#### UN Battery Classification Test Method Development and Testing

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#### Introduction

- Currently all lithium batteries are classified as either lithium-ion or lithium metal
- All lithium-ion or lithium metal batteries are not created equal
- New classifications take into account actual hazards:
  - Initiation
  - Propagation
  - Fire
  - Gas Hazard
  - Temperature Hazard





## **Lithium Battery Classification**

- By Default, no testing will be required, all hazards would be considered worst case with common chemistry
- Purpose of this testing is to determine worst case as well as developing test methods for individual batteries to be classified on their own
  - Gas Test
  - Propagation Test
  - Flammability and temperature hazard determined in one of these tests



- Single cell placed in 21.7L pressure vessel and heated until thermal runaway
- Instrumented with pressure transducers and thermocouples for heater, battery, and ambient air
- Chamber is evacuated with vacuum pump, then filled with nitrogen at atmospheric pressure
- Battery gas volume is calculated from temperature and pressure measurements
- All cells at 100% SOC





- Heating rate controlled with temperature controller
- Cells heated at rates of 5°C, 10°C, and 20°C per minute
- Example shows an 18650 cell heated at 20°C/min





- Chamber pressure and temperature data from same test
- Calculated amount of gas (in moles) using ideal gas law
- Converted to liters of gas at NIST normal temperature and pressure (NTP – 20°C and 1 atm)
- This test produced 3.39L of gas





- Repeated tests 3 times to get
  repeatability data for two cells
- 2600 mAh 18650:

	5°C/min	10°C/min	20°C/min
Average	3.38	3.70	3.43
Std. Dev.	0.06	0.21	0.10
% Std. Dev.	1.64%	5.75%	3.02%

• 2400 mAh 18650:

	5°C/min	10°C/min	20°C/min
Average	3.19	3.25	3.29
Std. Dev.	0.13	0.12	0.30
% Std. Dev.	3.92%	3.63%	9.03%





- Tested 10 lithium-ion cells
  - Size from AAA to 18650
  - LCO, NMC, LFP, LTO chemistries
- Tested 6 lithium metal cells
  - Size AAA, AA, and CR123A
  - LiFeS<sub>2</sub> and LiMnO<sub>2</sub> chemistries



Lithium-ion batteries tested



Lithium metal batteries tested



- Looking for relation between battery capacity and volume of gas emitted
- All cells tested so far





- Lithium-ion cells only
- Comparing highest volume from each cell





- Lithium ion cells only
- Comparing gas volume to capacity (mAh) instead of energy (Wh)





Lithium metal cells only





UN Battery Classification Testing



# **Ignitor in Chamber**

- Tested cells in nitrogen first
- Then tested in air w/ ignitor to determine flammability
- Much greater pressure rise in air showed that ignition took place
- Fire/explosion inside chamber can damage wiring/instruments inside
  - Shorted out the heater and burned up temperature controller in the process





- 6 cells placed in a line in an insulated box to determine if thermal runaway will propagate down the line
- Cell #1 heated at 20°C/min until thermal runaway occurs, then heater is turned off
- Thermocouple placed on each cell to measure temperature
- Top of box is vented to allow gas to escape
- Spark ignitor placed 6 inches above the box
  - To determine if gas is flammable
  - Ignitor turned off after first cell goes into thermal runaway
- All cells at 100% SOC









- Tested repeatability for two sets of cells, both AA (14500) size
- LiCoO<sub>2</sub> cell propagated with very repeatable test results





- LiFePO4 cell did not propagate
- Second cell vented for all three tests





- All LCO cells propagated except AAA size
- No LFP cells propagated
- LiFeS<sub>2</sub> propagated at AA size\*, not AAA
  - \*Non-propagating AA cell may not have been heated enough
- All cells produced flammable gas

	Propagation Testing of Various Cells									
	Number of Cells Propagated									
gated	C	)	1	2	3	4	5			
ĺ	LiCoO2 18650									
gated at AA Ion	LiCoO2 18650									
	LiCoO2 18500									
	LiCoO2 AA									
	LiCoO2 AAA									
	Li2TiO3 18650									
	LiFePO4 AA									
	LiFePO4 AA									
Metal -	LiFeS2 AA									
	LiFeS2 AA									
	LiFeS2 AAA									
	LiMnO2 CR123A									
	LiMnO2 CR123A									
	LiMnO2 CR123A									



## **Conclusion and Future Work**

- Battery gas volume increases with battery capacity in lithium-ion cells
  - No relation so far with lithium metal cells
- Battery propagation test works well for testing propagation
  - Ignitor placed above cell #1 always ignited flammable gases
  - Cells must be secured in box
- Additional testing needed



#### **Questions?**

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