

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

Sub-Committee of Experts on the Transport of Dangerous Goods

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Item 4 (b) of the provisional agenda

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

## **Report of the informal working group on hazard-based classification of lithium batteries and cells on its third session (5-6 December 2018)**

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

#### **Introduction**

1. Claude Pfauvadel (France) and Dave Brennan (IATA) welcomed participants to the 3<sup>rd</sup> session of the 2017-2018 Informal Working Group on Lithium Batteries (working group) and presented the tentative agenda for the meeting. The Chairman explained the purpose of the meeting was to continue discussion the proposed system of identifying and categorizing inherent hazards associated with lithium batteries. Based on lessons learned and experience gained, the Sub-Committee issued a mandate to the working group to consider a hazard-based system to classify lithium batteries and cells for transport. Such a system would include determining the inherent hazards represented by lithium batteries and the types of reaction that may result from accidents or abuse. Destructive testing should be considered.

2. For the 3<sup>rd</sup> Session, the group was requested to:

- (a) Consider the issues identified from the lunchtime working groups at the 53<sup>rd</sup> Session of the UN Subcommittee (UN/SCETDG/53/INF.66). These issues include:
  - (i) A definition of propagation must be established;
  - (ii) The group must consider how the temperature of propagation should be evaluated
  - (iii) The method for initiation needs to be better defined;
  - (iv) The issue of projection hazard should be considered and placed either in the flow chart or as a general condition of concern;
  - (v) When considering GAS HAZARD, differentiation may be needed to determine toxicity and explosive atmosphere of gas as well as volume;
  - (vi) The group should determine how to address bias of test methodology regarding the size of the cell. (i.e. is the hazard represented by larger cells or batteries overly emphasized due to size alone);

- (vii) How does cell propagation relate to battery propagation?
    - a. At which point is it possible to stop testing and assign classification by reasoning?
    - b. Many of these topics were summarized in UN/SCETDG/54/INF.42 and were provided to the UN Subcommittee at the 54<sup>th</sup> Session by France and RECHARGE
  - (viii) Provide additional presentations or data to support the discussion.
3. Presentations were distributed to the group prior to the meeting and are available from the RECHARGE Website: <https://www.rechargebatteries.org/3rd-un-informal-working-group-2017-2018-lithium-batteries-classification>
4. In addition, all historical documents related to the current Informal Working Group are also posted on the RECHARGE Website.
5. The working group took note INF 42 and reviewed the listed topics.

## Definition of propagation

6. The definition of propagation was reviewed in INF.42, Annex 1:
- (a) Propagation – Transfer of heat energy from a cell experiencing thermal runaway that results in thermal runaway in one or more adjacent cells or batteries.
  - (b) The criteria for propagation is defined in INF.42, Annex 2 as:
    - (i) The witness cell vents, leaks or goes into thermal runaway;
    - (ii) the temperature of the witness cell increases abruptly;
    - (iii) the temperature of the witness cell is higher than 170 °C.
  - (c) Other definitions critical to the discussion:
    - (i)  $T_{\text{ignition}}$  – the temperature (°C) at which the temperature of the cell starts to increase faster than the temperature set by the thermal pad.
    - (ii) Thermal Runaway – Uncontrolled increase in the temperature of a cell or battery driven by exothermic process.
7. Some participants questioned whether leaks or vents should be considered propagation. It was argued that the concern regarding propagation is that adjacent cells would enter into thermal runaway. Vents and leaks that do not lead to thermal runaway in adjacent cells may not be critical. The tests proposed in INF.42, Annex 2 demonstrate a potential test example. The test involves three (3) cells (Trigger cell, transfer cell, witness cell) where the result of the witness cell is monitored. Vents and leaks are normal safety conditions to prevent over-pressurization. Often, mass loss is expected. If leaking and venting is considered a failure of the propagation test, cell designers may design cells to not vent until higher temperatures are reached.
8. *The group agreed that leaks and vents that do not lead directly to a propagation of the witness cell should not be considered an indicator of propagation. Gas generation is considered separately from propagation. Therefore, leaks and vents should not be mentioned in the criteria for propagation.*

9. In reviewing the other criteria for propagation, it was noted that an abrupt increase in temperature of the witness cell may not necessarily lead to a thermal runaway. To the contrary, an abrupt temperature change may not be large enough to lead to an unsafe condition. Further, the normal failure temperature may be battery-chemistry dependent. As a result, it might make more sense to include language such as “the temperature of the witness cell increases to within 10% of the normal failure temperature of the cell based on chemistry”. Others felt that it is more critical to monitor temperature increases from internal processes. However, these measurements are difficult to monitor and may not be consistently reproducible from lab to lab. The intention of the test is to create a controlled environment where the heat introduced to the system within the “box” is strictly measured, the trigger cell is taken to thermal runaway, and then the reaction of the witness cell is monitored. It is assumed more than 3 cells in the box would create a heat sink and equilibrate the temperature across all the cells instead of applying a worst-case condition to the witness cell.

10. It was suggested that the  $T_{\text{ignition}}$  condition could be applied as a condition to the witness cell as well. If the temperature of the witness cell increases faster than the temperature being introduced to the test, this could be considered a condition of failure.

11. The Chairman reminded the working group the intention of the testing scheme is to review the inherent hazards associated with lithium batteries and develop a testing scheme to enable categorization of overall hazard risk.

12. Concerns were voiced that the test presented would be very difficult to reproduce as some interaction with the environment is inevitable, and it is difficult to understand how the transfer cell will affect the system. For this reason, some questioned whether a “screening” test could be conducted first to determine if the cell/battery design is capable of creating a dangerous evolution of heat. The Chairman explained the test system proposed measures multiple conditions and hazards, and propagation is only one of the many hazards being assessed. Other hazards include fire, gas production, and maximum temperature reached. But identification of initial test parameters is critical. At least 3 cells are required to conduct the test. The trigger cell would be heated. The transfer cell may receive heat from the heater used to initiate the trigger cell. Therefore, the transfer cell is needed to isolate energy from the heater to the witness cell. The witness cell is then monitored for reaction.

13. The US FAA Testing Lab shared data they have collected related to similar efforts:

- (a) Report DOT/FAA/TC-16/37 entitled: Summary of FAA Studies Related to the Hazards Produced by Lithium Cells in Thermal Runaway in Aircraft Cargo Compartments, (July 2016), is a compilation of test data and results from projects conducted by the Fire Safety branch over the past 15 years. <https://www.fire.tc.faa.gov/pdf/TC-16-37.pdf>
- (b) Report DOT/FAA/TC-16/17 entitled: Fire Hazard Analysis for Various Lithium Batteries, (March 2017), is a report of fire test conducted on lithium ion cells (pouch, cylindrical) and lithium metal cells (cylindrical) of various cathode chemistries and sizes to evaluate their failure effects. <https://www.fire.tc.faa.gov/pdf/TC-16-17.pdf>
- (c) Technical Note DOT/FAA/TC-TN16/22 entitled: Energy Release by Rechargeable Lithium-Ion Batteries in Thermal Runaway (April 2016), and its publication: Richard E. Lyon, Richard N. Walters. “Energetics of lithium ion battery failure.” Journal of Hazardous Materials 318 (2016) 164-172. It is on the energy released by failure of rechargeable 18650 cylindrical lithium ion cells/batteries measured in a bomb calorimeter for four different commercial cathode chemistries over the full range of charge using a method developed for this purpose. <https://www.fire.tc.faa.gov/pdf/TC-TN16-22.pdf>

- (d) <http://www.sciencedirect.com/science/article/pii/S0304389416306008>

## Philosophy of lithium battery classification

14. The Chairman provided the working group summary of previous discussions and conclusions. As a basis, the diagram in INF.42, paragraph 5 provides the visual logic of the categorization of cells based on criteria that is measured from tests. Thus, the result of the test is data, but the data itself does not mean the cell is or is not safe. It means that the data would then need to be compared to the criteria to determine the nature of the hazard, similar to how explosives are classified, and then the level of packaging can also be determined. The goal of the working group is therefore to produce a classification scheme and testing methodology that can be presented and adopted by the Subcommittee.

15. Several participants felt that additional granularity was needed for flammable and toxic gas production and hazard. But as this data is difficult to collect and limited data is currently available, it is challenging to be more prescriptive at this time

16. *It was noted that data on lithium metal batteries has been sparse but is now being collected and can be shared with this group in the future.*

17. It was emphasized that additional data is still necessary to refine the flow chart and logic in INF.42, paragraph 5, and that the effort for the working group meeting should be directed to confirming the logic of the flow chart, and then to consider the level of acceptability of hazards (propagation, fire hazard, gas production, and maximum temperature reached).

18. The working group discussed whether explosion or smoke production should be considered. Projection hazards from the cell are critical if they damage other cells or create additional hazards. But explosion as a criterion is a product of gas production and should be covered under the Gas Hazard criteria. The inherent bias of certain tests to cell size must also be considered. Certain concepts, such as heat production can be dependent on cell size. The larger the cell, the more heat that can be released. Thus, the measurements for these data points could be given in rates (e.g. heat released/mass \* time). However, the concern may simply be the total amount of heat released over a given time period. The heat release rate may be size independent. The group was divided on whether the heat release rate was relevant except in terms of the propagation rate. RECHARGE shared their previously collected data that shows while the total heat released is increased with battery size, their data shows that the max rate of heat release is not size dependent. Larger batteries take longer for cells to propagate within the battery. It was noted that the concept of heat release rate will be different for cells and for batteries. For example, the heat release rate from a cell is independent of adjacent cells. But in a battery, the heat release rate may lead to an increase in the propagation within the battery between cells.

19. The Chairman pointed out that the origin of this effort was based on testing from Ineris that compared the result of fires involving lithium batteries and non-dangerous goods. In these tests, the propagation of a fire involving aerosols and even plastic packaging was faster than the propagation of lithium ion batteries in packaging. The working group is therefore attempting to properly determine intrinsic hazards of lithium cells and batteries. The original documents are listed below:

- (a) <http://www.unece.org/fileadmin/DAM/trans/doc/2016/dgac10c3/UN-SCETDG-50-INF31e.pdf>
- (b) <http://www.unece.org/fileadmin/DAM/trans/doc/2016/dgac10c3/UN-SCETDG-50-INF31-Add.1e.pdf>

- (c) <http://www.unece.org/fileadmin/DAM/trans/doc/2016/dgac10c3/UN-SCETDG-50-INF31-Add.2e.pdf>

20. The working group agreed that the classification system being discussed is independent of mode or packaging. It was discussed that this concept may have applicability outside of transport, such as in storage or usage. But the concept must be developed first.

21. The origin of the propagation rate was in relation to cells that are then placed into a battery. A cell that propagates faster is likely to lead to a more aggressive propagation within a battery. Given several questions regarding the goal of the group, the flow chart and criteria were further discussed, and the group conceded that categorization has not been fully developed. In consideration of propagation rate, the working group were divided on whether the rate was relevant or needed for granularity. Some participants felt the speed of reaction was needed to determine the voracity of a reaction. Others commented on the difficulties with measuring the rate or determining the criteria.

(a) *Why was 10 min chosen? It was estimated that above 10 min, the rate of propagation may not be fast enough to cause a major concern.*

(b) *What would be the impact to classification?*

22. It was suggested, and the working group agreed, that if a classifier did not want to test, then the worst-case or highest risk category could be applied.

23. Some participants questioned the need in the test to place the cells side-by-side. It was explained that this scenario is designed to be a worst-case test to measure the inherent hazards of the cell. While the hazard can be reduced or eliminated through packaging, the mandate from the Subcommittee is to identify a system independent of packaging or packing methods

24. *The working group agreed to keep the idea of propagation speed, but it would be verified further with data and examples review further to determine if it is needed.*

25. Some delegations questioned what the dashed boxes in the flow chart signified. The dashed boxes are assumed to be represented by the previous hazard and is included in the worst-case condition. For example, if a cell propagates and a fire results, then a gas hazard and high temperatures are assumed to exist. Therefore, there is no reason to further define.

## **Discussion of high temperature hazard**

26. The value of 170 °C is identified as the auto-ignition temperature of paper. Therefore, if the heat produced by a cell exceeds this value, it creates a condition that could lead to a reaction outside the cell. This value is already referenced in 38.3.4. A high temperature hazard is represented when the difference between the maximum temperature and the initiation temperature is more than 150 °C. It is measured on the Trigger Cell because the Transfer and Witness cell would not have reacted. If a cell propagates or fire results, the high temperature hazard is assumed to exist without considering maximum temperature. It was acknowledged the location of the thermocouple on the abused cell has an impact on the test result, and that location may need to be dependent on cell size and shape.

27. The Chairman asked whether an additional bonfire or extreme test would be required to provide a “fully safe” battery that represents no risk? The working group discussed that the currently proposed test includes a heating of the cell to 200 °C for 1 hour and whether this already covers such a condition. It was explained that the 1 hour was chosen to allow for a homogenous distribution of heat in the cell, and that longer periods would lead to

unintended heat in the system. Participants noted that the 1-hour requirement is already very difficult.

28. *The working group also discussed the possibility that if all effects of the testing were contained within the package, that a full exception could be provided. The working group was invited to submit suggestions or ideas in this area.*

## **Discussion of gas hazard**

29. The working group discussed the difficulties of measuring gas hazard, particularly distinguishing between flammable, non-flammable, and toxic gases, and whether opacity is a consideration. Some participants argued that flammability should be based on concentration rather than volume. However, others note that if we were reviewing the inherent concentrations of the gas, then the concentration was valid. But in this case, we are reviewing the inherent risks of the article (the cell). Therefore, the production and volume provide enough data to qualify the level of gas hazard. The toxicity and flammability can be determined based on calculation of reactants, but actual measurement is very difficult. Participants shared that state of charge and heating rate make a significant difference in gases released, volume produced, and concentration. Due to these variabilities, the test methods and result criteria are simplified to assume the gas is both flammable and toxic. In the case of fire in the cell, the gases emitted will combust. Although the gases will change, they are still assumed to be hazardous. Thus, the gas hazard is present. When no fire is present, it is assumed that much of the gas released (based on previous experience) is hydrogen. Thus, even if additional gases, like HF, are produced, the gas can be assumed to be flammable and toxic.

30. Some participants shared experience with venting of cells during testing. The volume of gas appears to be directly related to the size of the cell (volume of electrolyte). The generation of fire is near 100% with lithium metal cells but is very sporadic with lithium ion cells. For this reason, nitrogen is often used in the test vessel to eliminate the fire hazard for testing. There is no hazard when the quantity of gas is small. However, it is not simple to completely classify the gases. Thus, when larger quantities of gas are produced, we should indicate a gas hazard exists. Measuring the nature and quantity of each gas produced is not currently captured by the test. But if it was demonstrated that a certain cell/battery chemistry cannot produce a flammable gas, then it may be possible to consider that cell as safe. The group concluded that gases emitted may be flammable or non-flammable, but it was agreed that all gases emitted are likely toxic. This information could be useful when considering resulting atmospheres in cargo transport units or vehicles.

31. The working group also questioned whether the condition of fire or no fire is necessary, or could it be replaced by determination of whether the gases emitted are flammable or not. This would simplify the flow chart and address inconsistent fires depending on concentration.

32. *The working group was encouraged to provide comments as to whether the specific gases emitted could be measured, how to assess the gases, and determine whether it is necessary to differentiate between flammable and non-flammable gases.*

## **Discussion on projection/disassembly hazard**

33. If disassembly of the Trigger cell occurs during initiation but before propagation, then it is impossible to determine propagation of the witness cell as the test is permanently interrupted. Some participants noted they currently interpret a cell that disassembles prior to

thermal runaway as a cell that propagates. But it was noted that size and chemistry of the cell may impact the result.

34. *The working group was encouraged to provide additional testing results to confirm or refute whether all cells that disassemble would propagate if the reaction was contained.*

35. The Chairman suggested the initiation method may be a cause of the disassembly before propagation. This topic will be considered on Day 2.

## Summary of working group mandate

36. For the benefit of new participants to the group, the Chairman summarized the work completed to date and the structure of the discussion. The requirements in the UN Manual of Tests and Criteria, Section 38.3 are identified as classification requirements for lithium batteries. However, these are really just tests that are intended to confirm that the batteries are capable of passing abuse conditions in transport. This system is not a pure classification system, but instead is a cell/battery performance requirement.

37. This system currently combines all lithium battery technologies in the same level of hazard. With other hazard classes, for example flammable liquids or corrosive materials, the level of hazard is defined by criteria that measures the relative hazard presented. Those systems result in packing group categories: PG I represents a high danger, PG II represents a medium danger, and PG III represents a low danger. Upon recognizing the current testing system did not adequately distinguish the level of hazard or even the inherent hazards lithium batteries may present, the UN Subcommittee requested the Informal Working Group on Lithium Batteries identify the inherent hazards posed by lithium batteries and develop a system to categorize the level of hazard posed.

38. The working group initially met in Spring 2017 in Montreal to identify the inherent hazards posed and determine what data may be needed to progress the work.

39. In the Fall of working group, a smaller group gathered to review testing data that was available for lithium batteries in order to sort the information and then present it to the working group. In December 2017, the 2<sup>nd</sup> meeting of the working group met in Geneva, Switzerland. At this session, data was reviewed, inherent hazards were identified and the list refined. It was determined that propagation was not a hazard, but it immediately led to the production of several hazards. Therefore, propagation was included in the testing scheme. The group also expanded the discussion to include a possible testing scheme, thought about how a single test or series of test could be used to collect relevant data, and indicated additional areas where data is needed.

40. The Chairman explained that the working group continues the work that was initiated in 2017. But the goal is to provide a refined classification philosophy and testing scheme to determine the level of intrinsic hazards posed by lithium batteries. Packaging is not intended to be reviewed at this step as packaging would attempt to mitigate inherent hazards. While such mitigation is important and may provide safe transport conditions, these topics will only be addressed after the inherent hazards of cells and batteries are defined and categorized.

41. A chronological list of related documents and reports is included in Annex 1 to this report.

42. It was clarified that the working group will address both cells and batteries. Initially, the concept of cell categorization is being reviewed. When batteries are considered, the process becomes increasingly more complicated, dealing with both completed batteries as well as component cells or batteries that may never be transported. Transport conditions for batteries contained in equipment would not be considered for classification but may

eventually be considered for hazard mitigation and could lead to appropriate exceptions when the inherent hazards of the cells or batteries are reduced. Further, the working group is not intending to define or limit the designs of cells or batteries, but instead to define categories of hazards and permit industry groups or standard organizations to modify cell or battery designs to mitigate identified hazards.

43. Participants discussed the fact that the new testing scheme is a complete revision of the current approach to lithium battery classification. It is recognized there will be an economic impact to industry, but this cost is balanced by an increased granularity to the hazards inherent to lithium batteries.

44. The Subcommittee works on a biennial cycle. The Subcommittee just completed work on the 21<sup>st</sup> Edition of the UN Model Regulations (or Recommendations). This document will be published in 2019 but will not be implemented by the modal bodies until 2021. Further, a large concept such as this system should not be presented at the last minute (December 2020) to the Subcommittee for adoption. The goal of the group could be to present information for consideration during the 2021-2022 UN biennial cycle, and adoption for the 23<sup>rd</sup> Edition of the Model Regulations in 2023. Realistically, this would mean that the provisions may not be implemented into the modes until 2025. If agreement within the working group can be reached more quickly, this would affect the dates estimated above.

## **Discussions on initiation of thermal runaway in a cell**

45. The working group discussed the challenges with initiating a cell and possible methods for reliably reproducing cell initiation. Several initiation methods are possible, but it may be that additional assessment is necessary to see if different methods affect the testing results.

- (a) RECHARGE discussed how the initiation applies to the currently proposed test scheme.
- (b) UL shared their experience with initiation during testing for the G-27 Standard development. They used both thick and thin heater tape but did not find any difference in test results between the two. Therefore, they preferred to use the thicker heater tape. The G-27 testing required temperatures to be held at 200 °C for 1 hour. The following conclusions were reached:
  - (i) No difference in performance of thin or thick heater tape
  - (ii) size of the heater tape did not matter but there were questions as to whether the larger tape heated adjacent cells.
  - (iii) 7-8 °F heating rate was found to be optimal for heating the cells
- (c) NREL provided a brief presentation on their device that may be imbedded in a cell to initiate a thermal runaway. To trigger the short circuit, the cell is heated to 57 °C. Wax in the device melts and leads to an aluminum to copper connection that provides a very efficient short circuit between the anode and cathode.
  - (i) It was noted that such batteries with the device installed would no longer meet the UN38.3 criteria. To move the cells, a competent authority approval with special packaging is used.
  - (ii) The device is initiated by heating the cell or battery in an oven. Heater tape is not necessary.

- (d) CATL presented a method of initiation that includes an external heater placed between a cell and an end plate in the battery. An insulator is placed between the heater and the end plate to ensure heat produced is directed to the cell and not the casing of the battery. The heater is powered by the Trigger cell itself. So the testing can be considered a closed system.
    - (i) Testing shows that more than 95% of the heat was transferred to the cell.
    - (ii) No additional energy needs to be applied to the cell.
    - (iii) Method is still under review and will be improved in the future.
    - (iv) Energy from the cell is consumed. Thus, when active, the SOC of the cell is reduced.
  - (e) The UK pointed out the initiation step is essentially a pre-screening to determine if cells can be put into thermal runaway. Therefore, they proposed simply conducting a cell-heating test where the cell is heated first to 50 °C and then to 200 °C for up to 1 hour. The temperature of the cell at thermal runaway could be measured.
    - (i) Based on the thermal runaway temperature, categorization could be considered.
      - a. Less than 50 °C could be Category 1.
      - b. Between 50 and 200 °C could be Category 2 or 3
      - c. Cells that do not go into thermal runaway but vent or rupture could be Category 4
      - d. Above 200 °C could be Category 5.
    - (ii) Categories A-C could then be tested for propagation.
    - (iii) Category D could be subject to additional tests to determine whether thermal runaway is necessary
    - (iv) Category E could then be classified as LITHIUM ION CELLS thermal critical temperature greater than 200 °C
    - (v) This approach would be prior to a propagation test.
  - (f) Other methods include:
    - (i) IEC 62133 – well developed and includes initiation test but only 4 countries recognize and highly debated.
    - (ii) Nickel particle – valuable but also highly debated.
46. Several participants suggested revised terms in the tests to make it clear to everyone.
- (a) Abused cell – renamed Trigger Cell
  - (b) Intermediate cell – renamed Transfer Cell
  - (c) *These minutes have been updated throughout to reflect this terminology change*
47. Initiation methods must be designed to be reproducible and induce a thermal runaway in trigger cells.
- (a) How do we make sure the trigger battery reacts or fails safe?

- (b) How do we make sure that if the initiation of the trigger battery does not produce a different result?

48. It was suggested that manufacturers should be able to review available test methods for initiation and chose the most appropriate for their particular cell. The working group agreed that alternate methods that are reliable and reproducible may be appropriate but should not be so specific that it prevents innovative ideas that can have the same result. The Model Regulations already include some similar language in a note in packing instruction P911 related to damaged defective batteries. But it was pointed out this language is very specific to damaged defective batteries and requires that packaging must be re-evaluated for each battery type. Thus, that language may be too limiting.

## **Initial data collection**

49. The US FAA proposed designing a system using 6 or more cells in a controlled environment, collecting data as presented in the CATL presentation. Different cell chemistries, design, and sizes could be tested. Such data that could be collected include:

- (a) temperature of initiation of trigger cell
- (b) max temperature of thermal runaway
- (c) temperature of initiation of transfer cell
- (d) max temp of runaway
- (e) max temp of the overall pack temperature
- (f) time to propagate
- (g) volume/identification of gas production

50. This data could be used to answer several questions:

- (a) How does the method of initiation affect the results?
- (b) Does the number of cells affect the results?
- (c) Do different chemistries affect the results?

51. It was suggested that two different kinds of cells should be chosen, then test at 2 or 3 different laboratories would test those particular cells plus several other kinds of cells. The result would be 2 common cell types tested and results from different labs, but also have a collection of additional cell types or chemistries. Data points could then be compared.

52. The common cells chosen should be designated to limit variability between laboratories. It was suggested:

- (a) 1 cylindrical and 1 pouch cell
- (b) same cell chemistry
- (c) same manufacturer
- (d) same state of charge

53. Test method should follow a specific test protocol with a heating rate.

54. The working group agreed to the following:

- (a) Test shall include 2 different cell types of identical design, chemistry, state of charge, manufacturer. PRBA offered to contact cell manufacturers and distributors to find a way to provide identical cells to all participating labs.

- (b) All labs participating shall follow the same test method for the 2 cells listed above *as well as any additional cell types they wish to test*. This would enable data collection on other cell types and expand the base knowledge for future discussion. Additional types to be tested should be coordinated with other labs so that redundant testing is not conducted other than the 2 common cells. If not all tests or data points can be collected by a given participating, the lab should collect the as many of the points as possible.
- (c) Results would be shared in a way that protects confidentiality of the manufacturer.
- (d) Details of the test methodology:
  - (i) 1 cylindrical and 1 pouch cell, same chemistry, same manufacture, same lot
  - (ii) External heater tape with a defined heating rate as initiation method.
- (e) Variations of testing methods could be presented using the same data collection points. Future proposals regarding different testing methods would only be considered if data presented is comparable using the same methods.
- (f) List of agreed conditions are identified in Annex 2.
- (g) *A select group who plan to participate in the initial data collection will meet outside the working group session to:*
  - (i) *finalize the details of the testing methodology*
  - (ii) *identify the data points to collect*
  - (iii) *define how to display/share the results*
  - (iv) *Plan for call by the end of March 2019 to be coordinated by France, RECHARGE and PRBA.*
- (h) *Participants interested in the testing aspect or in developing the detailed methodology are encouraged to notify Claude Chanson (RECHARGE) and/or George Kerchner to be added to the contact list. Additional information will be available from the RECHARGE Website noted above.*

## Discussions on “Additional tests”

55. Some questioned what additional tests would be applied when the initiation attempt fails. RECHARGE explained that additional tests are detailed in INF.42, paragraph 15. It was explained first that external heat is applied (during the initiation test). However, if external heat does not lead to thermal runaway, other initiation methods would be considered including producing heat internal to the cell. Participants shared that at 200 °C, you will begin melting of the separator and even electrodes. Thus, if no reaction is occurring through the initial reaction, some believed this creates a safe cell. However, others felt that an external heat of 200 °C did not mean that propagation will not happen, only that it will not happen based on the initial test. To ensure it is non-propagating, an additional abuse test such as an internal short circuit as described in paragraph 15, would be necessary to ensure it is not capable of entering thermal runaway. Alternate proposals are welcome but must be intended to attempt to induce a thermal runaway in the cell at all conditions.

## Discussion on batteries

56. The working group discussed how cell propagation relates to battery propagation. Is it necessary to retest a battery if component cells propagate? Some participants suggested that if component cells propagate, then the cells installed within the module or battery would also propagate. Is it necessary to retest a battery if component cells do not propagate? It was suggested that if cells are included in a small battery, then it is not likely to lead to a larger reaction as the battery design is likely very similar to the test conducted to determine cell propagation and no additional test may be necessary. However, if the battery is large, then an additional test to a module or battery may be required.

57. Some considerations on this topic include:

- (a) Is the condition in the battery more or less than the conditions in the cell initiation test?
- (b) Can the battery be designed to prevent propagation? How do we confirm no propagation?
- (c) Is there a need to change the initiation method?
- (d) Based on these questions, does the logic of the flow chart remain valid? What should be changed?
- (e) What is a reasonable size limit that can be assessed according to this scheme?
- (f) Are there existing tests or standards that can be used to determine categorization according to this scheme?
- (g) Are there other data points or considerations that should be applied for large batteries?
- (h) Can the packaging efforts at G-27 be considered for large batteries?
- (i) Are the existing definitions of large batteries appropriate to apply to this scheme and relevant testing? Do they need to be revised?
- (j) What is a benign cell, and if a benign cell is placed in a battery, is the battery benign?

58. The working group concluded that batteries are complex with additional casing, wiring, battery management systems, and other battery components that may impact propagation, fire, gas and heat generation. The scheme could be revised to say that for batteries, the logic of the flow chart could be applied with some limitations regarding size. Large batteries may not be required to be tested. But if not tested, the battery would be placed in the most restrictive categorization. That would permit additional testing if a different categorization is applied.

59. It was pointed out that initiation in a battery could occur due to other short circuits in the battery that are not related to cell initiation.

60. Some suggested that State of Charge should remain in the discussion as a possible safety mechanism. The Chairman pointed out that SOC cannot be considered until the testing scheme has been achieved and a direct link between SOC and battery propagation was confirmed.

61. The objective of the effort is to categorize the way cells and batteries react or if they react under certain abuse conditions. If the effort is successful, the result will provide an incentive for cell and battery manufacturers to create safer cells and batteries.

## Schedule of next meetings

62. The following timeline is suggested for future meetings
- (a) Feb/Mar 2019 - Call for testing methodology in Feb or March 2019
  - (b) July 2019 –
    - (i) INF paper to Subcommittee sharing current results
    - (ii) Lunchtime working group during the 55th Session to discuss current testing status and possible additional testing that remains
    - (iii) finalize working group meeting details, if necessary
  - (c) October 2019 – Reconvene working group to discuss results and review whether classification scheme remains valid. Current proposed location would be October 14-16 at the University of Texas in Arlington (Dallas), Texas and hosted by Fulcrum Testing.

## Outstanding points/Action items

63. *Additional data is necessary to determine if lithium metal batteries will be sufficiently covered by this classification scheme, or whether additional criteria or categories need to be addressed.*
64. *The working group agreed to keep the idea of propagation speed, but it would be verified further with data and examples review further to determine if it is needed.*
65. *The working group also discussed the possibility that if all effects of the testing were contained within the package, that a full exception could be provided. The working group was invited to submit suggestions or ideas in this area.*
66. *The working group was encouraged to provide comments as to whether the specific gases emitted could be measured, how to assess the gases, and determine whether it is necessary to differentiate between flammable and non-flammable gases.*
67. *The working group was encouraged to provide additional testing results to confirm or refute whether all cells that disassemble would propagate if the reaction was contained.*
68. *A select group who plan to participate in the initial data collection will meet outside the working group session to:*
- (a) *finalize the details of the testing methodology*
  - (b) *identify the data points to collect*
  - (c) *define how to display/share the results*
  - (d) *Plan for call by the end of March 2019 to be coordinated by France, RECHARGE and PRBA.*
69. *Conduct testing at participating laboratories.*
70. *Prepare an INF paper for July 2019 UN Session to discuss progress over lunchtime working group*
71. *Reconvene working group in Fall 2019 to share test data and lessons learned.*
72. *Participants interested in the testing aspect or in developing the detailed methodology are encouraged to notify Claude Chanson (RECHARGE) and/or George Kerchner to be*

*added to the contact list. Additional information will be available from the RECHARGE Website noted above.*

## Annex 1

1. 2016/84 – Request by ICAO to provide additional granularity to lithium battery classification
  - a. <https://www.unece.org/fileadmin/DAM/trans/doc/2016/dgac10c3/ST-SG-AC.10-C.3-2016-84e.pdf>
2. Report of the 50<sup>th</sup> Session of the UN Subcommittee
  - a. paragraphs 48-50 <https://www.unece.org/fileadmin/DAM/trans/doc/2016/dgac10c3/ST-SG-AC10-C3-100e.pdf>
3. 1<sup>st</sup> meeting working group Montreal report
  - a. <https://www.rechargebatteries.org/wp-content/uploads/2018/12/3-report-1-UN-Informal-Meeting-on-Lithium-Batteries-Meeting-March-2017-Montreal-Canada-v1.1-Clean.pdf>
4. 2<sup>nd</sup> meeting working group Geneva report
  - a. <https://www.rechargebatteries.org/wp-content/uploads/2018/12/3-report-2-UN-Informal-Meeting-on-Lithium-Batteries-Meeting-December-2017-Geneva-Switzerland.pdf>
5. June 2018 UN documents
  - a. INF.66 - <https://www.rechargebatteries.org/wp-content/uploads/2018/12/3-Report-3-Jul-2018-UN-SCETDG-53-INF66e.pdf>
6. December 2018 UN documents
  - a. INF.42 - <https://www.rechargebatteries.org/wp-content/uploads/2018/12/1-Working-document-UN-SCETDG-54-INF42e.pdf>

## Annex 2

### Test methodology

- (a) 6 or more cells are to be placed in a row.
- (b) Test shall include 2 different cell types of identical design, chemistry, state of charge, manufacturer. PRBA offered to contact cell manufacturers and distributors to find a way to provide identical cells to all participating labs.
- (c) All labs participating shall follow the same test method for the 2 cells listed above above *as well as any additional cell types they wish to test*. This would enable data collection on other cell types and expand the base knowledge for future discussion. Additional types to be tested should be coordinated with other labs so that redundant testing is not conducted other than the 2 common cells. If not all tests or data points can be collected by a given participating, the lab should collect the as many of the points as possible.
- (d) Results would be shared in a way that protects confidentiality of the manufacturer.
- (e) Details of the test methodology:
  - (i) 1 cylindrical and 1 pouch cell, same chemistry, same manufacture, same lot
  - (ii) External heater tape with a defined heating rate as initiation method.
- (f) Variations of testing methods could be presented using the same data collection points. Future proposals regarding different testing methods would only be considered if data presented is comparable using the same methods.

### Data points to be collected

- (a) temperature of initiation of trigger cell
  - (b) max temperature of thermal runaway
  - (c) temperature of initiation of transfer cell
  - (d) max temp of runaway
  - (e) max temp of the overall pack temperature
  - (f) time to propagate
  - (g) volume/identification of gas production
  - (h) Data would be collected and displayed in several ways including the way presented by CATL.
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