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COMMITTEE OF EXPERTS ON THE TRANSPORT OF DANGEROUS GOODS

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WORK OF THE SUB-COMMITTEE OF EXPERTS ON THE TRANSPORT OF DANGEROUS GOODS

Draft amendments to the Model Regulations on the Transport of Dangerous Goods Manual of Tests and Criteria

38.3 Lithium Batteries

Transmitted by the Expert from Canada

Background

1. At the 15th Session of the Sub-Committee the expert from Canada pointed out that the existing provisions on lithium batteries had been established for certain types of small cells and batteries. He accepted the need to provide credible tests for application to larger batteries, such as EV batteries, but he observed that one series of tests may not be suitable for both categories (small and large). He advised that the applicability of existing and proposed tests to small cells and batteries was being reviewed in Canada and this could result in a proposal for a revision of the tests to apply to small cells and batteries. As it was not possible to structure reasonable tests for small lithium cells and batteries that were also reasonable for large lithium cells and batteries, or vice-versa, this proposal is to leave the existing material in the Model Regulations and Manual of Tests and Criteria to be applied to large cells and batteries and to add corresponding material to address small cells and batteries.

Introduction

2. The principal concerns with the transport of lithium cells and batteries are the potential for a rapid release of energy affecting the contents of the cell or battery or the surrounding area, the release of the lithium or lithium alloy from the cell or battery and the release of other material from the cell or battery.

3. The existing series of tests appearing in Section 38.3 of the Manual of Tests and Criteria were developed for small cells and batteries when these were new products. Since that time, batteries have increased in size and have been improved. It is also noted that a large number of small cells and batteries have been transported without incident, due in a large part to effective packaging. Recent changes to make the existing series of tests more applicable to larger batteries is further reducing their appropriateness for use in testing the current small cells and batteries. In this paper the class of small cells and batteries is defined and a test series for these, independent of the test series for larger cells and batteries, is proposed.

Discussion

4. The focus of the proposed tests is on small cells and batteries in transport as opposed to requirements which would be applicable during their use.

5. Many small cells and batteries have been transported safely by the modes under grandfather clauses exempting them from portions of the existing tests. If the proposal to remove the application of these grandfather clauses for transport by air on January 1, 2001 comes into effect, many of these safe transportation situations will be prohibited. This is further reason for ensuring that the test series are brought up to date.

6. Some elements of the existing test series are not relevant to a non-operating cell or battery packaged for transport, however, some elements of the existing test series will be retained and strengthened in order to compensate for some of these deletions. Specifically:

a) the extreme temperature exposure test is expanded to stress connections within cells and battery packs;

b) the vibration test is expanded in frequency range to be representative of conditions of all modes of transport; and

c) the current shock test is replaced by a more universal shock test.

7. The following present series T tests are not carried over because they relate to performance standards and product safety during the operation of the cells or batteries, or they are compensated for in the proposed tests:

(i) the short circuit tests in T.1 and T.2 (covered in SP 230);

(ii) the charge test in T.3 (not applicable to non-operating units in transport);

(iii) the internal short circuit test in T.4 (in light of strong packaging, cause would be vibration or shock, hence these tests have been strengthened)

(iv) the low capacity cell test in T.5 (not applicable to non-operating units in transport); and

(v) the forced discharge test in T.6 (not applicable to non-operating units in transport).

New Test Prescriptions

8. The first proposed test series is identified by the designation ST.1 to distinguish it from the current test series T.1. Test Series ST.1 will apply to small cells which will be defined as cells containing not more than 15 grams of lithium metal or lithium alloy, or not more than 25 equivalent grams of lithium in the case of a lithium ion cell (equivalent grams of lithium will also be defined). Test Series ST incorporates the altitude simulation, extreme temperature exposure, vibration and shock tests.

9. The second proposed test series is identified by the designator ST.2 to distinguish it from the current test series T.2. Test Series ST.2 will apply to small batteries which will be defined as batteries containing not more than 750 grams of lithium metal or lithium alloy, or not more than 1000 equivalent grams of lithium in the case of a lithium ion battery (equivalent grams of lithium will also be defined). Test Series ST.2 incorporates the altitude simulation, extreme temperature exposure, vibration and shock tests.

Proposal

Amendment instruction 1:

Replace the heading 38.3 with

“38.3 Large lithium cells or batteries”

Amendment instruction 2:

Replace the text of clause 38.3.1 of the Manual of Tests and Criteria with the following:

“This section presents the procedures to be followed for the classification of large lithium cells which are cells containing more than 15 grams of lithium metal or lithium alloy, or more than 25 equivalent grams of lithium in the case of a lithium ion cell and the classification of large lithium batteries which are batteries containing more than 750 grams of lithium metal or lithium alloy, or more than1000 equivalent grams of lithium in the case of a lithium ion battery (see UN 3090 and UN 3091, and special provisions 188 and 230 of Chapter 3 of the recommendations).”

Amendment instruction 3:

Add the following clauses after clause 38.3.3.2 of the Manual of Tests and Criteria.

"**38.4 Small lithium cells or batteries**

38.4.1 ***Purpose***
This section presents the procedures to be followed for the classification of small lithium cells which are cells containing not more than 15 grams of lithium metal or lithium alloy, or not more than 25 equivalent grams of lithium in the case of a lithium ion cell and the classification of small lithium batteries which are batteries containing not more than 750 grams of lithium metal or lithium alloy, or not more than 1000 equivalent grams of lithium in the case of a lithium ion battery (see UN 3090 and UN 3091, and special provisions 188 and 230 of Chapter 3 of the recommendations).

38.4.2 ***Scope***

38.4.2.1 Small lithium cells and batteries offered for transport are not subject to the Recommendations if they meet the requirements of Special Provision 188 of Chapter 3 of the Recommendations.

38.4.2.2 Small lithium cells and batteries may be assigned Class 9 if they meet the requirements of Special Provision 230 of Chapter 3 of the Recommendations.

38.4.2.3 As required by Special Provisions 188 and 230, a small lithium cell type shall be subjected to Test ST.1, or may be subjected to a more stringent qualification test, prior to the transport of that cell type, and a lithium battery type shall be subjected to Test ST.2, or may be subjected to a more stringent qualification test, prior to the transport of that battery type. Small lithium cells and batteries, which differ from the tested type, with a change in design to any part of the cell or battery that could materially affect the test results, shall be considered a new type and shall be subjected to the required tests. In the event that a lithium cell or battery type does not meet the test criteria in 38.4.4.3, steps should be taken to correct the deficiency or deficiencies that caused the failure before such a cell or battery type is retested.

38.4.3 ***Classification procedure***

38.4.3.1 Small lithium cells and batteries which are required to be tested shall be subjected to Test ST.1 and Test ST.2, respectively, of section 38.4.4 and shall be classified according to the criteria given in 38.4.4.3.

38.4.3.2 For the purposes of classification, the following definitions apply:

Battery means two or more cells which are electrically connected together by a permanent means.

Cell means a single encased electrochemical unit which exhibits a voltage difference across its two terminals.

Component cell means a cell contained in a battery.

Cycle means one sequence of fully charging and fully discharging a rechargeable cell or battery.

Disassembly means a vent or rupture where solid matter is ejected from any part of a cell or battery.

Distortion means the change in any dimension of a cell or battery beyond its design tolerances.

Effluent means a liquid or gas released when a cell or battery vents or leaks.

Equivalent grams of lithium means, for lithium-ion cells and batteries, the quantity in grams obtained by multiplying the rated capacity in ampere-hours of the cell or battery by 0.3 g per ampere-hour.

First cycle means the initial cycle following completion of all manufacturing processes.

Fully charged cell or battery means a rechargeable cell or battery which has been charged to its designed starting condition or a primary cell or battery which is charged to at least 95% of its rated capacity.

Fully discharged cell or battery means either:

a primary cell or battery which has been discharged to remove 100% of its rated capacity; or

a rechargeable cell or battery at its lowest voltage limit.

Lithium-ion cell means a rechargeable electrochemical cell in which the positive and negative electrodes are both intercalation compounds (intercalated lithium exists in an ionic or quasi-atomic form within the lattice of the electrode material) with no metallic lithium in either electrode.

More stringent qualification tests mean tests in which the altitude simulation, extreme temperature exposure, vibration and mechanical shock testing methods reflect conditions more severe than those contained in the series ST tests [Examples of more stringent qualifications are those for airworthiness, such as the US FAA TSO C-97, the proposed US FAA TSO C-142 and the British Standard, G 239.].

Primary means a cell or battery which is not designed to be charged or recharged electrically.

Protective device means a device such as a fuse, diode or current limiter which stops the current flow, blocks the current flow in one direction or limits the current flow in an electrical circuit.

Rated capacity means the capacity, in ampere-hours, of a cell or battery as measured by subjecting it to a load, temperature and voltage specified by the manufacturer.

Rechargeable means a cell or battery which is designed to be recharged electrically.

Short circuit means a direct connection between positive and negative points of a cell or battery that provides a virtual zero resistance path for current flow.

Type means a particular electrochemical system and physical design of cells or batteries.

Vent means the intended activation of the pressure relief device of a cell or a battery to allow excessive internal pressure to be safely reduced without fire or disassembly.

38.4.4 ***Series ST test prescriptions***

38.4.4.1 ***Test ST.1: Cell tests***

38.4.4.1.1 *Introduction*

These tests are intended for small cells identified in Special Provision 188 or Special Provision 230 as being subject to these tests. The altitude simulation, extreme temperature exposure, vibration and shock tests are designed to determine the ability of cells to withstand exposure to environmental conditions encountered during transport. A comparison of the cell appearance before and after these tests is intended to detect cell damage such as leakage and venting, the disintegration, cracking, swelling or distortion of the cell, or any other abnormal observation which could constitute a transportation safety hazard.

38.4.4.1.2 *Apparatus and materials*

38.4.4.1.2.1 The following apparatus is required for this test: a balance with sufficient accuracy to detect mass losses identified in Table 38.4.4.3.1, a vacuum chamber, a controlled temperature chamber, a vibration machine and a shock test apparatus.

38.4.4.1.2.2 The number and state of cells to be tested to qualify a given cell type are:

(a) For a primary cell, ten cells which should be tested in the fully charged state.

(b) For a rechargeable cell, ten cells which should be tested in the state of charge in which they are to be transported [in the fully charged state].

38.4.4.1.3 *Procedure*

Each cell is subjected in sequence to the test procedures described below.

38.4.4.1.3.1 Altitude simulation

Cells are stored at 20 °C for at least 6 hours at an absolute pressure equal to 11.6 kPa or less.

38.4.4.1.3.2 Extreme temperature exposure

Cells are stored for at least 6 hours at a temperature equal to 75 °C, followed by at least 6 hours at a temperature equal to -40 °C. The maximum time between temperature extremes is 30 minutes. The cycle is repeated for a total of 10 times, after which the cells are stored at room temperature for at least 24 hours.

38.4.4.1.3.3 Vibration

Cells are firmly secured to the platform of the vibration machine without distorting the cells in such a manner as to faithfully transmit the vibration. The vibration shall be a sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz, traversed in 15 minutes. This cycle shall be repeated 12 times for a total of 3 hours for each of three mutually perpendicular mounting positions of the cell. One of the directions of vibration must be perpendicular to the terminal face.

The logarithmic frequency sweep is as follows: from 7 Hz a peak acceleration of 1 g is maintained until 18 Hz is reached. The amplitude is then maintained at 0.8 mm (1.6 mm total excursion) and the frequency increased until a peak acceleration of 8 g occurs (approximately 50 Hz). A peak acceleration of 8 g is then maintained until the frequency is increased to 200 Hz.

38.4.4.1.3.4 Shock

Cells are secured to the shock test apparatus by means of a rigid mount without distorting the cells in such a manner as to faithfully transmit the shock impact. Each cell is subjected to three shocks in the positive direction, followed by three shocks in the negative direction, in each of three mutually perpendicular mounting positions of the cell, for a total of 18 shocks. One of the directions of the shock must be perpendicular to the terminal face. The minimum peak acceleration should be 50 g in a half-sine waveform over a minimum duration of 11 milliseconds.

38.4.4.1.4 *Test criteria and method of assessing results*

The lithium cells should be assessed after all the tests are completed unless any single result clearly indicates that it is unsafe and may only be transported with special authorization granted by the competent authority. The test criteria and method of assessing results are given in 38.4.4.3.

38.4.4.2 **Test ST.2: Battery tests**

38.4.4.2.1 *Introduction*

These tests are intended for batteries identified in Special Provision 188 or Special Provision 230 as being subject to these tests. The altitude simulation, extreme temperature exposure, vibration and shock tests are designed to determine the ability of batteries to withstand exposure to environmental conditions encountered during transport. A comparison of the battery appearance

before and after these tests is intended to detect battery damage such as component cell leakage and venting, the disintegration, cracking, swelling or distortion of the battery pack, or any other abnormal observation which could constitute a transportation safety hazard.

38.4.4.2.2 *Apparatus and materials*

38.4.4.2.2.1 The following apparatus is required for this test: a balance with sufficient accuracy to detect mass losses identified in Table 38.4.4.3.1, a vacuum chamber, a controlled temperature chamber, a vibration machine and a shock test apparatus.

38.4.4.2.2.2 The number and state of batteries to be tested are:

(a) For primary batteries; eight, of which four must be tested in the fully charged state and four must be tested in the fully discharged state;

(b) For rechargeable batteries; eight, of which four must be tested after 50 deep cycles ending in the fully charged state, and four must be tested after 50 deep cycles ending in the fully discharged state.

38.4.4.2.3 *Procedure*

Each battery is subjected in sequence to the test procedures described below.

38.4.4.2.3.1 Altitude simulation

Batteries are stored at 20 °C for at least 6 hours at an absolute pressure equal to 11.6 kPa or less.

38.4.4.2.3.2 Extreme temperature exposure

Batteries are stored for at least 6 hours at a temperature equal to 75 °C, followed by at least 6 hours at a temperature equal to -40 °C. The maximum time between temperature extremes is 30 minutes. The cycle is repeated for a total of 10 times, after which the batteries are stored at room temperature for at least 24 hours.

38.4.4.2.3.3 Vibration

Batteries are firmly secured to the platform of the vibration machine without distorting the batteries in such a manner as to faithfully transmit the vibration. The vibration shall be a sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz, traversed in 15 minutes. This cycle shall be repeated 12 times for a total of 3 hours for each of three mutually perpendicular mounting positions of the battery. One of the directions of vibration must be perpendicular to the terminal face.

The logarithmic frequency sweep is as follows: from 7 Hz a peak acceleration of 1 g is maintained until 18 Hz is reached. The amplitude is then maintained at 0.8 mm (1.6 mm total excursion) and the frequency increased until a peak acceleration of 8 g occurs (approximately 50 Hz). A peak acceleration of 8 g is then maintained until the frequency is increased to 200 Hz.

38.4.4.2.3.4 Shock

Batteries are secured to the shock test apparatus by means of a rigid mount in such a manner as to faithfully transmit the shock impact without distorting the batteries. Each battery is subjected to three shocks in the positive direction, followed by three shocks in the negative direction, in each of three mutually perpendicular mounting positions of the cell, for a total of 18 shocks. One of the directions of the shock must be perpendicular to the terminal face. The minimum peak acceleration should be 50 g in a half-sine waveform over a minimum duration of 11 milliseconds.

38.4.4.2.4 *Test criteria and method of assessing results*

The safety of lithium batteries should be assessed after all the tests are completed, unless any single result clearly indicates that it is unsafe and may only be transported with special authorization granted by the competent authority. The test criteria and method of assessing results are given in 38.4.4.3.

38.4.4.3 ***Series ST test criteria and method of assessing results***

38.4.4.3.1 A lithium cell or battery type fails the test if

(a) for any one of the tested units of that type

(i) distortion, venting, leaking, disassembly, discharge or fire is evident; or
(ii) for a unit subject to the mass requirements in Special Provision 230 the loss of mass exceeds that shown in Table 38.4.4.3.1; or

(b) in the case of test ST.2 for batteries, at the conclusion of the test the four batteries tested while fully charged are fully discharged and any one battery's capacity in not within 10% of the average capacity of the four batteries which were fully discharged before the test.

Table 38.4.4.3.1: PERCENTAGE MASS LOSS CRITERIA

Mass of cell or battery	**Maximum mass loss (%)**
More than 1.0 g	0.2

38.4.4.3.2 A lithium cell or battery, subject to the mass requirements given in Special Provision 230, is assigned to Class 9 if it passes the test ST.1 or ST.2 according to the criteria in 38.4.4.3.1.

38.4.4.3.3 Where a lithium cell or battery cannot be exempted from the Recommendations under Special Provision 188 or assigned to Class 9, it may only be transported with special authorization granted by the competent authority."

10. Amendments to Special Provisions 188, 230 and 231 are a necessary complement to the amendments proposed for the Manual of Tests and Criteria, Part III, sub-sections 38.3 and 38.4.

Amendment Instruction 4:

In Chapter 3.3 of the UN Recommendations change the first phrase of Special Provision 188 to

"188 **Part A:** Large lithium cells and batteries, as defined in subsection 38.4.3.2 of the Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, offered for transport are not subject to these Regulations if they meet the following provisions:"

Amendment Instruction 5:

In Chapter 3.3 of the UN Recommendations add the following at the end of Special Provision 188:

"**Part B:** Small lithium cells and batteries, as defined in subsection 38.4.3.2 of the Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, offered for transport are not subject to these Regulations if they meet the following provisions:

(a) Cells and batteries contain:

(i) not more than 5 g of lithium metal or lithium alloy if a cell,

(ii) not more than 25 g of lithium metal or lithium alloy if a battery,

(iii) not more than 8 equivalent grams of lithium if a lithium ion cell (equivalent grams of lithium is defined in subsection 38.4.3.2 of the Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Part III), and

(iv) not more than the 40 equivalent grams of lithium if a lithium ion battery;

(b) Each cell or battery is undamaged and in good condition;

(c) Cells and batteries are separated so as to prevent the development of short circuits;

(d) Cell and battery terminals or switches are protected in such a manner as to prevent accidental operation during transport;

(e) Batteries in equipment must have an effective mechanism which prevents accidental operation during transport;

(f) Each primary battery containing cells connected in parallel, or series of cells connected in parallel is equipped with blocking diodes in each parallel string or an alternate circuit in order to prevent reverse current flow between the parallel strings;

(g) Cells and batteries are sealed in plastic and packed in strong packagings except when installed in equipment; and,

(h) Each cell and battery type must have satisfied the tests set out in subsection 38.4 of the Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Part III, except that the following cell and battery types are exempt from this requirement:

(i) a cell containing not more than 1 g of lithium metal or lithium alloy,

(ii) a battery containing not more than 2 g of lithium metal or lithium alloy,

(iii) a lithium ion cell containing not more than the 1.5 equivalent grams of lithium

(iv) a lithium ion battery containing not more than 8 equivalent grams of lithium, and

(v) a cell or battery type which will only be transported while installed in equipment for the purposes of keeping memory alive, clocks operating or other similar very low current operation."

11. The amount of lithium metal or lithium alloy per cell is raised from 12 to 15 grams and the amount of lithium metal or lithium alloy per battery is raised from 500 to 750 grams. This recognizes products now in development that exceed the previous limitations. Lithium-ion rechargeable batteries are included.

Amendment Instruction 6:

In Chapter 3.3 of the UN Recommendations change the first phrase of Special Provision 230 to:

"230 **Part A:** Large lithium cells and batteries as defined in subsection 38.4.3.2 of the Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, may be transported under this entry if they meet the following provisions:"

Amendment Instruction 7:

In Chapter 3.3 of the UN Recommendations add the following at the end of Special Provision 230:

"**Part B:** Small lithium cells and batteries as defined in subsection 38.4.3.2 of the Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, may be transported under this entry if they meet the following provisions:

[(a) Each cell contains not more than 15 g of lithium metal or lithium alloy or 25 equivalent grams of lithium if the cell is a lithium ion cell; (equivalent grams of lithium is defined in subsection 38.4.3.2 of the Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria , Part III.)]

[(b) Each battery contains not more than 750 g of lithium metal or lithium alloy or 1000 equivalent grams of lithium if the battery is a lithium ion battery;]

(c) Each cell or battery is undamaged and in good condition;

(d) Each cell and battery incorporates a safety venting device or is designed to preclude a violent rupture under conditions normally incident to transport;

(e) Each cell and battery is equipped with an effective means of preventing the development of external short circuits;

(f) Each primary battery containing cells connected in parallel, or series of cells connected in parallel is equipped with blocking diodes in each parallel string or an alternate circuit in order to prevent reverse current flow between the parallel strings;

(g) Cells are packaged in inner packagings to prevent the development of short circuits and to prevent movement which could lead to short circuits;

(h) Batteries are sealed in plastic bags and packed in inner packagings to effectively prevent the development of short circuits and to prevent movement which could lead to short circuits;

(i) Cells and batteries are prevented from operating during transport;

(j) Cell and battery terminals or switches are protected in such a manner as to prevent accidental operation during transport;

(k) Batteries in equipment are equipped with an effective mechanism preventing accidental operation during transport; and,

(l) Each cell or battery type has been determined to meet the criteria for assignment to Class 9 on the basis of tests carried out in accordance with the Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Part III, sub-section 38.4.

Amendment Instruction 8:

In Chapter 3.3 of the UN Recommendations add the following at the end of Special Provision 231:

"Despite the preceding, when small lithium cells and batteries, as defined in subsection 38.4.3.2 of the Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, are included in Class 9 and are packed with equipment, they shall be sealed in plastic bags and packed in inner fibreboard packaging that meet the requirements for Packing Group II. Battery terminals or switches are to be protected in such a manner as to prevent accidental operation during transport.

In addition, when small lithium cells and batteries included Class 9 are contained in equipment, the equipment shall be sealed in plastic bags and packed in strong outer packaging in such a manner as to prevent accidental operation during transport."

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