Intertek

Valued Quality. Delivered.

Guide to the UN requirements for lithium battery testing prior to transportation

Intertek
Cleeve Road, Leatherhead, Surrey KT22 7SB UK

info.uk@intertek.com 01372 370900 www.intertek.com

Contents

Introduction

Whether you are deeply entrenched in lithium technology or planning on using these batteries in the near future you will likely come across the problem of transporting them.

The sometimes tricky prospect of transporting lithium cells or batteries from one country to another has stumped even the largest of manufacturers, but it is very common that transportation regulations are not considered during the battery development or sourcing cycle.

We are often approached by parties who never considered the resources needed to transport lithium batteries and the safety and logistical issues which need to be resolved. In this paper we'll look at the obligations faced by companies transporting lithium batteries internationally and how to meet them successfully.

History

One of the key drivers behind the implementation to test lithium batteries in transit was the fire at LAX airport in 1999. This incident escalated calls for tighter measures to ensure greater safety in lithium battery transportation and to tighten existing measures already in place. The US Department of Transport (DOT) has been instrumental behind the changes and, after meeting with the Committee of Experts on the Transport of Dangerous Goods, set the wheels in motion for industry wide changes.

In December 2000 the Economic and Social Council's Committee of Experts on the Transport of Dangerous Goods presented the test methods and procedures *(Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria)* to be used as a supplement for the United Nations Recommendations on the Transport of Dangerous Goods' Model Regulations. Subsequently, the Committee of Experts on the Transport of Dangerous Goods and the Globally Harmonized System of Classification and Labelling of Chemicals have governed the transportation of dangerous goods and chemicals since 2001.

The UN Subcommittee meet approximately twice a year to consider proposals to revise the contents of the UN Model Regulations and the Manual of Tests and Criteria. The contents of which are then adopted into the applicable international modal regulations (IMDG Code for maritime, ADR/RID for European road and rail and ICAO Technical Instructions for air transport). The UN Model Regulations are also intended for adoption into national transport regulations such as in the US code of federal regulations 49 CFR.

The 17th revised edition of the UN Model Regulations and the 54th edition of IATA DGR will come into effect January 2013 which in turn references the Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria. This UN Manual has undergone revisions every couple of years and the current one at the time of writing is ST/SG/AC.10/11/Rev.5 - this will also come into effect January 2013.

Broadly speaking, the UN creates recommendations which are generally adopted by regulatory bodies such as the International Air Transport Association (IATA), ICAO (International Civil Aviation Organisation) and other bodies for industries and countries under their remit. Therefore it is of great importance to both get in touch with your local and destination authorities to understand what you need to do regarding transporting lithium batteries. Regulations may vary from country to country and the method of transport also plays a critical factor.

The UN manual gets adopted by several groups who write the regulations, such as:

- **IATA** (International Air Transport Association)
- **ICAO** (International Civil Aviation Organization)
- **ADR** (European Agreement concerning the International Carriage of Dangerous Goods by Road)
- **IMO** (International Maritime Organization)
- **DOT** (US Dept of transportation)

Testing the batteries will eliminate much of the cost, delays and frustration down the line as most countries accept the UN recommendation to facilitate international transport. Testing is generally common between all parties; therefore

UN testing according to the Manual of Tests and Criteria can be considered mandatory.

Please bear in mind that testing forms only a part of the requirements. Labelling, packaging, shipping names, number of batteries per box and other details will affect how lithium batteries can be transported. Regulations are constantly evolving, especially dealing with a relatively "new" technology, so check with your certification partner what the current requirements are prior to each new compliance project.

Typical Examples of further requirements to transport your lithium batteries

Most logistics companies refer to the packaging guidelines as outlined by IATA and ICAO. They will often refuse to transport batteries not compliant with the provisions.

This document is not an inclusive of all the requirements but we will look at the testing required for batteries. The packaging will need to fulfil the criteria as shown in IATA's latest PI (Packaging Instructions). According to IATA's 53rd edition of the IATA Dangerous Goods Regulations (DGR), all of the PI battery groups (except large battery packs) require testing to the UN Manual of Tests and Criteria Part III 38.3 and there are no 'small' battery exclusions. Furthermore, there are additional classification requirements to consider:

UN 3090 – Lithium metal batteries (Primary Batteries)
UN 3480 – Lithium ion batteries
UN 3091 – Lithium metal batteries contained in equipment
UN 3091 – Lithium metal batteries packed with equipment
UN 3481 – Lithium ion batteries contained in equipment
UN 3481 – Lithium ion batteries packed with equipment

Always seek profession advice and guidance from the relevant authorities when working toward battery or power cell conformity – as the market changes regularly; and if your consignment is not compliant with the current rules, then you run an increased risk of it being rejected. This can hamper movement on any project by weeks or in some cases months at huge cost as well.

Higher energy densities and certain lithium battery chemistries combined with poor handling have unfortunately led to some high-profile accidents. These measures are in place to ensure that at least a MINIMAL level of safety has been addressed to ensure a viable commercial future for this technology. It is the shared responsibility of the supply chain to ensure that all current legal requirements are met and extra testing or checks completed to optimise safety of their battery

product before it reaches the consumer or end-user. This should help eliminate inferior products being placed on the market.

The UN manual of tests and criteria part III 38.3 tests

This is to test cells and batteries ONLY – they do not apply to the packaging. This UN Manual covers the following battery types:

1. Lithium metal containing cells and battery packs
2. Lithium ion (rechargeable) cells and battery packs

The weight or Lithium Content plays a strong role in the UN Manual. Before looking at the different tests you should remember the following:

Small Cells	Up to 12 grams lithium content, or up to 150 Wh for lithium ion cells
Large Cells	Over 12 grams lithium content, or over 150 Wh for lithium ion cells
Small Battery	Gross mass not more than 12kg
Large Battery	Gross mass more than 12kg

There are 8 different tests in total, T1 to T8. Not all tests will be applicable to every cell or battery type (full breakdown elsewhere in paper). Special provisions for Battery Assemblies whose cells and modules have already passed all applicable tests:

Only 1 Battery needs to be tested for battery assemblies assuming the battery used in Tests T.3 - T.5 are NOT damaged and can be used for test T.7 (up to 500 grams lithium metal or an ELC up to 6,200 Wh) whose cells and modules have already passed all applicable tests.

- For Primary Battery Assemblies, tests T.3, T.4, and T.5 only, tested in the fully charged state.
- For Secondary Battery Assemblies, tests T.3, T.4, T.5, and T.7 only, tested in the fully charged state, after 25 cycles

No testing is required for very large battery assemblies (over 500 grams lithium metal or an ELC greater than 6,200 Wh), provided the sub-assemblies have passed all applicable tests and if they are equipped with a BMS (Battery Management System) capable of monitoring the battery assembly and preventing short circuits, over discharge between the batteries in the assembly, and any overheat or overcharge of the battery assembly.

Number of Samples required for testing along state of charge state.

CELLS:

	Altitude	Thermal Shock	Vibration	Shock	External Short	Impact	Overcharge	Forced Discharge
	T.1	T.2	T.3	T.4	T.5	T.6	T.7	T.8
Primary Cells, Cylindrical • Undischarged • Fully Discharged			10 10			5 5	N/A	------- 10
Primary Cells, Prismatic • Undischarged • Discharged			10 10			10 10	N/A	------- 10
Rechargeable Cells, Cylindrical • 1st cycle, charged • 1st cycle fully discharged • 1st cycle 50% discharged • 50 cycles, fully discharged			10 ---------- ---------- ----------			------- ------- 5 -------	N/A	------- 10 ------- 10
Rechargeable Cells, Prismatic • 1st cycle, charged • 1st cycle fully discharged • 1st cycle 50% discharged • 50 cycles, fully discharged			10 ---------- ---------- ----------			------- ------- 10 -------	N/A	------- 10 ------- 10

BATTERIES:

	Altitude	Thermal Shock	Vibration	Shock	External Short	Impact	Overcharge	Forced Discharge
	T.1	T.2	T.3	T.4	T.5	T.6	T.7	T.8
Small Primary Batteries (up to 12kg) • Undischarged • Fully Discharged			4 4			N/A	N/A	N/A
Large Primary Batteries (over 12kg) • Undischarged • Fully Discharged			4 4			N/A	N/A	N/A
Small Rechargeable Batteries (up to 12kg) • 1st cycle, charged • 50 cycles, charged			4 4			N/A	4* 4*	N/A
Large Rechargeable Batteries (over 12kg) • 1st cycle, charged • 25 cycles, charged			2 2			N/A	2* 2*	N/A

---

* May use the same samples from tests T.1 - T.5 if undamaged. Otherwise, will require new samples.

Summary of the tests required by UN 38.3 – to be carried out in order.

T1: Altitude Simulation	
REASON	Low pressure testing
APPLICABLE TO	
Primary Cells?	Yes
Primary Batteries?	Yes
Secondary Cells?	Yes
Secondary Batteries?	Yes
TEST	Store Batteries at 11.6kPa for > 6 hours at ambient.
CRITERIA	• No Mass Loss, Leaking, Venting, Disassembly, Rupture, or Fire. • Voltage within 10% of pre-test voltage

T2: Thermal Test	
REASON	Integrity check during rapid and extreme temperature changes
APPLICABLE TO	
Primary Cells?	Yes
Primary Batteries?	Yes
Secondary Cells?	Yes
Secondary Batteries?	Yes
TEST	Store Batteries according to the following: • 6 hours @ -40℃ (12 hours for large cells/batterie s) • <30minute transition • 6 hours @ +75℃ (12 hours for large cells/batterie s) • <30 minute transition • Repeat for total of 10 cycles May be performed in a single chamber or thermal shock chamber.
CRITERIA	• No Mass Loss, Leaking, Venting, Disassembly, Rupture, or Fire. • Voltage within 10% of pre-test voltage

T3: Vibration	
REASON	Simulates vibration during transportation
APPLICABLE TO	
Primary Cells?	Yes
Primary Batteries?	Yes
Secondary Cells?	Yes
Secondary Batteries?	Yes
TEST	Sine Sweep: 7Hz – 200Hz – 7Hz in 15 Minutes; 12 Sweeps (3 hours); 3 mutually perpendicular axes
CRITERIA	• No Mass Loss, Leaking, Venting, Disassembly, Rupture, or Fire. • Voltage within 10% of pre-test voltage

T4: Shock	
REASON	Simulates vibration during transportation
APPLICABLE TO	
Primary Cells?	Yes
Primary Batteries?	Yes
Secondary Cells?	Yes
Secondary Batteries?	Yes
TEST	Half-Sine pulse 150G/6ms for small cells/batteries 50G/11ms for large cells/batteries 3 pulses per direction 6 directions (+/-z, +/-x, +/-y)
CRITERIA	• No Mass Loss, Leaking, Venting, Disassembly, Rupture, or Fire. • Voltage within 10% of pre-test voltage

T5: External Short Circuit	
REASON	Simulates external short circuit
APPLICABLE TO	
Primary Cells?	Yes
Primary Batteries?	Yes
Secondary Cells?	Yes
Secondary Batteries?	Yes
TEST	Sample case monitored for temperature. Stabilize sample at temperature of +55℃ Apply short circuit (<0.1ohm) across terminals. Maintain at least hour after sample temperature returns to +55 +/-2℃. Remove Short circuit and monitor sample for additional 6 hours.
CRITERIA	• Case temperature does not exceed +170℃ • No disassembly, rupture, or fire within 6 hours of test

T6: Impact	
REASON	Simulates impact to case of cell
APPLICABLE TO	
Primary Cells?	Yes
Primary Batteries?	No
Secondary Cells?	Yes
Secondary Batteries?	No
TEST	Sample placed on flat surface, temperature monitored. 15.8mm diameter bar placed across the centre of the sample. 9.1kg mass dropped onto bar above sample from 61cm height. One Impact per sample. Sample monitored for 6 hours after test.
CRITERIA	• Case temperature does not exceed +170℃ • No disassembly or fire within 6 hours of test

T7: Overcharge	
REASON	Simulates overcharge on rechargeable battery
APPLICABLE TO	
Primary Cells?	No
Primary Batteries?	No
Secondary Cells?	No
Secondary Batteries?	Yes
TEST	Sample connected electrically to a DC power Supply or Battery Charger/Cycler, with programmable voltage and current control. An overcharge current of 2x the manufacturers recommended charge current shall be applied for 24 hours. Charge Voltage applied: - If recommended Charge voltage is 18V or less: - 2x charge voltage, up to 22V - If recommended Charge voltage is >18V: - 1.2x maximum charge voltage
CRITERIA	No disassembly or fire within 7 days of test.
T7 NOTES	Rechargeable batteries without built-in overcharge protection are exempt from this test if are meant to be incorporated, through means of deliberate design, into a battery assembly which does afford such protection. However, if at any point you plan on transporting the rechargeable batteries without the battery assembly with protection, for example as spares, then T7 WILL apply.

T8: Forced Discharge	
REASON	Simulates forced discharge of cells
APPLICABLE TO	
Primary Cells?	Yes
Primary Batteries?	No
Secondary Cells?	Yes
Secondary Batteries?	No
TEST	Sample connected in series with +12V DC Power Supply and load resistor. Load resistor shall be sized to provide the maximum discharge current of the battery with 12V applied in series. Duration is calculated from the rated Amp hours of the cell Duration(h) = rated Ah / Initial Current(A)
CRITERIA	• No disassembly or fire within 7 days of test

Points to remember about lithium batteries when incorporating them into your product in relation to UN Manual of Tests and Criteria (38.3)

- Always try and get a copy of the UN Manual of Tests and Criteria (38.3) certificates and report, if possible, for the cells and/or battery pack.
- Make sure the certificate is current and of good quality as you show compliance through self-certification. Ultimately, you will take responsibility for it when you use it in your product.
- Get a copy of the MSDS (Material Safety Data Sheet)
- Obtain copies of the assembly drawing/s showing Construction, Size and Mass of batteries.
- As part of due diligence always verify compliance of cells and batteries, through your own testing or a through reputable 3rd party body accredited by an appropriate authority to conduct UN 38.3 testing.

What are the key differences between 38.3 REV. 5 and 38.3 REV.5 Amend 1?

The revision mostly consists of clarifications to certain clauses and definitions within the scope. As far as testing is concerned, there are some minor changes but the biggest change in testing is T6 – the Impact/Crush test on cells. Here are some of the changes:

Changes to the Scope (38.3.2)	
38.3.2.1	Rechargeable cells with overcharge protection will be subject to T7 (Overcharge Test)
38.3.2.2	The cell and battery will need to be subject to retesting (full compliment of samples) if any changes to the cell or battery have been made which would lead to failure of any tests.
38.3.2.3	Various clarifications on certain definitions and the inclusion of some new ones such as fire, nominal energy and open circuit voltage. It provides a list of Standards to follow to determine the rated capacity: IEC 61960 1st Edition IEC 62133 1st Edition IEC 62660-1 1st Edition

Changes to Number of Samples for Testing	
38.3.3 (c)	T6 – now the number of samples for prismatic and cylindrical cells are the same. 10 primary and 10 secondary cells

Changes to testing	
T2 Thermal testing	Initial storage temperature is now 72°C ±2°C.
T3 Vibration	The difference in testing of small and large batteries as defined by 38.3 has now been clearly split. Cells and small batteries: 7Hz of 1g until 18Hz is reached; Increased until 8g (≈ 50Hz) then maintained until frequency = 200Hz Large batteries: 7Hz of 1g until 18Hz is reached; Increased until 2g (≈ 25Hz) then maintained until frequency = 200Hz
T6 Impact/Crush	The test now includes impact or crushing which may lead to internal short circuit. Impact (applies to cylindrical cell >20mm in diameter) • Placed on flat surface • 15.8 mm ± 0.1mm Type 316 at least 6cm stainless steel bar across centre of sample • 9.1kg ± 0.1kg mass dropped from 61 ± 2.5 cm on bar and sample intersection at 90 degrees Crush (prismatic, pouch, coin and cylindrical cell <20mm in diameter) • Crushed between 2 flat surfaces • Gradual speed of ≈ 1.5cm/s first point of contact • Continue until either: Applied for reaches 13kN ± 0.78kN or; Voltage drops by at least 100 mV or; cell deformation by 50% or more of original thickness • Sample to be observed for another 6 hrs

How Can Intertek Help?

From hybrid electric vehicles to medical device batteries, personal electronics, and renewable energy, Intertek has a depth of experience in battery testing services. We help to ensure your energy storage technologies meet performance, reliability and safety criteria, as well as UN Transportation requirements. Intertek's complete range of services for UN 38.3 includes Tests 1-8 of this specification:

T1 – Altitude Simulation (Primary and Secondary Cells and Batteries)
T2 – Thermal Test (Primary and Secondary Cells and Batteries)
T3 – Vibration (Primary and Secondary Cells and Batteries)
T4 – Shock (Primary and Secondary Cells and Batteries)
T5 – External Short Circuit (Primary and Secondary Cells and Batteries)
T6 – Impact (Primary and Secondary Cells)
T7 – Overcharge (Secondary Batteries)
T8 – Forced Discharge (Primary and Secondary Cells)

From testing to consultation Intertek can help ensure you are on the right path to meeting the relevant Directives and Regulations. Far from being just a testing facility, Intertek can be your point of contact when it comes to keeping pace with the ever-changing landscape of energy storage compliance.

About Intertek

Intertek is a leading provider of quality and safety solutions serving a wide range of industries around the world. From auditing and inspection, to testing, quality assurance and certification, Intertek people are dedicated to adding value to customers' products and processes, supporting their success in the global marketplace. Intertek has the expertise, resources and global reach to support its customers through its network of more than 1,000 laboratories and offices and

over 30,000 people in more than 100 countries around the world. Intertek Group plc (ITRK) is listed on the London Stock Exchange in the FTSE 100 index.

For more information on specific testing and certification information, please contact Intertek at 1-800-WORLDLAB, email icenter@intertek.com, or visit our website at www.intertek.com.