UNITED NATIONS

ST

Secretariat

Distr.
GENERAL

ST/SG/AC.10/2000/13
18 September 2000

ORIGINAL : ENGLISH

COMMITTEE OF EXPERTS ON THE TRANSPORT OF DANGEROUS GOODS

**(Twenty-first session,
4-13 December 2000,
agenda item 2 (b))**

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

Draft amendments to the Recommendations on the Transport of Dangerous Goods

Test methods for lithium batteries

Manual of Tests and Criteria

Transmitted by the experts from Japan and the United States of America

1. The experts from Japan and the United States of America propose that the test methods for lithium batteries be revised in accordance with the proposals in Annex.

2. Test methods provided in Annex are substantially the same as those agreed by the working group convened in Ottawa, Canada in March 2000 and reported to the eighteenth session of the Sub-Committee in Information Paper 4. Substantial changes include:

.1 The order for conducting the first four tests (the proposed order: altitude, thermal, vibration and shock) was altered as this order was considered to be more rigorous.

.2 At the Ottawa working group meeting there was disagreement on whether to retain the existing T.4 Internal Short Circuit Test, to substitute a modified test or to delete the test entirely. Annex 1 includes the modified Internal Short Circuit test that was originally included in the proposal by the experts from Canada and Japan in document ST/SG/AC.10/C.3/1999/73.

.3 The definition of battery was amended to clarify that “battery packs” are treated as batteries (see also discussion below); and

.4 Provisions to accommodate testing of large batteries were included as described in paragraphs 6, 7 and 8 below.

3. Paragraph 12 of Information Paper 4 noted a number of issues which working group participants identified as still requiring resolution. Points that are still considered relevant by the experts from Japan and the United States of America are discussed in the following paragraphs.

4. *Whether to base the various tests on “normal conditions of transport”*. Opinions were divided on the appropriateness of certain tests. Namely, it was argued by some Ottawa working group participants that the internal short circuit, the overcharge and forced discharge tests did not simulate normal conditions of transport. The experts from Japan and the United States of America note that testing beyond what may reasonably be expected under normal conditions of transport is not uncommon under the UN Recommendations. Tests for explosives, organic peroxides and air bags are but a few of the types of dangerous goods that are subject to tests significantly more severe than what can be characterized as normal conditions of transport. It is the view of the expert from Japan and the United States of America that tests more severe than tests simulating normal conditions of transport are appropriate to justify regulating lithium cells and batteries under class 9 or as not subject to the Regulations. It is acknowledged that the overcharge test and the forced discharged tests are tests that simulate conditions when a battery is in use or under recharge conditions. However, these conditions can exist in some transport circumstances. For example, recharging of batteries is now possible on some aircraft. Conditions of forced discharge could also exist in transport if batteries are inadvertently incorrectly installed in equipment or are misused onboard a transport unit. It should also be noted that these tests are included in IEC test procedures and that these tests are currently already required in the Manual of Tests and Criteria.

5. *Whether battery packs are to be treated as batteries?/ Whether the term “equipment” needs to be defined?* There is at present no standard for battery packs. While some battery packs may include hard cased plastic outer protection, in the absence of a standard for battery packs, they could also simply consist of cells tightly wrapped together by tape. In the absence of a standard that justifies more lenient treatment, battery packs should be subject to transport provisions applicable to lithium batteries. Battery packs may in some cases contain additional electrical equipment. The question was raised as to whether such battery packs should be treated as equipment or whether they should continue to be treated as batteries. It is proposed that such battery packs continue to be treated as batteries and that this clarification be included in the definition of batteries.

6. *Testing of large lithium batteries.* “Large” lithium batteries, which are envisaged for use, for example, for purposes of electric vehicle (EV) propulsion are quite, expensive, and produced in relatively small numbers as compared to “small” lithium batteries. This being the case some changes are proposed to reduce testing costs for large batteries without jeopardizing safety.

7. Identical large lithium batteries (often referred to a “modules” by EV lithium battery developers) may be electrically inter-connected in many different arrangements (“assemblies”) depending on the requirements for individual vehicles. A particular concern is that if each of these different arrangements is viewed as a distinct “battery” design for testing purposes, the costs of testing would become prohibitive. It is not considered necessary or appropriate to subject each distinct assembly to the full testing regime applicable to a different “battery” design, provided it can be determined (either through selective testing, engineering analysis, or other appropriate means) that the assembly would be capable of passing the non-destructive tests (Test 1 to 5). To allow for this, new text has been added at the end of paragraph 38.3.3.

8. In the Ottawa proposed testing provisions, 38.3.4 (“Procedure”) requires that Tests 1 to 5 be conducted with the same batteries, while Test 7 be conducted with not previously tested batteries. The authors believe that batteries used for the non-destructive Tests 1 to 5, if undamaged, may be used as the “deep cycled” batteries required to be tested in Test 7. Paragraph 38.3.4 has been changed accordingly.

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Annex

Testing Requirements for Inclusion in the Manual of Tests and Criteria

{Note: The changes to the introductory portions of the tests and criteria for lithium batteries show additions in bold type and deletions are indicated by strikeout. Beginning with paragraph 38.3.4, the existing text should be deleted in its entirety and replaced with the text below beginning with 38.3.3.}

38.3 Lithium batteries

38.3.1 Purpose

This section presents the procedures to be followed for the classification of lithium cells and batteries (see UN 3090 and UN 3091, and **the applicable** special provisions ~~188 and 230~~ of Chapter 3.3 of the Model Regulations).

38.3.2 Scope

~~38.3.2.1 Lithium cells and batteries offered for transport are not subject to the Model Regulations if they meet the requirementsof Special Provision 188 of Chapter 3.3 of the Model Regulations.~~

~~38.3.2.2 Lithium cells and batteries may be assigned to Class 9 if they meet the requirements of Special Provision 230 of Chapter 3.3 of the Model Regulations.~~

38.3.2.~~3~~ **1** Lithium cells and batteries should be subjected to **the** ~~series T~~ tests~~, where applicable,~~ as required by special provisions 188 and 230 **of Chapter 3.3 of the Model Regulations** prior to the transport of a particular cell or battery type. Lithium cells or batteries which differ from a tested type by:

(a) A change of more than 20% by mass to the cathode, to the anode, or to the electrolyte; or

(b) A change that would materially affect the test results

should be considered a new type and should be subjected to the required tests. In the event that a lithium cell or battery type does not meet **one of** the test **requirements** ~~criteria in 38.3.4.7~~, steps should be taken to correct the deficiency or deficiencies that caused the failure before such cell or battery type is retested.

~~38.3.3 Classification procedure~~

~~38.3.3.1 Lithium cells and batteries which are required to be tested should be subjected to each test of series T in section 38.3.4 and should be classified according to the criteria given in 38.3.4.7.~~

38.3.~~3~~.2.**2** For the purposes of classification, the following definitions apply:

Aggregate lithium content means the sum of the grams of lithium content or **lithium equivalent content** contained by the cells comprising a battery.

Battery means two or more cells which are electrically connected together by ~~a~~ permanent means, **including case, terminals, and marking**. **Units that are commonly referred to as "battery packs"**

having the primary function of providing a source of power to another piece of equipment are for purposes of these Regulations treated as batteries.

Cell means a single encased electrochemical unit **(one positive and one negative electrode)** which exhibits a voltage differential across its two terminals. **Under these Regulations, to the extent the encased electrochemical unit meets the definition of "cell" herein, it is a "cell," not a "battery," regardless of whether the unit is termed a "battery" or a "single cell battery" outside of these Regulations.**

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 from any part of a cell or battery penetrates a wire mesh screen (annealed aluminium wire with a diameter of 0.25 mm and grid density of 6 to 7 wires per cm) placed 25 cm away from the cell or battery.

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

Equivalent lithium content is defined in the definition of lithium content.

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

Fully charged means a rechargeable cell or battery which has been electrically charged to its design~~ed starting condition~~ rated capacity.

Fully discharged means either:

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

a rechargeable cell or battery which has been electrically discharged to ~~a load voltage or less than 2/3 of its starting open circuit voltage~~ **its endpoint voltage as specified by the manufacturer**.

Large battery means a battery in which the aggregate lithium content of all anodes, when fully charged, is more than 500 g.

Large cell means a cell in which the lithium content or lithium equivalent content of the anode, when fully charged, is more than 12 g.

***Leakage* means the escape of material from a cell or battery.**

Lithium content **is applied to lithium metal and lithium alloy cells and batteries, and for a cell** means the mass of lithium in the anode of a lithium metal or lithium alloy cell, which for a primary cell is measured when the cell is in an undischarged state and for a rechargeable cell is measured when the cell is fully charged~~, except that in the case of a lithium ion cell the lithium content is measured in terms of equivalent lithium content, which in grams is calculated to be 0.3 times the rated capacity in ampere hours~~. **The lithium content of a battery equals the sum of the grams of lithium content contained in the component cells of the battery.**

Lithium-equivalent content **is applied to lithium-ion cells and batteries, and for a cell is measured as 0.3 times the rated capacity of the cell in ampere -hours, with the result expressed in grams. The lithium-equivalent content of a battery equals the sum of the grams of lithium-equivalent content contained in the component cells of the battery.**

Lithium-ion cell or battery means a rechargeable electrochemical cell or battery in which the positive and negative electrodes are both intercalation compounds (intercalated lithium exists in an ionic or quasi-atomic form with the lattice of the electrode material) constructed with no metallic lithium in either electrode. **A lithium polymer cell or battery that uses lithium-ion chemistries, as described herein, is regulated as a lithium-ion cell or battery.**

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

Protective devices means devices such as fuses, diodes and current limiters which ~~stop~~ **interrupt** the current flow, block the current flow in one direction or limit 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 cutoff point specified by the manufacturer.

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

Rupture **means the mechanical failure of a cell container or battery case induced by an internal or external cause, resulting in exposure or spillage but not ejection of solid materials.**

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

Small battery means a battery composed of small cells, and in which the aggregate lithium content of all cell anodes, when fully charged, is not more than 500 g.

Small cell means a cell in which the lithium content of the anode, when fully charged, is not more than 12 g.

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

Undischarged means a primary cell or battery **that** ~~which~~ has not been **wholly or partly** discharged. ~~; such a discharge does not include normal self-discharge resulting from reactions during storage.~~

Venting **means the release of excessive internal pressure from a cell or battery in a manner intended by design to preclude rupture or disassembly.**

Mass loss **means a loss of mass that exceed the values in Table 1 below. In order to quantify the mass loss, the following procedure is provided. Mass loss = $(M_1 - M_2)/M_1 \times 100\%$ where M_1 is the mass before the test and M_2 is the mass after the test. When mass loss does not exceed the values in Table 1, it shall be considered as "no mass loss".**

Table 1 - Mass loss limits

Mass *M* of cell or battery	**Mass loss limit**

M **< 1 g**	**0.5%**
1 g < M < 5 g	**0.2%**
M **> 5 g**	**0.1%**

Delete 38.3.4 in its entirety and replace with the following:

38.3.3 When a cell or battery type is to be tested under this sub-section, the number and condition of cells and batteries of each type to be tested are as follows:

(a) When testing primary cells and batteries under tests 1 to 5, the following shall be tested:

(i) ten cells in undischarged states,
(ii) ten cells in fully discharged states,
(iii) four batteries in undischarged states, and
(iv) four batteries in fully discharged states.

(b) When testing rechargeable cells and batteries under tests 1 to 5 the following shall be tested:

(i) ten cells, at first cycle, in fully charged states,
(ii) ten cells, at first cycle, in fully discharged states,
(iii) four batteries, at first cycle, in fully charged states,
(iv) four batteries, at first cycle, in fully discharged states,
(v) four batteries after fifty deep cycles ending in fully charged states, and
(vi) four batteries after fifty deep cycles ending in fully discharged states.

(c) When testing primary and rechargeable cells under test 6, the following shall be tested:

(i) for primary cells, five cells in undischarged states and five cells in fully discharged states,
(ii) for component cells of primary batteries, five cells in undischarged states and five cells in fully discharged states,
(iii) for rechargeable cells, five cells at first cycle at 50% of the design rated capacity and five cells after 50 deep cycles ending in fully discharged states, and
(iv) for component cells of rechargeable batteries, five cells at first cycle at 50% of the design rated capacity and five cells after 50 deep cycles ending in fully discharged states.

For prismatic cells, ten test cells are required for each of the states of charge being tested, instead of the five described above, so that the procedure can be carried out on five cells along the longitudinal axes and, separately, five cells along the other axes. In every case, the test cell is only subjected to one crush.

(d) When testing rechargeable batteries under test 7, the following shall be tested:

(i) four rechargeable batteries, at first cycle, in fully charged states, and
(ii) four rechargeable batteries after fifty deep cycles ending in fully charged states.

(e) When testing primary and rechargeable cells under test 8, the following shall be tested:

(i) ten primary cells in fully discharged states,
(ii) ten rechargeable cells, at first cycle in fully discharged states, and
(iii) ten rechargeable cells after fifty deep cycles ending in fully discharged states.

When large batteries having passed all applicable tests are offered for transport electrically connected to form a battery assembly, the battery assembly must be capable of passing Tests 1 to 5.

38.3.4 Procedure

Each cell and battery type must be subjected to tests 1 to 8. Tests 1 to 5 must be conducted in sequence on the same cell or battery. Tests 6~~,~~ 7 and 8 should be conducted using not otherwise tested cells or batteries. **Test 7 may be conducted using undamaged batteries previously used in Tests 1 to 5 for purposes of testing on deeply cycled batteries.**

38.3.4.1 Test 1: Altitude simulation

38.3.4.1.1 Purpose

This test simulates air transport under low pressure conditions.

38.3.4.1.2 Test Procedure

Test cells and batteries shall be stored at a pressure of 11. 6 kPa or less for at least six hours at ambient temperature.

38.3.4.1.3 Requirement

Cells and batteries meet this requirement if there is no mass loss, no leakage, no venting, no disassembly, no rupture and no fire and if the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

38.3.4.2 Test 2: Thermal Test

38.3.4.2.1 Purpose

This test assesses cell and battery seal integrity and internal electrical connections. The test is conducted using rapid and extreme temperature changes.
38.3.4.2.2 Test Procedure

Test cells and batteries are to be stored for at least six hours at a test temperature equal to 75 (± 2) °C, followed by storage for at least six hours at a test temperature equal to -40 (± 2) °C. The maximum time interval between test temperature extremes is 30 minutes. This procedure is to be repeated 10 times, after which all test cells and batteries are to be stored for 24 hours at ambient temperature (20 (± 5) °C.). For large cells and batteries the duration of exposure to the test temperature extremes should be at least 12 hours.

38.3.4.2.3 Requirement

Cells and batteries meet this requirement if there is no mass loss, no leakage, no venting, no disassembly, no rupture and no fire and if the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

38.3.4.3 Test 3: Vibration

38.3.4.3.1 Purpose

This test simulates vibration during transport.

38.3.4.3.2 Test Procedure

Cells and batteries 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_n 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_n occurs (approximately 50 Hz). A peak acceleration of 8 g_n is then maintained until the frequency is increased to 200 Hz.

38.3.4.3.3 Requirement

Cells and batteries meet this requirement if there is no mass loss, no leakage, no venting, no disassembly, no rupture and no fire and if the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

38.3.4.4 Test 4: Shock

38.3.4.4.1 Purpose

This test simulates possible impacts during transport.

38.3.4.4.2 Test Procedure

Test cells and batteries shall be secured to the testing machine by means of a rigid mount which will support all mounting surfaces of each test battery. Each cell or battery shall be subjected to a half-sine shock of peak acceleration of 150 g_n and pulse duration of 6 milliseconds. Each cell or battery shall be subjected to three shocks in the positive direction followed by three shocks in the negative direction of three mutually perpendicular mounting positions of the cell or battery for a total of 18 shocks.

However, large cells and large batteries shall be subjected to a half-sine shock of peak acceleration of 50 g_n and pulse duration of 11 miliseconds. Each cell or battery is subjected to three shocks in the positive direction followed by three shocks in the negative direction each of three mutually perpendicular mounting positions of the cell for a total of 18 shocks.

3 8.3.4.4.3 Requirement

Cells and batteries meet this requirement if there is no mass loss, no leakage, no venting, no disassembly, no rupture and no fire and if the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

38.3.4.5 Test 5: External Short Circuit

38.3.4.5.1 Purpose

This test simulates an external short circuit.

38.3.4.5.2 Test Procedure

The cell or battery to be tested shall be temperature stabilized so that its external case temperature reaches 55 (± 2) °C and then the cell or battery shall be subjected to a short circuit condition wth a total external resistance of less than 0.1 ohm at 55 (± 2) °C. This short circuit condition is continued for at least one hour after the cell or battery external case temperature has returned to 55 (± 2) °C. The cell or battery must be observed for a further six hours for the test to be concluded.

38.3.4.5.3 Requirement

Cells and batteries meet this requirement if their external temperature does not exceed 160°C and there is no disassembly, no rupture and no fire within six hours of this test.
38.3.4.6 Test 6: Internal Short Circuit

38.3.4.6.1 Purpose

This test simulates an internal short circuit.

38.3.4.6.2 Test Procedure

The cell or component cell to be tested shall be crushed between two flat surfaces. The force shall be applied by a vice or by a hydraulic ram. The crushing shall be continued until

(1) the cell or component cell voltage drops abruptly or is reduced to at least one third, or
(2) a pressure reading of either 17 Mpa (an applied force of approximately 13kN) or a maximum force of 1 000 times the weight of the cell is attained, whichever is greater.

Once the voltage drops abruptly or is reduced to at least one third, or the maximum pressure has been attained, the pressure shall be released.
A cylindrical cell or component cell shall be crushed with its longitudinal axis parallel to the flat surfaces of the crushing apparatus. A prismatic cell or component cell shall be crushed by applying the force in the direction of one of the two axes perpendicular to its longitudinal axis and, separately, with another test cell or component cell, by applying the force in the direction of the other one of these two axes. A button/coin cell or component cell shall be crushed by applying force on its flat surfaces.

Each cell or component cell used in the test shall only be crushed once.

38.3.4 6.3 Requirement

Cells and component cells meet this requirement if their external temperature does not exceed 160 °C and there is no disassembly and no fire within six hours of this test.

38.3.4.7 Test 7: Overcharge

38.3.4.7.1 Purpose

This test evaluates the ability of a rechargeable battery to withstand an overcharge condition.

38.3.4.7.2 Test Procedure

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

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

(b) when the manufacturer’s recommended charge voltage is more than 18V, the minimum voltage of the test shall be 1.2 times the maximum charge voltage.

Tests are to be conducted at ambient temperature. The duration of the test shall be 24 hours.

38.3.4.7.3 Requirement

Rechargeable batteries meet this requirement if there is no disassembly and no fire within seven days of the test.

38.3.4.8 Test 8: Forced Discharge

38.3.4.8.1 Purpose

This test evaluates the ability of a primary or a rechargeable cell to withstand a forced discharge condition.

38.3.4.8.2 Test Procedure

Each cell shall be forced discharged at ambient temperature by connecting it in series with a 12 V D.C. power supply at an initial current equal to the maximum discharge current specified by the manufacturer. The specified discharge current is to be obtained by connecting a resistive load of the appropriate size and rating in series with the test cell. Each cell shall be forced discharged for a time interval (in hours) equal to its rated capacity divided by the initial test current (in Ampere).

38.3.4.8.3 Requirement

Primary or rechargeable cells meet this requirement if there is no disassembly and no fire within seven days of the test.

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