Figure 1) simulates the effect of the kind of vibration that could be applied to a cell or battery during transport. During the test, a sample is secured to a vibration machine and subjected to vibrations of varying amplitudes (dependent upon the size and weight of the sample being tested) over a three-hour period in each of three mutually perpendicular mounting positions. To pass this test, the sample must not leak, vent, disassemble, rupture or ignite. In addition, upon completion of testing of a cell in its third perpendicular mounting position, the open circuit voltage of the tested sample must be at least 90% of the sample's voltage as measured immediately prior to this procedure.

Figure 1: Engineer preparing battery for vibration test

REQUIRED TESTS	TEST DESCRIPTION
Test 4: Shock Test	The Shock test is intended to assess the robustness of cells or batteries against cumulative shocks, such as those that might be encountered during transport. During the test, a sample is secured to a testing device and subjected to three calibrated shocks of varying intensity (again, dependent upon the size and weight of the sample being tested) in both a positive and negative direction in each of three different mounting positions, for a total of 18 separate shocks. To pass this test, the sample must not leak, vent, disassemble, rupture or ignite. In addition, the open circuit voltage of the tested sample must be at least 90% of the sample's voltage as measured before the test.
Test 5: External Short Circuit	As the name implies, the external short circuit test simulates an external short circuit to determine the ability of a cell or battery to withstand a maximum current flow without adverse consequences. During the test, a sample that has been heated to a specified temperature is then subjected to a specified short circuit condition for at least one hour after the sample's external case temperature has reverted pre-test specified temperature (small cells or batteries), or (in the case of large batteries) has decreased by half of the maximum temperature increase observed during the test. To pass this test, the external temperature of the sample must not exceed 170°C, and the sample must not disassemble, vent or ignite during the test, or within the six-hour period following the test.
Test 6: Impact/Crush Test	The impact/crush test (Figure 2) determines the ability of a cell or battery to withstand an impact or crush that may result in an internal short circuit. During the impact test (applicable to cylindrical cells equal to or greater than 18 mm in diameter), a sample is subjected to a single impact from a mass of a specified weight dropped from a specified height. During the crush test (applicable to prismatic, pouch, coin/button cells and cylindrical cells less than 18 mm in diameter), a sample is crushed between two flat surfaces at a defined speed until either the applied force reaches a calculated limit, the voltage of the cell drops by at least 100 mV, or the cell is deformed by 50%. To pass this test, the external temperature of the sample must not exceed 170°C, and the sample must not disassemble or ignite during the test, or within the six-hour period following the test.  Figure 2: Impact/crush test equipment

REQUIRED TESTS	TEST DESCRIPTION
Test 7: Overcharge Test	The Overcharge test evaluates the ability of a rechargeable cell or battery to withstand an overcharge condition without adverse consequences. During the test, a sample is subjected to a current charge equal to twice that of the manufacturer's maximum recommended continuous charge current at ambient temperature for a period of 24 hours. To pass this test, the sample must not disassemble or ignited during the test, or within the seven-day period following the test.
Test 8: Forced Discharge Test	The forced discharge test assesses the ability of a cell or battery to withstand a forced discharge condition. During the test, a sample is forced discharged at ambient temperature at an initial current equal to the maximum discharge current specified by the manufacturer and for a calculated time interval. To pass the test, the sample must not disassemble or ignite during the test, or within the seven-day period following the test.

Application of Section 38.3 Tests

Under Section 38.3 requirements, cells and batteries are subject to specific tests depending on their type, as follows:

- All cell types must be subjected to Tests 1 through 6, as well as Test 8
- All non-rechargeable battery types (including those comprised of previously tested cells) must be subjected to Tests 1 through 5
- All rechargeable battery types (including those comprised of previously tested cells) must be subjected to Tests 1 through 5, as well as Test 7
- Rechargeable single cell batteries featuring overcharge protection must also be subjected to Test 7
- Component cells that are transported separately from a battery assembly must be tested as a cell
- Component cells that are not transported separately from a battery assembly are subjected only to Test 6 and Test 8.

In addition to the required tests, Section 38.3 also subjects cells and batteries to specific test sequencing requirements, and defines the limits of their use in testing. Tests 1 through 5 must be conducted in sequence on the same battery sample. The overcharge test can be conducted using undamaged battery samples from the earlier tests. However, the impact test and the forced discharge test must be conducted on battery samples not previously used for other tests.

Conclusion

Lithium batteries are the primary source of power for a wide range of today's electrical and electronic products. While the overall failure rate of lithium batteries in use is low, safety concerns still exist, particularly in connection with their transport in aircraft. UN/DOT 38.3 details testing requirements that are now applicable to all lithium cells and batteries, and manufacturers of lithium batteries and products using lithium batteries must account for these testing requirements in the design, manufacture and distribution of their products.

TÜV SÜD is an internationally recognised testing, inspection and certification organisation, with hundreds of technical experts in more than 30 countries on six continents. This extensive network makes TÜV SÜD an effective single source for manufacturers seeking world-wide access for their products.

TÜV SÜD provides testing and validation services for the most advanced energy storage devices and systems, including primary and secondary battery cells and packs, ultra capacitors, and other electric vehicle components and systems. TÜV SÜD operates battery testing laboratories in the U.S. Germany, China, Singapore and other key markets, providing direct access for vehicle manufacturers worldwide and thereby saving time and resources in bring new products to the global market.

FOOTNOTES

[1] "Global Lithium Ion Battery Market – Industry Analysis, Size, Share, Growth, Trends, and Forecast 2013-2019," Transparency Market Research, September 2015. Summary available at https://globenewswire.com/news-release/2015/09/10/767307/10148912/en/Lithium-Ion-Battery-Market-High-Life-Cycle-for-Consumer-Electronics-to-Drive-Lithium-Ion-Market-to-Register-14-4-CAGR-through-2019-Transparency-Market-Research.html (as of February 18, 2016).

[2] "Report on UPS Jet's Crash Highlights Cargo of Batteries," Wall Street Journal, April 3, 2011. Accessed on the Internet on January 10, 2012, http://online.wsj.com/article/SB10001424052748703806304576241563707603894.html.

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