

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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**Recommendations made by the Sub-Committee
on its forty-seventh, forty-eighth and
forty-ninth sessions and pending issues:
electric storage systems**

Transport of damaged/defective Lithium Batteries, Step II

Transmitted by the European Association for Advanced Rechargeable Batteries (RECHARGE)

Introduction

1. The transport of damaged/defective Lithium batteries is currently regulated in SP376. It allows two ways of transport, either P908/LP904 for the transport of damaged/defective lithium batteries, non-reactive under normal transport conditions (category A) or using a competent authority approval to transport damaged / defective lithium batteries possibly reactive under normal transport conditions (category B).

2. An working document has been presented for the Sub-Committee (50th session, ST/SG/AC.10/C.3/2016/67), proposing a new packaging solution for the case of category B. In complement to this document, and following discussions during the Informal Working Group in Bordeaux on the 31 March 2016, it is proposed to describe the packaging performance in relationship to the severity of the battery hazards it has to contain, in order to specify the adapted protection at the packaging level for each type of battery.

3. The type of hazards which may result from a Li battery in thermal runaway are identified in the SP376. The severity of these hazards depends on the battery chemistry, state of charge, and other conditions. Nevertheless, conditions for a “worth case” thermal runaway can be identified for each battery type, and the resulting hazard severity was quantified in laboratory testing. See for example following references for scientific literature review:

– Investigation on the fire-induced hazards of Lithium-ion battery cells by fire calorimetry, INERIS. G. Gachot, P. Ribière, D. Mathiron, S. Grugeon, M. Armand, J.-B. Leriche, S. Pilard, S. Laruelle *Anal. Chem.*, 2011, 83 (2), pp 478–485 and P. Ribière, S. Grugeon, M. Morcrette, S. Boyanov, S. Laruelle, G. Marlair, *Energy Environ. Sci.*, 2012, 5, pp5271;

– Li-ion batteries safety RECHARGE report: (June 2013-
<http://www.rechargebatteries.org/wp-content/uploads/2013/07/Li-ion-safety-July-9-2013-Recharge-.pdf>;

- Federal Aviation Administration: Lithium Battery Update, The Effect of State of Charge On Flammability and Propagation of Thermal Runaway (Systems Working Group, Harry Webster, May 23, 2012, <https://www.fire.tc.faa.gov/systems/Lithium-Batteries>);
- Federal Aviation Administration: The aircraft hazards of flammable gasses produced by lithium batteries in thermal (Harry Webster for ICAO-FAA Fire Safety, juil-15, <https://www.fire.tc.faa.gov/systems/Lithium Batteries>.)

4. The air transport regulation ICAO has mandated the SAE organisation to define a standard for the test of packaging in case of thermal runaway of the Li batteries. For harmonization reasons, it is proposed to use the same criteria for the protection performance of the packaging as the one proposed in this standard.

The list of the criteria regarding packaging performance is the following:

- No hazardous temperature outside the packaging (peak temperature 200°C, average 150°C);
- No hazardous flame outside;
- No hazardous ejection of particles;
- No damage of the packaging e.g.;
- Limited quantity of gas, or gas management (e.g. filter system, air circulation, containment for gas etc.).

5. The level of severity in case of thermal runaway can be identified for each battery hazard. It is proposed to create a 3 level scale to categorize them: Benign, Medium and High.

The level “High” corresponds to the maximum hazard expected in case of complete thermal run-away, based on data compiled from the literature and confirmed by industry and administrations tests (see point 3).

The level “Medium” corresponds to a measurable event representing a threshold, either in the event nature or in the protection method: for example the medium level for gas venting has been set at 50liters/kg of cell, because this corresponds to a venting mechanism, which can possibly interrupt any further thermal runaway. In the same way, the medium level for temperature increase has been set at 150°C because it is below the 200°C maximum temperature considered for the external packaging temperature, and therefore avoids the risk of thermal runaway propagation.

The level “Benign” corresponds to a minor or the absence of hazard, requiring no specific protection measure.

The result is described in table 1

<i>Type of hazard</i>	<i>Hazard quantification</i>	<i>Unit</i>	<i>Maximum severity level (based on standard scale)</i>		
			Benign	Medium	High
Disassembly	Energy of particle ejections	kJ	no disassembly	disassembly	
Flame	flame duration	s	<2	<120	<21600
	Flame power	MW/m2	<0,1	<0,5	<5
Heat	Heat Release rate	MW/m2	<0,1	<0,5	<5
	Maximum Energy released	MJ/kg of cell	<0,1	<2	<10
	Maximum temperature increase	°C	<50°C	<150°C	<800°C
Corrosive liquid	Corrosion severity	according GHS, UN MT&C, 37.4	non corrosive	<category 1	category 1
	Other				
Gas emission	Maximum flow	l/s	0,1	1	50
	Maximum volume	l/kg cells	1	50	500
	Explosion, flammability (according composition)	according GHS classification 2.2	non flammable	category 2	category 1
	Toxicity	according composition, GHS 3.10	non toxic	category 2	category 1

Table1: Batteries hazards classification

6. Before proposing them for transport, mitigation measures can be applied to the batteries, in order to reduce the severity of the reactions. In such a case, the result of the mitigations measures has to be identified, in order to assign the battery to the fitting level in the hazard scale.

The following possible prevention measures are identified:

- Cooling (request for specification of minimum temperature at which the battery is inert, minimum time for cooling, applicable duration of transport, when dry ice or liquid nitrogen is used as a coolant, the requirements as specified in section 5.5.3 of the UN Recommendations on the Transport of Dangerous Goods shall apply)
- Discharging (request a process verifying that all cells are discharged, in the damaged battery condition)

7. The packaging properties shall be specified in order to offer adequate protection for each of the potential hazards of the battery as proposed for transport: the required properties are identified in table 2. It is proposed to assign to the packaging protection level a category corresponding to the hazard level it is containing: Benign, Medium and High.

In addition, it is proposed to define and quantify the expected properties for the packaging environment during transport. As these properties may not depend on the weight of battery transported, they are proposed as absolute values. Three levels are also proposed, the “medium” level corresponding to industrial conditions standard: i.e. the medium level for gas circulation flow is proposed at 22m³/h, which is the minimum requirement for European standard for EN 13779 (Ventilation for non-residential buildings — Performance requirements for ventilation and room-conditioning systems). Ventilated conditions in cargo compartments largely exceed these values.

<i>Type of hazard</i>	<i>Packaging protection level</i>				<i>specification</i>
	Benign	Medium	High		
Disassembly	Mechanical resistance level (structural calculation, materials resistance)	mechanical calculation according the battery type			Materials type and thickness
Flame	Flame resistance level (flame resistance materials scale)	packaging material selection according the flame duration and power			Material flame resistance category
Heat	Thermal insulation Thermal capacity Packaging thermal resistance: max external temperature after 6hours (°C)	thermal calculation according the packaging material selected (specific heat in kJ/kg and thermal conductivity in W/m*K), the packaging design (material thickness) and the battery type and maximum weight			Materials type and thickness maximum external temperature (°C)
Corrosive liquid	Packaging material chemical resistance or protection	packaging material selection according the battery type			Material type and thickness
Gas emission	overpressure pulse resistance (structural calculation)	mechanical calculation according the battery type and maximum weight			Materials type and thickness
	vent flow (L/s)	venting size according the battery type and maximum weight			l/s
	specific containment/treatment (flammability reduction, toxicity reduction ...)				specific
	environment requirements: maximum pulse pressure resistance	0,5	3,5	350	kPa
	environment requirements: minimum volume for gas dilution	0,1	2	20	m3
	environment constraints:gas evacuation/ circulation flow	0,1	22	1000	m3/h

Table 2: packaging protection classification

8. Finally, a suitable packaging can be selected based on the properties of the batteries offered for transport, and the applied mitigations measures. The packaging properties must comply with at least the suitable protection level according the table 1, and be sized according the maximum batteries total dimensions and weight. A table summarizing the information of table 1, table 2 and the mitigations means is presented in the table 3, using a typical example of Li battery. In addition, the table 3 provides information about the required properties of the packaging environment during transport, such as gas evacuation when required.

In case the level of hazard is exceeding the limits proposed in table 1, or other hazards have been identified, the battery shall not be transported except under conditions specified by the competent authority, as currently specified in SP376.

<i>Battery characteristics</i>				<i>Mitigation means</i>		<i>Packaging characteristics</i>		
Battery chemistry or type :	Li-ion battery example XX			description	reduced State of Charge: 30%	Packaging identification or type		Packaging example YY
						Maximum total weight	kg	
						Maximum total surface	m2	0,5
Type of hazard	Hazard quantification	Unit	Maximum severity level	Resulting severity level	Packaging properties	Packaging protection level	packaging description	
			Benign/ Medium/ High	Applicable/ Non applicable	Benign/ Medium/ High		Benign/ Medium/ High	
Disassembly	Energy of particle ejections	kJ	B	N/A	B	Mechanical resistance level (structural calculation, materials resistance)	B	Materials type and thickness: 2 mm cardboard
Flame	flame duration	s	M	A	B	Flame resistance level (flame resistance materials scale)	B	Material flame resistance category: N/A
	Flame power	MW/m2	H	A	B			
Heat	Heat Release rate	MW/m2	B	A	B	Thermal conductivity	B	Materials type and thickness:2 mm Cardboard
	Maximum Energy released	MJ/kg of cell	B	A	B	Thermal capacity		

<i>Battery characteristics</i>			<i>Mitigation means</i>			<i>Packaging characteristics</i>		
	Maximum temperature increase	°C	M	A	B	Packaging thermal resistance: max external temperature after 6hours (°C)		maximum external temperature (°C): 200°C
Corrosive liquid	Corrosion severity	according GHS, UN MT&C, 37.4	B	N/A	B	Packaging material chemical resistance or protection	B	Material type and thickness: 2 mm cardboard
Gas emission	Maximum flow	l/s	M	A	B	vent flow (l/s)	M	l/s= 50
	Maximum volume	l/kg cells	B	A	B	overpressure pulse resistance (structural calculation)	B	Materials type and thickness : N/A
	Explosion, flammability (according composition)	according GHS classification 2.2	H	N/A	H	specific containment/tr treatment (flammability reduction, ...)	N/A	Specific: N/A
	Toxicity	according composition, GHS 3.10	H	N/A	H	specific containment/tr treatment (toxicity reduction ...)	N/A	Specific: N/A
						environment requirements: maximum pulse pressure resistance	N/A	kPa: N/A
						environment requirements: minimum volume for gas dilution	M	m ³ = 20, or ventilation
						environment constraints:gas evacuation/ circulation flow	M	m ³ /h: 22, or minimum volume 20 m ³

Table 3: Packaging selection according the battery hazards

The packaging selected according table 3 should be qualified and identified according the following criteria:

- (a) Methods for verification of these packaging criteria. A guidance is provided in the annex of ST/SG/AC.10/C.3/2016/67 The aim is to verify that:
- The performance is demonstrated by a test or by a calculation corresponding to the cell/battery type [as defined in UN Manual, in the condition of transport (e.g. SOC etc.).
 - The calculation has ran on a verified model. The verification has been done under a quality management system (it should consider all material properties, the worst failure modes, [be compared to a test result]).
 - The packaging selection criteria are described on a report available on demand, including the batteries identification (name, number,) and the table 3 filled with the suitable information.
- (b) Means for identification and traceability of the packaging qualification.
- [The packaging should be of a UN qualified type II (or I ?)]
 - [The packaging should be identified by a reference allowing to check the qualification references].

Proposal

Recharge proposes to use this method to identify and qualify an adequate packaging based on the informal document INF.12 (49th session) as the next step and as a basis for the calculation of packagings to transport damaged/defective Li batteries comparable with standard performance based packagings.

Conclusion

The new method is proposed for consideration by the TDG as a way to develop the specifications of working document ST/SG/AC.10/C.3/2016/67 further and for a general advancement of the dangerous goods regulations.
