UN Informal Working Group on Lithium Batteries – 2023-2024

24-26 April 2023 – Seoul, Korea

Introduction

1. Claude Pfauvadel (France, Chairman), Claude Chanson (RECHARGE) and KBIA welcomed participants to the session. The intent of the meeting was to review the current status of the hazard-based classification system for lithium batteries.
2. Agenda meeting:
    i. Review previous meeting minutes from the previous sessions and the latest laboratory testing calls to provide current status.
    ii. Introduce the document "UN IWG approach for a new classification of lithium batteries".
    iii. Update the latest laboratory test plans and results.
    iv. Introduction of ISO 6469-1 AMD and GTR 20 Phase 2.
    v. Finalize paper for presentation to the UN Subcommittee in July 2023.
    vi. Consider future action plan for testing labs and IWG.
    vii. Wrap-up and conclusion by the Chairman including discussion of future meetings.
3. Information and presentations given at the meeting will be available from RECHARGE after the meeting. Presentations and historical documents including minutes from previous meetings (2016-2021) are available from the RECHARGE Website https://rechargebatteries.org/sustainable-batteries/unsctdg/.

Review of previous minutes, and future work (informal document to be presented at the UN SCTDG).

4. The previous minutes were commented. It was reminded that the new classification protocol was optional, and also included a testing of the batteries. It was greed that the IWG should ask for a mandate of the UN SCTDG to introduce also the usage of the classification to characterize the hazards of cells and batteries at low State of Charge (SOC) , as well as cells and batteries in packaging. It is reminded that the new testing protocol was enabling the possibility to demonstrate the effectiveness of reducing the SOC and /or packaging conditions to mitigate the lithium batteries hazard.

Review latest test lab results

5. BAM reported on their latest test results on small Lithium iron phosphate (LFP) cells. They compared cell initiation in both air and nitrogen atmospheres to see if there were any impacts. They monitored the temperature and pressures.
    a) At 100% SOC, most cells propagated and showed similar initiation temperatures in both air and nitrogen. However, some of the cells did not initiate at all, even at 100% SOC and 250 °C.
    b) Additional tests were conducted at 50 and 30% SOC. They observed fewer propagations at 50% and only one encountered a thermal event at 50% at 250 °C.

c) They suggested that additional testing could be with temperatures up to 400 °C to see if non-reactive cells will react at higher temperatures.

d) Finally, they measured the quantity of gas released using different cell designs. They observed a gas release of 0.5-0.6 L/Wh. However, based on previous test result, they typical volume produced is 0.7 L/Wh with a maximum release of 1.15 L/Wh.

6. The group discussed cell reaction based on volume of gas released, and suggested that increased volumes of gas were expected to result from a more complete reaction.
7. INERIS shared that they analyzed the gases released vented in a thermal event both before and after combustion.
   a) CH_2O, POF_3, and HF are highly toxic, but not flammable.
   b) CO and Carbonates are both toxic and flammable.
   c) CH_4, H_2, and C_2H_4 were non-toxic but highly flammable.
8. It was acknowledged that gas analysis will be difficult for all cells. But the proposed concept will consider the maximum or worst case flammability for the expected gases to be released. These gases composition have been included in the proposed paper being presented to the Subcommittee.
9. INERIS also experienced a 0.5-0.7 L/Wh gas volume for LFP in a closed chamber, but they saw an increase to 1-1.8 L/Wh in an open atmosphere. For nickel manganese cobalt (NMC), the volumes were 0.7-0.9 L/Wh and 1.1-1.8 L/Wh in an open atmosphere. As this last case corresponds to the gas combustion in air, it is not considered as representative of the gas volume generated directly from the cells.
10. UL experienced a higher volume of gas produced at higher states of charge. But they also observed a 0.2-0.5 L/Wh.
11. Based on these results, it was suggested that the protocol assume a conservative value of 1 L/Wh for gas volume production.
12. BAJ presented the results of tests applied to solid state batteries (small cells). The test result demonstrate the absence of thermal run-away, including after maintain 1 hour at 200°C. Based on other ttest run internally, it is also expected that no Thermal run-away would happen until 400°C.

UN IWG approach for a new classification of lithium batteries

13. The group reviewed the draft working paper for presentation to the UN Subcommittee.
14. The draft paper will include areas highlighted in green that will need to be considered as specific wording reviewed with the group.
15. The group discussed the default conditions for the decision tree:
   a) The propagation rate was proposed to be below 1 min for 100 mm but others questioned whether this value was supported by data and whether it was truly a worst case situation. BAM shared they have experienced propagation rates as low as 100 mm/8 sec.
   b) Others felt it important to include a maximum temperature to be consistent with other areas of the document.
16. Others felt the information in paragraphs 3, 4 and 5 could be combined to simplify the introduction. However, paragraph 5 explains that the system requires 3 tests to be completed., and was maintained.

17. The Chairman clarified the point of the paper is to present the principles of the system recognizing that some of the details may be further debated. He added the default criteria in paragraph 4 is for the paper only and is not expected to be reproduced in the actual regulatory text.
18. In paragraph 6, the group discussed whether there was value in noting the capability for significant toxic or flammable gas generation. Some felt it was not necessary. The group agreed to reference “the capability to generate significant quantities of gas. The gas composition may be flammable or toxic. The working group decided not to differentiate between the two properties but base the classification criteria on the volume of gas.
19. The IWG discussed whether the term “flame” or “fire” should be referenced. The Chairman pointed out the term fire is defined in UN38.3.
20. Gas generation rate was further discussed by the group. If the system does not distinguish between rapid or not rapid gas generation, there will be an assumption that the gas generation will occur all at once. For firefighting, it may be useful to differentiate between a battery that may generate gas very quickly from one that generates gas at a slower rate. Nevertheless, it was also stated that the main driver for the gas generation speed was the propagation rate, that will be measured during the test protocol.

End of Day 1

Day 2

Introduction of ISO 6469-1 AMD and GTR 20 Phase 2

Rapid Heating Test Methodology Canada

21. The Canadian National Research Council presented on rapid heating methodology for thermal runaway testing in large cells. The testing has been used to determine hazards to occupants in an electric vehicle. They noted that traditional methods (mechanical, electrical, cell defect introduction and cell heating) have both benefits but also drawbacks. Single cell heating was proven to the be most effective.
    a) Applied high power heat pulses (20-50^{o}C/Sec) to a small (<20%) area using thermostatic controlled temperature feedback loop. It was found effective to lead to self-propagating, exothermic decomposition reaction.
    b) The method has been adopted in ISO 6469-1:Amd 1 and is being considered for the UNECE Global Technical Regulation on Electric Vehicle Safety.
    c) The method does not impact adjacent cells but has been proven effective on all cell designs (cylindrical/pouch/prismatic) and different chemistries. The ISO Standard has several options for heating element selection.
    d) Application of the heating element may change with each of the battery pack designs and the ISO standard uses an opportunistic approach. But an insulating barrier between the heating element and adjacent cells is very important.
    e) Experience shows large prismatic cells are the most difficult to initiate due to heat loss due to transfer within the cell.

f) Typical initial heating time is within 20-30 sec to 500 °C. Energy added to the system is 2-3.5% of the cell. The method currently avoids side wall rupture but questioned whether this would be of concern for the UN-TDG.

g) Can apply a higher heat flux for reduced time to thermal event.

h) Being tested for inclusion in UN GTR and has been adopted as one of 3 method options in the ISO 6469-1 Amd-1. They are also working closely with many vehicle OEMs and test labs globally.

22. The group discussed the details of the methodology. Canada explained that in their experience, side wall failures typically happen above 350 °C for pouch cells and at 400 °C for cylindrical and prismatic cells. Soak times are really short for pouch cells (perhaps less than 10 sec) but may be 30+ sec for other cell designs. They added that the thermocouple must be incorporated directly onto the heater element to ensure the heat doesn't exceed the intended value and result in a side wall rupture. This method uses low voltage heating systems.
23. The Chairman noted that the group could include a statement in the UN paper that additional cell initiation methods are being considered, and that would allow for this method to be included at a future revision.
24. It was noted that the current GTR regulation does not include cell heating methodology but this method is being considered for inclusion in a future revision. The effort is supported by China, Korea and Canada and round robin testing is underway to confirm reproducibility.

Update the from the FAA Testing Results

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25. The FAA presented recent gas volume and composition testing for lithium batteries.

a) Over all the tests, they are experiencing up to 0.7 L/Wh. This data aligned well with other testing done by BAM and INERIS.

  i. The air in the chamber was vacuumed and filled with nitrogen prior to testing.
  ii. They have tested 20 lithium ion and 9 lithium metal cells so far.
  iii. Each cell design was tested 3 times.
  iv. For lithium ion, the largest volume was produced by LCO. For Lithium metal, the largest volume was produced by LTO.

b) They also shared experience with the Battery Propagation testing.

  i. All lithium ion LCO cells propagated. However, no LFP batteries propagated.
  ii. For lithium metal, $LiFeS_2$ propagated at AA size, not AAA size.
  iii. For flammability testing, they placed an ignitor 4 inches away from the top of the testing assembly. As a result, all cells produced flammable gas except for the $LiSO_2$ cells.
  iv. CR2430 button cell propagated (0.855 Wh)

c) Based on their results, they opined the number of cells could be reduced from 6 to 4 in the propagation test.

26. The group discussed the fact that for cells with higher power (for example 300 Wh), this may result in a production of more than 100 L of gas. Some participants questioned whether larger chambers are available. INERIS confirmed they could use a very large chamber. Others shared that they have used smaller chambers that are designed for higher pressures.

UL presentation on Fire Suppressant Testing

27. UL shared experience with applying fire suppressant while conducting propagation tests. They found that the reaction was allowed to continue with the production of flammable gas, without having fire.

Presentation to the UN Subcommittee

28. The group continued to review the draft proposal of principles to be presented to the UN Subcommittee. Actual changes to the document were captured and are presented in an attachment to this document.
    a) Although the current method requires the sample temperature to reach 400 °C, the G27 method is using 375 °C and the ISO standard presented at this meeting uses 350 °C. The sample temperature is the temperature on the surface of the cell.
    b) Some participants questioned why such high temperatures are being proposed. It was explained that the purpose of the test is to force the initiation cell into a thermal runaway. Some cells will not initiate at lower temperatures, and thus the test would not proceed. Given that the results of the tests will be used to determine a categorization of the cells, a test method that is not robust enough may be questioned as giving false or incomplete data.
    c) It was felt the IWG could share with the Subcommittee that in the majority of commercially available cells, temperatures between 350-400 °C will lead to a thermal runaway. However, the group was also aware of rare but specific cases where no initiation occurs (new solid state technology). Although this question needs additional investigation in the IWG, it may also be appropriate that if no reaction occurs at the maximum temperature (350-400 °C), then two options are possible:
        i. The cell could be assigned to the relevant category according to the test result (Category 1 to 3).
        ii. If option 1 is not supported, such cells may be eligible for transport under conditions authorized by competent authorities until regulations are amended to address new technologies (e.g. solid state batteries).
    d) Some questioned how to address the case where the heating of the initiation cell leads to damage to the second cell but no thermal runaway was experienced. The group concluded that in such a situation, the cell would be deemed to not propagate. The test would need to be reproduced 2 more times (for a total of 3 tests) to see if the same result occurs.
29. The group discussed the heating rate for small and large cells. There was a suggestion to refer to UN GTR/ISO 6469-1, Amd-1 to determine if different rate needs to be considered for larger cells. The rate of 15 °C (+/- 5 °C)/min is currently proposed for all cells.

30. Following discussions on Day 1, the IWG discussed whether the propagation rate needed to be calculated to distinguish between Categories 8 and 9. The group initially considered 3 different rates (below 10 mm/min, 10-100 mm/min, or more than 100 mm/min) as defining criteria. However, after further discussion, a higher rate of 1000 mm/min was suggested to be included in square brackets for the paper. To clarify the propagation rate is of concern, the decision box for Category 8 or 9 was changed to "Rapid Propagation" with the propagation rate of 1000 mm/min as the defining criteria. It was also shared that the test methods can create conditions where propagation will occur very rapidly. Therefore, measuring the propagation rate through the test may result in artificially high propagation rates. Others opined that real life fires may also lead to similar conditions as those encountered in the tests. It was agreed to include the distinction until additional experience is gained.
31. In considering the criteria for evaluation of the gas hazard, the IWG agreed to the premise that all lithium batteries generate toxic gas. So the evaluation of toxicity is not necessary. However, to distinguish between Categories 6 and 7, the group agreed to include an option of either an additional test or method to determine if flammable gas is generated or not. If no test is conducted, then Category 7 would be the default assignment. Reference to the applicable ISO standard for the gaz flammability determination method would be beneficial.
32. The volume of gas produced is a distinguishing factor between Categories 1/2 and 3/4. Participants discussed the criteria for consideration as a volume concern, and decided to allow the Subcommittee to provide additional input on a particular value. It was suggested that a calculation could be made instead of an actual test.
33. With regards to temperature, the group noted that the test methodology could be simplified as it is only relevant when propagation does NOT occur. The measurement would need to be taken on the initiation cell before thermal runaway. If the maximum temperature exceeds 150 ^{o}C above the temperature reached after then heater is stopped, then a temperature hazard is present.
34. Given the amount of time remaining, the group agreed to review paragraphs 11-13 of the paper.
    a) The group discussed consideration of State of Charge. Unless SOC is indicated otherwise, the SOC is assumed to be 100%. However, testing results indicate that cells at a lower state of charge would be assigned to a different category. To permit the option of assigning a different category based on SOC, cells could be tested at 100% SOC and at the lower state of charge. The group considered several options but agreed that the concept needed additional discussion before sharing possible options with the Subcommittee.
    b) The paper includes in paragraph 12 a request for the Subcommittee to authorize the IWG to consider the test method to assess the danger of cells and batteries inside a packaging and define transport conditions to those packagings.

<u>End of Day 2</u>

<u>Day 3</u>

Presentation to the UN Subcommittee

35. The group continued to review the draft proposal of principles to be presented to the UN Subcommittee. Actual changes to the document were captured and are presented in an attachment to this document.
36. The document included intrinsic hazards associated with lithium batteries. The hazards are similar to those for cells and the two sections of the documents were aligned. Some were concerned that the intrinsic hazard section implied that all batteries were likely to propagate and would lead to battery to battery testing. The language was clarified to note the tests are to address propagation of cells within a battery. Such propagation within a battery would be a concern if the hazards escaped the battery and led to battery-to-battery propagation. Therefore, the tests are designed to identify the hazards that could be released from a single battery and are not intended to be expanded to multiple batteries. The group believed this would possibly lead to safer battery designs.
37. The IWG recalled a previous opinion that if a battery is composed of non-propagative cells, the battery may be considered as non-propagative. However, it is possible that abuse or specific conditions may call this approach into question in certain cases. The group will continue to discuss this point at a future meeting, but it was agreed that it was premature to draw any conclusions at this point without additional technical data.
38. Significant discussion was had whether to reference the packaging test found in P911. It was agreed that the text should remain broad and flexible in the draft paper so that the concept is introduced to the Subcommittee, but will be further developed at future sessions.
39. The IWG discussed whether a cell heater should always be applied, or whether other options may be used. In general, the group was open to permitting alternate equivalent ignition methods. But it was felt that the heater method should be the primary and preferred cell initiation method.
40. The location of the heater placement within the battery on an initiation was discussed, as well as other technical details of the test as applied to batteries. The group agreed to further develop the details for where to measure the temperatures, how to deal with hot or melting casings, and when casings are not present.

Conclusions and Next Steps (Action Plan)

41. The draft paper will be circulated to participants for review. Comments are be submitted to the editorial group within the next two weeks (by 10 May 2023).
    a) Key items for the Subcommittee will be highlighted in the paper and summarized in an “executive summary” at the introduction of the paper for easier discussion.
42. The IWG will present the drafted Paper as an informal paper (INF) to the UN Subcommittee at the July 2023 Session. The Annex to the working paper for the Subcommittee will be provided as information for future consideration. If the Subcommittee validates this work, the IWG will:
    - Draft amendment proposals to translate the presented hazard classification and test protocol into a new text for the Model Regulations, and
    - Develop proposals for the transport conditions of each category.
    - The test protocol used by the labs can be used for this purpose.
43. Additional details related to battery testing will be discussed further based on additional testing, experience, and proposals at future IWG meetings.

44. Additional laboratory testing will likely be required for batteries. The next meeting for the laboratories will be planned for 3rd/4th quarter 2023.
45. The next scheduled meeting of the IWG will be held following the UN Subcommittee meeting in December 2023 in Geneva, Switzerland. (Dec 6-8).
46. Following the discussion at the December 2023 session, it is anticipated the IWG will meet again in 2024 to finalize proposals for presentation at the December 2024 UN Subcommittee.

End of Day 3