

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

1 June 2022

### **Sub-Committee of Experts on the Transport of Dangerous Goods**

#### **Sixtieth session**

Geneva, 27 June-6 July 2022

Item 4 (b) of the provisional agenda

#### **Electric storage systems: Hazard-based system for classification of lithium batteries**

## **Work of the informal working group on hazard-based classification of lithium batteries and cells**

### **Transmitted by the expert from France on behalf of the informal working group**

### **Introduction**

1. Since the publication of document ST/SG/AC.10/C.3/2021/45 for the fifty-ninth session of the Sub-Committee, the informal working group (IWG) on hazard based classification of lithium batteries and cells hold several virtual meetings on 30 September and 17 November 2021. In addition, a sub-group of representatives of testing laboratories virtually met recently on 9 February, 9 March, 5 April and 12 May 2022.

2. The meeting minutes on the discussions are reproduced in annex 1 to this report. A summary on the progresses is proposed below. This summary is not intended to present the final result of the group discussions, but rather the progress of the discussions, including the views of the testing labs sub-group, and the proposed ways forward.

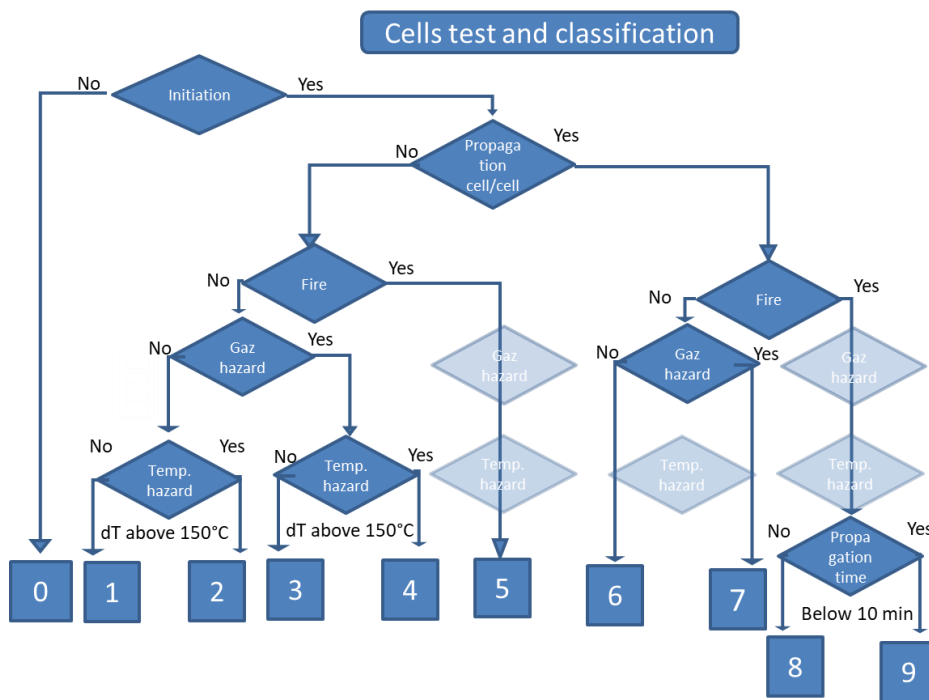
### **Introduction of the new classification proposal**

3. As presented in the previous report, the hazards related to lithium batteries have been identified and agreed upon as follows:

- The capability for a thermal runaway to propagate from cell to cell, and battery to battery;
- The capability to generate a flame;
- The capability to generate significant quantities of toxic and/or flammable gas;
- The capability to produce high temperature.

4. The possible combinations of these hazards have been considered, and a proposal for a classification of cells, according to these hazards, is under discussion. A classification tree, enabling to clarify the presence or absence of each hazard relative to a product, has been proposed.

5. This classification tree below represents at its last line the potential grouping of hazards, applicable to the various lithium batteries chemistries.



6. In this tree, light blue diamonds are representing hazards that are always applicable in this class, and therefore are not submitted to test verification. The hazard level of each class is not related to the class numbering.

7. At the current stage of the discussion, the above classification is intended to be applied on fully charged or undischarged cells, without considering the packaging. Nevertheless, the same classification, based on tests, may be used to identify the hazards of the products as transported, including mitigation means of the hazards such low state of charge or packaging protections.

8. At a later stage, several classes might be grouped together to simplify the classification and the regulation (for example packing instructions, special provisions, ...).

### Introduction of the testing requirements to support the classification

9. The practical usage of the classification tree requires the availability of robust test methods capable to generate and characterize the identified hazards.

10. The method applied to generate the hazards is based on the principle that abusive conditions can generally initiate a thermal runaway reaction in fully charged lithium batteries. The propagation and gas tests are based on the initiation of the thermal runaway of the cell or battery by a thermal abuse method, using of a heater to overheat a local point of the cell. This method is representing the best compromise between the simulation of the internal short circuit, the control of the implementation and the reproducibility of the reaction. The large number of tests realized by the group has demonstrated a relevant level of repeatability and reproducibility of the method.

11. Based on the good knowledge of the lithium cells and batteries representative of the market, it is proposed that no testing would be mandatory for the classification of the Li-ion or lithium metal cells and batteries. By default, all the hazards identified are considered as applicable, as they are representative of the worst case products of typical Li-ion or lithium metal batteries with common chemistries: typically, based on the data measured during the first set of tests, the propagation is happening from cell to cell with a rate of 2 seconds per cell, the gas emissions contain 50 % hydrogen and 100 ppm HF with a volume of 1 L/Wh of cell. The fire risk is considered applicable in all cases (values TBC at a later stage).

12. For the declaration of a different set, or less hazardous properties, a propagation test (test 1) and a gas test (test 2) would be needed for demonstration. The test setup is defined to verify the worst case conditions of propagation risk and gas or flame emission risk.

### **Battery classification**

13. Default classification would be the same as the cells within the battery. For gas quantities, it would be the quantity of gas from the cell times the number of cells in the battery. Optional: a battery test could be used to determine actual quantity of gas or propagation limitation. Test of only a single battery by driving one cell into thermal runaway is necessary. The propagation risk between batteries would be assessed based on the battery external emissions (casing temperature, flame, gas and particle emissions) based on the single battery test.

14. The distinction between metal and ion may remain, through existing UN numbers or some logical evolution in the classification.

### **Definition and verification of the testing protocols**

15. The group of testing laboratories has prepared a draft document to describe the proposed protocols applicable to characterize the hazards as follows:

- A test for the determination of the propagation risk, the flame risk and the temperature risk;
- A test to determine the quantity of gas and, if applicable, the flammability or toxicity of the gas emitted;
- A test applicable to batteries, for the determination of the risk of propagation inside and outside the battery, including flame and temperature.

16. The description is provided in annex 2 to this report.

17. The group has elaborated a testing plan with the global objective: going forward with a robust test method for classification, applicable to all products. This plan has two steps:

1<sup>st</sup> step: General objective is to: determine the feasibility for all cases, propose and test solutions to the issues identified, and propose text protocol improvements. This first step includes the test of specific products and conditions where there is a need to clarify the feasibility of the test protocol proposal.

2<sup>nd</sup> step: Define and run a round robin test, on specific cases identified, to verify reproducibility.

18. A table summarizing the test proposed for the first step, as well as the expected timeline, is described in annex 3 to this report.

## **Conclusion**

19. A classification tree is proposed to define classes based on hazards at the cell level.

20. A protocol for testing at the cell level has been defined thanks to the first round of testing and is now being further developed in a second round of tests.

21. The classification tree and protocol for testing at battery level is now actively discussed in the IWG.

22. The IWG will meet again virtually on 7 July 2022 to review the first results of the tests in the first step and prepare the tests for the second step. The technical information resulting from these tests will be used to finalize the classification proposal.

23. The Sub-Committee is invited to take note of the work in progress and comment, as appropriate.

## Annex I

### UN Informal Working Group on Lithium Batteries – 2021-2022

#### Meeting on 30 September 2021 – Video Conference

##### Introduction

1. Claude Chanson (RECHARGE) welcomed participants to the session. The intent of the meeting was to discuss the classification flowchart(s) and how data collected by the testing laboratories can be used. Given the continued restrictions on travel due to the COVID-19 pandemic, the group was not able to meet in person.
2. Agenda meeting:
  - (a) Review of proposed classification flowcharts discussed in the past meetings.
  - (b) Discussion of some key points identified to clarify/simplify the existing proposals:
    - i. Categories of hazards justifying a specific class (i.e. different categories according to toxicity of toxic gases?)
    - ii. Organization of the flowchart (cases of bursting and case of no self-ignition – bonfire test?)
    - iii. Integration of the batteries in the flow chart.
  - (c) Discussion of new proposals and update of the flowchart.
  - (d) Wrap up and next steps.
3. Information and presentations given at the meeting are available from the RECHARGE Website <https://rechargebatteries.org/sustainable-batteries/unsctdg/>
4. In addition, all historical documents related to the current Informal Working Group are also posted on the RECHARGE Website.
5. At the end of the meeting, the group will decide whether the UN Sub-Committee will need to be updated on the discussion.

##### Review of proposed classification flowcharts discussed in the past meetings (C. Chanson)

6. The group reviewed the previously developed global decision tree for cells (*see slide 4 from the RECHARGE Presentation*). The key decisions in the tree are:
  - (a) Does the cell initiate?
  - (b) Does the reaction propagate to adjacent cells?
  - (c) Does a fire result of the event (ignition of flammable gases)?
  - (d) Are there gas hazards that result (flammable or toxic)?
  - (e) What are the maximum temperatures that result?
7. Each of the answers to these questions lead to additional questions or identify the sum of all hazards that result from the questions. In two situations (when no cell initiation occurs or when rapid disassembly leads to a fire), a bonfire test is also added to determine the energy released when burned.
8. The flow chart includes a few assumptions:

- (a) A cell would be submitted for testing, applicable for cells and for batteries;
  - (b) Results of testing of the cell would be expected to be worse than testing in a battery;
  - (c) It is assumed the classification obtained at a battery level could possibly be more advantageous.
9. Slide 6 provided the cell to battery connection. When tested in a battery, the flowchart questions whether propagation within the battery occurs:
- (a) If cells used do not propagate from cell to cell, the battery would be classified on the basis of the component cells;
  - (b) If cells propagate in the cell tests, the battery would be tested to see if cells propagate within the battery. If no propagation occurs, battery would be classified similarly to cells that do not propagate (due to protections in when installed in a battery);
  - (c) If cells propagate in a battery, battery to battery tests would need to be conducted to see if propagation occurs.
10. The group questioned whether tests need to be conducted on both the cells and batteries if testing of a battery (propagation test) proved no propagation occurred. RECHARGE proposed that a thermal propagation test could potentially eliminate the need for additional tests at a cell level, when the battery has been tested.
11. The group discussed topics raised on propagation testing during the May 2021 meeting (see paragraphs 17-21 from 26 May 2021 meeting minutes) and whether the additional tests (such as the bonfire of bursting power) would lead to additional classification differentiation. Participants shared that bursting power and ejecta is likely already known. Thus, is it necessary to conduct the tests if existing knowledge can be used to determine the hazard? Does toxicity matter if non-DG goods can produce the same toxicity when subjected to burn tests? The question of toxicity needs to be considered and addressed as quickly as possible as it represents a significant data collection issue. If it is not to be considered, the group could focus on other topics.

## **Gas considerations**

12. During the last session, it was discussed that toxicity is being closely reviewed by G-27 and the UN LBWG should work from their conclusions. Some commented that cell level data may indicate non-toxic gases, but there are toxic products in batteries not found in cells that may produce toxic gases or vapors. The G-27 test follows only a gas generation test, not a toxic or flammable analysis test. The group questioned whether this level of granularity is necessary.
13. Some felt that the maximum temperature change for the least reactive category (A or B in the flow chart) should be limited to a change of 100 °C instead of 150 °C. Their point was that initiation already occurs between 150 and 200 °C, and that the existing condition would allow temperatures up to 350 °C. Others felt that if a cell does not propagate, there would be expectation of an increase in heat. If a cell/battery propagates, the temperature change would be irrelevant. Heat production would be seen in the results of the test. If removed from consideration, Category A and B could require some level of packaging to ensure heat does not impact the outer packaging.
14. Participants discussed the value of the discussion and the flow chart. Some questioned whether this effort was necessary given that existing data can demonstrate whether cells/batteries propagate, etc. It was explained that the granularity of the tests and classes allows for decisions to be made as to what is “worst case” and what can be considered representing a reduced risk, and therefore may be eligible for reduced requirements from “worst case”. But the flow chart can be simplified by recognizing similar hazards.

15. Some participants suggested that the group could assume all gas production was toxic and packing provisions could be introduced to address. In this approach, only volume would be considered. Thus, the group could identify a threshold volume of gas above which the gas hazard could be considered (for toxicity or flammability). Some commented the volume should be significant so that average cells would not be overclassified.

16. The group addressed the generation of HF. While HF is produced during the venting of lithium ion batteries, the volume and concentration of HF is well documented in existing data and HF would not represent a significant percentage of the gas produced. For this reason, if the volume of gas is limited, it is appropriate to assume the volume of gas would not create a toxic atmosphere due to HF production.

17. ***Based on the discussion, the group agreed that differentiation between toxic and flammable was not necessary. Therefore, the “subcategories” of 1 and 2 in the flowchart is also not necessary.***

### **Cell initiation and cells that do not initiate**

18. The group discussed how to deal with cells/batteries that do not initiate through the existing test method (heat induction or heater tape). Should additional initiation methods be considered? Some felt the complications created by other methods are too varied. Instead, the group should agree to a single method using the heat induction. While the group agreed in general, some participants felt that the initiation temperature should be higher than 200 °C. It was argued that the initiation temperature should be related to the maximum energy potential contained within a cell.

19. It was suggested that the Explosives Test Series 6(c) could be used to determine as the bonfire test for J and K. However, others questioned whether such a test would provide any value. If propagation would not occur, is there a reason to conduct the bonfire test? Existing data could be used to make a hazard determination. It is also reminded that the approach used in the G-27 standardisation committee about the maximum applicable energy could be used to define a cap in the heater abuse process. The group generally agreed to remove the bonfire test from the flowchart. Instead, these cells could be handled by exception (professional judgement, additional data, usage of the technical knowledge of the flammability of the electrolyte/cell materials).

### **Cells that rapidly disassemble**

20. The right side of the flowchart involves cells that rapidly disassemble but then create a situation in the test where the full conditions of the test are not maintained. Ejection of the core represents a projection hazard, but can/should that be measured? Some participants suggested that a cell that rapidly disassembles would automatically fail the propagation test. This would lead to improved cell design. However, others pointed out that “rapid disassembly” is currently used in UN 38.3 and in other locations in the Model Regulations. Therefore, the group may still need to address even if the right side of the flowchart is removed. In practice, the test set-up of the propagation test is now including a lid, that should enable to make a conclusion of the test in most cases. In conclusion, the group agreed that cells that rapidly disassemble would be considered to either propagate according to the propagation test result, or will require additional criteria to confirm classification. Thus, the right side of the flowchart will be eliminated.

21. ***As a result of the discussion, categories A-I, J and K would remain. Others would be dropped.***

### **Cell/battery connection**

22. The group considered applying the same concepts of cell testing to battery testing. Such a flowchart may have additional complications but would not create new

categories/classes. Participants were reminded that this approach is independent of packaging. Once classifications are determined, additional consideration will need to be made on how to properly pack each of the classifications. The battery classification flowchart is based on the results of the cells. If data is not available on the cell, a separate flowchart for batteries would be needed.

### **Next steps**

23. Next meeting should be used to clarify and combine the cells and the batteries classification trees, according to this meeting decisions. This should also clarify the possible ways to use the classification tree (flexible entry points either as single cell or as battery).

24. A second topic for the next meeting is the need to verify that the existing test protocol can enable the collection of the required data for classification according to the proposal. This would go together with the clarification of the test conditions for cells and batteries, following the results achieved in December 2019 report.

### **Schedule of next meetings**

25. Next flowchart subgroup will be planned for either 16 or 17 November 2021

26. Further meeting following UN Meeting – December 2021 (to be confirmed).

## Annex II

### UN Informal Working Group on cells and batteries test protocol

#### Draft test protocol following the April 2022 meeting

##### 1. Rationale

Description of a test protocol for the determination of the hazardous properties of lithium cells and batteries in case of thermal runaway initiation and propagation.

General chemical or electrical properties and related hazards (such as high voltage batteries hazards) are not considered in this protocol.

Abusive conditions rationale for thermal runaway initiation: The propagation and gas tests are based on the initiation of the thermal runaway of the cell or battery by an abuse method representing the best compromise between the simulation of the internal short circuit, the control of the implementation and the reproducibility of the reaction. The selected method is the application of heat on the surface of the cell or battery by a controlled heater to abuse a localized zone of typically 1 cm<sup>3</sup> (0.1 cubic inch) until the thermal runaway reaction is initiated inside the product.

##### Cell Classification

No testing is mandatory for classification of the Li-ion or lithium metal batteries. By default, the hazards are identified as the one of representative products (worst case) of typical Li-ion or lithium metal batteries with common chemistries: The propagation is happening from cell to cell with a rate of 2 seconds per cell, the gas emissions can contain up to 50 % hydrogen and 100 ppm HF with a volume of 500 l/kg of cell. The fire risk is considered applicable in all cases.

For the demonstration of a different set of hazardous properties at cell level, a Propagation test (test 1) and a Gas Volume test (test 2) will need to be verified.

Test 1: The propagation test is applicable to 6 [4?] cells in a row, in ambient air, on undischarged primary cells or batteries cells or 100 % SOC secondary cells or batteries, for the initial classification, or at a specified SOC for specific transport conditions at a reduced SOC.

Test 2: The gas test is applicable to a single cell or battery, in inert atmosphere at 100 % SOC.

The gas test addresses at least the determination of the volume. In case the test includes a gas composition analysis (optional test 3), then it can also address the question of flammability and toxicity. Only one test is required to determine the properties the gas.

The test setup is defined to verify the worst case conditions of propagation risk and gas or flame emission risk.

The distinction between lithium metal and lithium ion remains: through existing UN numbers or some logical evolution in the UN Model Regulations.

Why keep distinction between lithium metal and lithium ion? For cells that are flammable and propagate, there is still a big difference between the hazard presented by a lithium metal and a lithium ion cell. Metals tend to burn hotter, propagate quicker and throw sparks. Thus, present a much greater hazard.



## Battery Classification

Default classification is the same as the cells within the battery, which would be the quantity of gas from the cell times the number of cells in the battery. For the demonstration of a different set of hazardous properties, a battery test can be run to determine propagation, and actual quantity of gas (test 4).

The distinction between metal and ion remains: that is UN 3090 for Metals and UN 3480 for Ions.

## 2. Scope

All chemistries of lithium cells and batteries

## 3. Test procedure for cells and batteries

### 3.1 Device Under Test (DUT)

The DUT are cells or batteries, according to the definition of MTC 38.3.

The State of Charge (SOC) shall be verified at 100 % SOC or undischarged primary cells or batteries, less than 72 h before test. The following IEC battery standards provide guidance in determining the capacity of secondary cell or battery: IEC 61960-3, IEC 62133-2, and IEC 62660.

The DUT shall be maintained at ambient temperature for a period of time necessary to reach a homogeneous stabilized temperature, as measured on the external casing of the cell or the battery, of  $20 \pm 10$  °C.

### 3.2 Test instrumentation and equipment

#### 3.2.1 Thermocouples (all tests)

The thermocouple shall be of type K or other suitable type to measure temperatures up to 600 °C. The precision shall be equal or better than 2 °C, the time response below 2 s. The temperature recording system shall be used at a minimum frequency of 1 Hz.

#### 3.2.2 Heater (all tests)

The heating source shall be capable to maintain a heating rate of  $15 \pm 10$  [5] °C/min between the initial a temperature and 250 °C minimum. (Rationale: the measure of the hazards will be mainly based on the consequences of the propagation, and less influenced by the initiation cell).

The size of the heater shall be of maximum 5 [or less?] cm<sup>2</sup> and 20 % of the cell surface (except for button cells and cells with surface below 1 cm<sup>2</sup>, where the heater can be as large as one face). (More test data needed for cells with thick can to specify the maximum size of heating rate). In case the criteria for heating rate cannot be verified or achieved, then a second criteria could be based on the maximum heat transferred to the next cell (based on the cell temperature).

#### 3.2.3 Thermally insulated container (only for cell propagation test)

A thermally insulated container shall be designed to tightly maintain the 6 cells in a row. The container must have 6 sides to maximize heat containment. The container shall have the required mechanical robustness to contain all mechanical ejections, including through the lid, but allow for gas exhaustion. See figure (typically holes or slits on the lid or on one side shall enable the gas exhaust).

The insulative material shall have a thermal conductivity below 0.3 W/m.K with a minimal thickness of 5 mm. Insulation material shall not melt or decompose below 800 °C.

The container shall be equipped with a system ensuring the compression of the cells in the direction of the row, with at least 1 kg force. This pressure shall be controlled before test initiation.

#### 3.2.4. Equipment to detect flammability of gas (for all tests)

Laboratories can propose an equipment for the testing the gas flammability (by test instead of composition). Usage of a sparking system, burner of gas, installed on a gas exit of the thermally insulated container: to be defined. To be preferred to the chamber test, which will be applicable in the gas volume test. Issue of gas velocity at the gas exit: may require an additive "dilution and accumulation chamber" to conduct the gas and test flammability.

Sparking in a chamber SAE AS6413: the chamber should be smaller than in the standard because limited number of cells? The sparking system can be communicated.

#### 3.2.5 Chamber for gas volume measurement (only for gas volume test)

The chamber for gas volume measurement shall be a tight enclosure, filled with inert gas (nitrogen or argon in case of already demonstrated flammable gas), or air (to demonstrate the absence of flammability) enabling to measure the gas volume released in the absence of combustion, thanks to a pressure gauge, or a valve with volume measurement.

The chamber size will be determined based on the size of the DUT and the potential maximum volume of gas released.

The chamber shall be equipped with a gas temperature measurement.

Option 2: the chamber will be equipped with a system enabling to take representative samples. Equipment specific properties to be described here?

#### 3.2.6 Camera for flame detection and recording (for the propagation test)

### 3.3 Test set up

#### 3.3.1 Propagation test setup

##### 3.3.1.1 For cells

The test is applied to [6 ] [4?] cells (rationale: the hazards measured on the final 4 cells are more representative of the real self-propagation, and less influenced by the initial triggering conditions).

Each cell is equipped with at least one thermocouple. The position of the thermocouple shall allow to record the representative cell temperature increase, with minimal influence of the temperature of cells having previously reacted, or influencing the heat transfer between cells (see figures for cylindrical and pouch/prismatic cell format).

One cell shall be equipped with a heater and a dedicated thermocouple for the heating rate control. The heater will be placed in the centre of one main surface of the cell, with minimal influence on other cells. This thermocouple shall be placed at a distance of  $10 \pm 5$  mm of the side of the heater.

The initiation cell shall be placed at one end of the row, with the heater on the opposite side of the row. All other cells will be placed side by side, with the larger side used as the contact surface, or the longer side for cylindrical cells. The compression of the row shall be verified.

The video recorder shall be placed in a way to detect the potential emission of flame through the vents of the thermally insulated container.

##### 3.3.1.2 For batteries

Batteries will act similarly to packaged cells. For that reason, the battery could be considered a package, and testing is conducted in this manner. When the purpose is the demonstration that the battery does not propagate to other batteries, this test would be sufficient.

Temperature measurements on the outside of the casing are acceptable.

The rationale is that even if cells propagate within the battery, the battery casing could prevent enough heat from escaping and igniting combustible materials or adjacent batteries. The battery test would be to determine if enough heat is generated on the external surface of the battery that could lead to propagation of adjacent cells or other packing materials. Provisions noted in P911 for damaged/defective cells would be an acceptable pass criterion (no temperature above 100 °C or a momentary spike above 200 °C).

As this is a propagation test, gas production would not be a consideration at this point in the protocol.

For placing the heater: best appropriate method to heat one cell on a battery edge. The selected cell should be the one providing more risk of propagation. Other equivalent ignition methods may be applied if the heater cannot be applied (overcharge of one cell, use of a laser, use of a specially prepared cells with internal short circuit system, ...)

For placing the thermocouples, representative positions for each side of the battery should be selected.

### 3.3.2 Gas volume test set up

The test is applied to one cell.

The cell shall be equipped with a heater and a dedicated thermocouple for the heating rate control. The heater will be placed in a way to directly heat the cell internal active material. This thermocouple shall be placed at a distance of  $10 \pm 5$  mm of the side of the heater.

The cell shall be placed vertically in the chamber, and the chamber filled with inert gas (or air if non-flammable gas)

By difference to the propagation test, the conditions for heating should be closely followed to avoid influence on the amount of gas generated: heating rate of  $15 \pm 10$  [5] °C/min between the initial a temperature and 250 °C minimum.

Option test 3: additive test setup conditions for the gas composition measurement (postponed)?

Case of the gas flammability determination: need to propose protocol: reference to UN test? Combined in a single test?

## 3.5 Tests conduct

### 3.5.1 Propagation test

All equipment shall be set to register the required information for the determination of the measured criteria.

The DUT shall be heated at a rate of  $15 \pm 5$  °C [10 °C] per minute, based on the measure of the control thermocouple. The power of the heater shall be controlled manually or electronically to maintain the heating rate constant during the whole test duration. The heater power shall be cut off when a thermal runaway is detected (detection of an increase of temperature slope without increase of the heater power (set a self-heating minimum criteria), or when the total energy used by the heater is exceeding the heated cell electrical energy content (with a potential margin to be discussed or check what's happening in the case of continuous heating as another option).

After cut-off of the heater, the DUT will remain under recording conditions for 3 hours (in the case of absence of an observed thermal runaway).

### 3.5.2 Gas volume analysis

Seal and evacuate the test chamber to approximately 0.2 psia:

- Add nitrogen (or air if non-flammable gas) into the chamber to bring the pressure back up to 14.7 psia.
- Activate the heater until thermal runaway occurs.

- Allow the chamber to cool to its initial temperature.
- Use the change in pressure caused by venting to calculate the volume of gas emitted (assume ideal gas).

Gas test conduct: Optional test 3: additive conditions for the conduct of the gas composition measurement **to be defined later?**

- Proposal: fill the chamber with nitrogen to 20 psia.
- Once the chamber again cooled to its initial temperature, vent the chamber into a gas sample bag or analyser.
- Convert gas concentrations to determine the concentrations of the gases if they had not been diluted.

### 3.6 Tests repetition

Three similar tests shall be run. The more severe criteria measured over the 3 tests shall be reported as the DUT hazard measurement criteria.

### 3.7 Criteria measurement and recording

The following criteria will be measured and recorded:

#### For the propagation test

##### 3.7.1 Thermal runaway propagation hazard

For cells: The temperature of the cells in the row will be used to detect the propagation of the thermal runaway. In case of propagation, the time difference between two successive thermal runaways in the row (based on the detection of the maximum temperature reached by each cell) will be measured. The average propagation time will be calculated based on the average of all the time differences measured during the 3 repetitions of the test.

For batteries: the propagation inside the battery will be measured in the same way as for the cells. Provisions noted in P911 for damaged/defective cells are an acceptable pass criterion: no temperature above 100 °C or a momentary spike above 200 °C.

##### 3.7.2 Flame hazard

The video recording of DUT will be analysed to detect the presence of flame during the test or not.

##### 3.7.3 The temperature hazard

The maximum temperatures measured during the test for each cell shall be recorded. To avoid erratic measures (such as intermittent record of flame temperature), only the maximum temperatures presenting a consistent value during at least two seconds shall be recorded.

#### For the gas volume test

##### 3.7.4 The gas volume hazard.

The pressure and the temperature of the gas shall be recorded, and the volume of gas ejected shall be calculated.

**Option 2: additive list of criteria and methods for the calculation of the gas composition?**

Annex III

Table of tests - Stage 1

			Ineris	BAM	Transport Canada	FAA	Fulcrum	UL	LG
<b>Propagation test + flammability</b>									
	Li-ion NMC	Large Pouch	4, 0 repro (with BAM)	with Ineris					4-6, 3 Rep
		Small pouch	4, 1 repro						
		dates	June						August September
	Supply?	Prismatic	4, 1 repro (supply)?		4-6? Rep?				4-6, 3 Rep
		dates	June		September				September
		button cells				4-6, 3 Rep		4-6, 3 rep	
		dates			September				
		cylindrical		2-3, 3 rep		3-6, 3 Rep			4-6, 3 Rep
		dates		July		September			August September
	Li-ion LFP	small cylindrical		2-3, 3 rep (18670 and 26650)				4-6, 3 rep	
		dates		July-August				May	
		small pouch		Possible?					
		dates							
	Li ion TBD?	TBD							
		dates							
	Li metal LISO2	small cylindrical				4-6, 3 Rep	4-6, 3 Rep		
		dates				September	June		
	Li metal LiSOCl2	small cylindrical		1 (4-5 for 3 Ah)		3-6, 3 Rep			
		dates		september		September			
	Li metal Manganese (button)								
<b>Gaz volume test</b>									
	Li-ion LFP	small cylindrical		1, 3 rep				1, multi SOC	1, no Rep
		dates		May-June				April	August
	Li-ion NMC	prismatic	1, no Rep (with BAM)	with Ineris				Test on different times	
		dates	June						
		Large Pouch	1, no Rep (with INERIS)						1, no Rep
		Small pouch	1, no Rep (with INERIS)					1 multi SOC	
		dates	June					April	August
	Li metal LiFeS2	cylindrical				1,3 rep		1, 3 rep	
		dates				June		June	
<b>Batteries test ( + gaz flammability?)</b>									
	Li-ion NMC	small batteries			Possible test, depending on supply	std test equiv to G27?	1, 3 rep	available data	
		dates			September	July/August?	May depend on procurement (June)		
	Li-ion LFP	small batteries		1, rep?			1, 3 rep	available data	
		dates		Sept-Oct				May	
	Li-ion	large module → yes if you	1, no rep						
		dates	June -july						
	Li metal	cylindrical cells							
		dates							