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Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals

Sub-Committee of Experts on the Transport of Dangerous Goods

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Item 2 (c) of the provisional agenda
Recommendations made by the Sub-Committee on its thirty-ninth, fortieth and forty-first sessions and pending issues: electric storage systems

Alternative testing requirements for lithium battery assemblies designed for use in vehicles

Transmitted by The Rechargeable Battery Association (PRBA) and the Council on Safe Transportation of Hazardous Articles (COSTHA)[1]

Introduction

1. At the forty-first session of the Sub-Committee, PRBA filed informal paper INF.62 regarding the implementation of paragraph 38.3.3(f) in the United Nations Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, which applies to testing of lithium "battery assemblies" with an aggregate lithium content of not more than 500 g, or, in the case of lithium ion batteries, a Watt-hour (Wh) rating of not more than 6200 Wh.

2. The implementation of paragraph 38.3.3(f) has given rise to a number of questions and varying interpretations due to the wording of the provision and the definition of "*Battery*" in the Manual, which includes a reference to "battery assembly" but does not specifically define it. PRBA and COSTHA are proposing amendments to 38.3.3(f) to more clearly define the testing requirements for battery assemblies.

3. PRBA and COSTHA also are proposing an alternative to the testing requirements in 38.3.3(f) of the Manual for lithium ion battery assemblies designed for use in hybrid-electric and electric vehicles. Lithium ion battery and automobile manufacturers now recognize that the vehicle-related design and engineering requirements for these lithium ion battery assemblies are, in some cases, wholly incompatible with certain tests in the Manual. Therefore, we believe the battery tests developed by the UNECE's World Forum for

[1] In accordance with the programme of work of the Sub-Committee for 2011-2012 approved by the Committee at its fifth session (refer to ST/SG/AC.10/C.3/76, para. 116 and ST/SG/AC.10/38, para. 16).

Harmonization of Vehicle Regulations provide a reasonable alternative and an equivalent level of safety to the testing requirements in 38.3.3(f) of the Manual of Tests and Criteria.

4. Lithium ion battery assemblies designed for use in hybrid-electric and electric vehicles with a Watt-hour rating of not more than 6200 Wh are subject to the requirements in 38.3.3(f). These battery assemblies also may be subject to industry testing standards from such organizations as SAE, IEC, ISO and ANSI. In addition, the UNECE's World Forum for Harmonization of Vehicle Regulations (WP.29) recently amended their testing standard applicable to rechargeable batteries designed for use in hybrid-electric and electric vehicles.

5. Because lithium ion batteries are rapidly being introduced for hybrid-electrical and electric vehicles, the UNECE's World Forum for Harmonization of Vehicle Regulations developed new safety requirements for vehicles and batteries as the 02 series of amendment to UNECE Regulation No. 100 (Battery electric vehicles) (See http://www.unece.org/fileadmin/DAM/trans/doc/2012/ wp29/ECE-TRANS-WP29-2012-102e.doc.) It is expected that this amendment will be adopted at its next session in November 2012 and enter into force in the middle of 2013. The UNECE Regulation No. 100 is annexed to the 1958 Agreement concerning the adoption of uniform technical prescriptions for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles and the conditions for reciprocal recognition of approvals granted on the basis of these prescriptions. It is applied by 43 countries, and is recognized as an internationally established regulatory instrument. Once amended it will include the following nine tests for lithium ion batteries (and other rechargeable batteries) designed for use in hybrid-electric and electric vehicles:

- Over-temperature
- Mechanical shock
- Mechanical integrity
- Vibration
- Fire resistance
- External short circuit
- Overcharge
- Over-discharge
- Thermal shock and cycling

The Manual of Tests and Criteria requires the following four tests for lithium ion batteries under 38.3.3(f):

- Shock
- Vibration
- External short circuit
- Overcharge

6. The test procedures in Regulation No. 100 take into consideration the unique features of the lithium ion battery assemblies designed to power hybrid-electric and electric vehicles without compromising safety. The Manual test procedures may, in some cases, be wholly incompatible with the vehicle-related battery designs and engineering requirements. For example, cooling system ducting and support structures, which are an integral part of many hybrid-electric vehicle and/or electric vehicle batteries, can cause resonant frequency vibration far in excess of the test criteria specified in the T.3 (vibration) and T.4 (shock) tests, resulting in battery test failures. In addition, the force multiplication effect of shock and vibration on large batteries can also result in test failures, particularly with batteries exceeding a net mass of approximately 30-35 kg.

7. A comparison of the four tests (Shock, Vibration, External Short circuit and Overcharge) that are required by both the UNECE Regulation No. 100 and paragraph 38.3.3(f) of the Manual of Tests and Criteria is provided on the following pages. In some cases, the Manual may differ from the UNECE Regulation No. 100. However, the lithium ion cells and lithium ion batteries that are electrically connected to form the battery assembly have been subjected to the full series of tests required in the Manual.

Comparison of four tests required by UNECE Regulation No.100-02 and UN Manual of Tests and Criteria

<table>
<tr><th></th><th>Manual Tests Procedures</th><th>UNECE Test Procedures</th></tr>
<tr><td>Vibration</td><td>

Sinusoidal waveform
Logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 minutes.
Cycle repeated 12 times for a total of 3 hours for each of three mutually perpendicular mounting positions.
For large batteries: from 7 Hz to a peak acceleration of 1 gn is maintained until 18 Hz is reached. Amplitude is maintained at 0.8 mm (1.6 mm total excursion) and the frequency increased until a peak acceleration of 2 gn occurs (approximately 25 Hz). Peak acceleration of 2 gn is maintained until the frequency is increased to 200 Hz.

</td><td>

Sinusoidal waveform
Logarithmic sweep between 7 Hz and 50 Hz and back to 7 Hz traversed in 15 minutes
Cycle shall be repeated 12 times for a total of 3 hours in the vertical direction of the mounting orientation of the REESS as specified by the manufacturer.

<table>
<tr><th>Frequency (Hz)</th><th>Acceleration (m/s2)</th></tr>
<tr><td>7 - 18</td><td>10</td></tr>
<tr><td>18 - 30</td><td>gradually reduced from 10 to 2</td></tr>
<tr><td>30 - 50</td><td>2</td></tr>
</table>

After vibration, the standard cycle in Annex 8 Appendix 1 shall be conducted if not inhibited by the test device, and followed by 1 hour observation @ ambient temperature

</td></tr>
<tr><td>Short Circuit</td><td>

External case temperature tested at 55 ± 2 °C
External resistance of less than 0.1 ohm at 55 ± 2 °C.
Short circuit condition continued for at least one hour after battery external case temperature has returned to 55 ± 2 °C.

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Tested at ambient temperature of 20 ± 10 °C
External resistance not exceeding 5 mΩ.
Short circuit condition continued until the operation battery´s protection function to interrupt or limit short circuit current is confirmed, or for at least one hour after the temperature measured on the casing of the tested-device has stabilised, such that the temperature gradient varies by less than 4°C through 1 hour.

</td></tr>
<tr><td>Overcharge</td><td>

Charge current shall be twice manufacturer's recommended maximum continuous charge current. Minimum voltage of the test shall be as follows:

(a) when manufacturer's recommended charge voltage is not more than 18V, the minimum voltage of test shall be the lesser of two times the maximum charge voltage of the battery or 22V.
(b) when manufacturer's recommended charge voltage is more than 18V, the minimum voltage of test shall be 1.2

</td><td>

Tested-device shall be charged with a charge current of at least 1/3C rate but not exceeding maximum current within the normal operating range as specified by the manufacturer.
Charging shall be continued until tested-device (automatically) interrupts or limits the charging.
Where an automatic interrupt function fails to operate, or if there is no such function the charging shall be continued until the tested-device is charged to twice of its rated charge capacity.

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</table>

	Manual Tests Procedures	UNECE Test Procedures
	times the maximum charge voltage. • Tests to be conducted at ambient temperature. Duration of test shall be 24 hours.	
Shock	• Acceleration – 50 g_n • Pulse form – Half sine • Duration – 11ms • Number of shocks – 18	• Acceleration – Ranges from 17 – 28 depending on type of vehicle battery is designed to power. • Pulse form – Single step • Duration – 80 ms

8. The Shock test in the Manual of Tests and Criteria has been particularly problematic for large lithium ion batteries designed for use in hybrid-electric and electric vehicles. COSTHA provided a very good explanation of this issue in working paper ST/SG/AC.10/C.3/2010/72 during the thirty-eighth session of the Sub-Committee. COSTHA correctly noted that the forces generated from the application of specified acceleration in T.4 Shock test greatly exceed those encountered in severe transport conditions. This point is supported by a recently published report from the IMO/ISO UNECE's informal group of experts for the revision of the IMO/ILO/UNECE Guidelines for Packing of Cargo Transport Units entitled "*Code of Practice for Packing of Cargo Transport Units* (CTUs)." The report provides examples of the accelerations in g's which could arise during transport operations.[2] These values are far below what is required by the Shock test for lithium batteries in the Manual of Tests and Criteria. Thus, the required peak acceleration of 50 gn is unreasonable abuse given a review of available testing data.

9. Therefore, to more clearly define the testing requirements for battery assemblies and provide a reasonable alternative to the testing requirements in sub-section 38.3.3 of the Manual of Tests and Criteria for batteries designed to power hybrid-electric and electric vehicles, PRBA and COSTHA propose the following changes to 38.3.3(f):

Proposal

Amend 38.3.3 (f) to read:

38.3.3(f) ~~When testing a~~One battery assembly, that is assembled from batteries that have passed all applicable tests, in which the aggregate lithium content of all anodes, when fully charged, is not more than 500 g, or in the case of a lithium ion battery, with a Watt-hour rating of not more than 6 200 Watt-hours, ~~that is assembled from batteries that have passed all applicable tests,~~ shall be tested ~~one battery assembly~~ in a fully charged state ~~shall be tested~~ under tests T.3, T.4 and T.5, and, in addition, test T.7 in the case of a rechargeable battery assembly. For a rechargeable battery assembly, the assembly shall have been cycled at least 25 cycles. Alternatively, one battery assembly designed for use in vehicles, that is assembled from batteries that have passed all applicable tests, may be tested in accordance with the Vibration, Shock, Short Circuit and Overcharge Tests in Annex 8 to Regulation No. 100, 02 Series of amendments, annexed to the 1958 Agreement concerning the adoption of uniform technical prescriptions for wheeled vehicles, equipment and parts which can be filled and/or be used on wheeled vehicles and the conditions for reciprocal recognition of approvals granted on the basis of these prescriptions.

[2] The table presented in the "Code of Practice for packaging of Cargo transport Units (CTUs)" provides examples of accelerations in g's which could arise during transport operations as follows:

Mode of transport	Forwards	Backwards	Sideways
ROAD	1.0g	0.5g	0.5g
RAIL	4.0g	4.0g	0.5g
SEA (North Sea Unrestricted)	0.4g	0.4g	0.8g

$1g = 9.81\ m/s^2$

For the activities of the group, refer also to www.unece.org/trans/wp.24 welcome.html.