RECHARGE

ADVANCED RECHARGEABLE & LITHIUM BATTERIES ASSOCIATION

Labs test plan, phase 2
First results analysis

September 1rst, 2020

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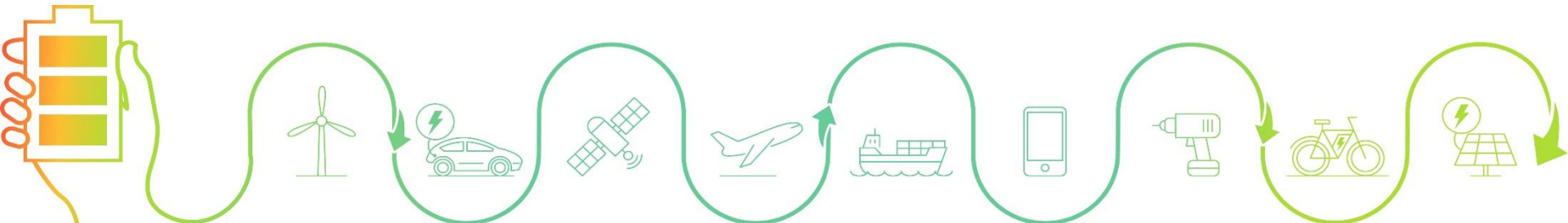


Content

General status of informal working group and test group

Labs test plan

Phase 1 results summary

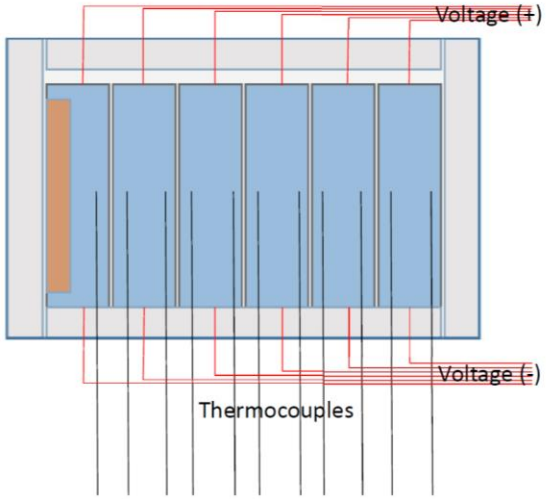
Phase 2 preliminary results

General Status of Informal Working Group (IWG) and Test Group

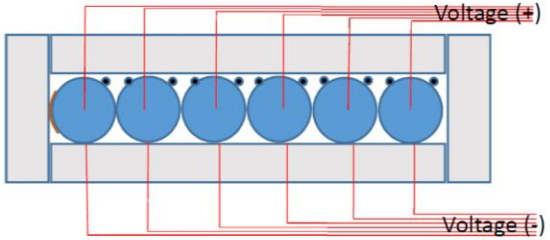
- Last IWG meeting held in Arlington, Texas USA (October 2019)
  - Reviewed data on first round of testing from 7 labs
  - All labs received from PRBA same Li ion cell designs from same manufacturers, tested at 100% state of charge
  - See UN/SCETDG/56/INF.33 for minutes of Arlington meeting
- IWG meeting scheduled for September 2020 in Brussels cancelled due to COVID-19 pandemic
- Test Group meeting scheduled for May 2020 also cancelled, continued web-based meetings, developed second round of tests
  - Additional Li ion cells provided by PRBA to 8 labs, tested at different states of charge
  - Partial results provided today for review by IWG
- Next IWG planned for December 2020 after UN Sub-Committee meeting

Test plan phase 1

- Phase 1: Test of repeatability: 7 labs tested propagation in a row of 6 cells, 3 répétitions of test for pouch and cylindrical, at 100% SOC.



Side View



Top View

Test plan phase 2

- test of effect of heating rate and SOC on propagation for 6 cells in a row (for test labs without gaz analysis, test series 2 and 5): received partial tests of 4 labs has of sept 1.
- test of effect of heating rate and SOC on propagation on gaz hazards, single cell test (for labs with gaz analysis, test series 4 and 6): received partial test of 2 labs has of Sept 1.

Experimental Procedure test series 2-5:

- Charge cells to SoC as in table below
- Heat cells according to Table 1.
- Each test is performed once

Table 1

	20% SoC	30% SoC	50% SoC	70% SoC	100% SoC
5 C/min					Priority #3
20 C/min	Priority #1	Priority #5	Priority #2	Priority #4	

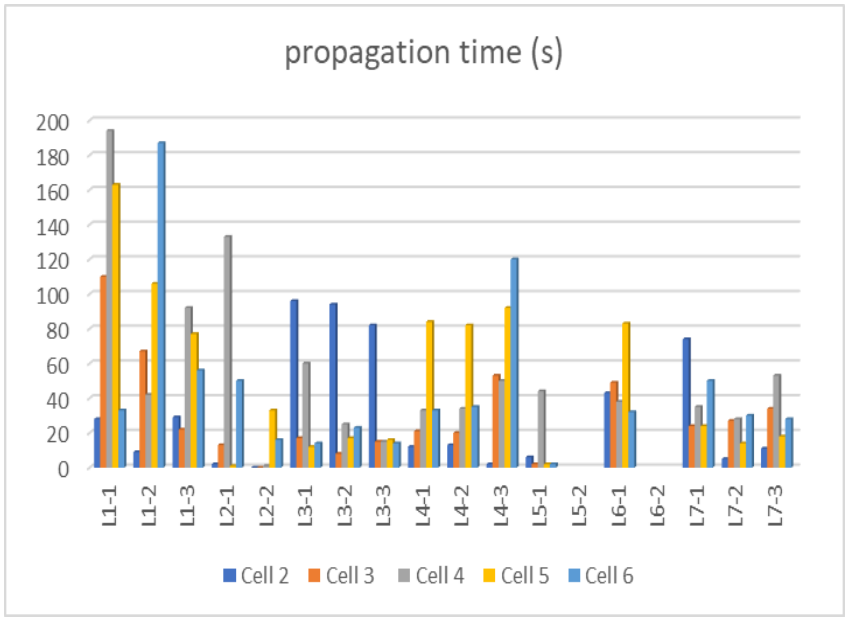
Test phase 2 results: table creation on going

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	cyclindrical	2450 mAh																		
2	Pouch	4800 mAh									based on the reading of the thermocouple opposite side of the initiation cell.									
3											time of TR	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4
4		cell type	heating device type	Heating powe	heating ra	SOC	max temp	Temp 3rd	compress	Closed ch	seconds	delta sec	delta sec	delta sec	delta sec	delta sec	Max temp	Max temp	Max temp	Max temp
39	L1-21	NMC/cylindrical	Omega heating pad (2,5 x 5	20	5	100	669	50	briks	Y	1980	62	31	81	22	7	669	757	702	766
40	L1-22	NMC/cylindrical	Omega heating pad (2,5 x 5	20	14	70	738	33	briks	Y	771,42857	120	120	0	170	122	737,91	617,32	700,63	624,99
41	L1-23	NMC/cylindrical	Omega heating pad (2,5 x 5	20	20	50	578	29	briks	Y	504	353	265	267	264	268	556,71	561,42	561,92	523,8
42	L1-24	NMC/cylindrical	Omega heating pad (2,5 x 5	20	20	20	200		briks	Y	0	0	0	0	0	0	361	213	69	34
43	L1-25	NMC/Pouch	Omega heating pad (5 x 5 cr	40	5	100	770	86	briks	Y	2040	27	7	11	5	8	769,08	769,5	769,07	769,5
44	L1-26	NMC/Pouch	Omega heating pad (5 x 5 cr	40	11	70	800	93	briks	Y	981,81818	31	0	30	20	19	678,43	726,15	574,93	799,81
45	L1-27	NMC/Pouch	Omega heating pad (5 x 5 cr	40	7	50	650	118	briks	Y	1628,5714	70	22	20	21	23	601,9	623,7	649,69	634,87
46	L1-28	NMC/Pouch	Omega heating pad (5 x 5 cr	40	6	20	200	123	briks	Y	0	0	0	0	0	0	204,8	151,46	122,7	108,47
47	L2-21	NMC/cylindrical	1"x 2" Kapton heater	20	10	75	796	121	No (Wool)	N	1174	195	173				762	796	394	
48	L2-22	NMC/cylindrical	1"x 2" Kapton heater	20	10	50	780	45	No (Wool)	N	1081	305	232	294	257	229	684	746	710	740
49	L2-23	NMC/cylindrical	1"x 2" Kapton heater	20	10	30	474	53	No (Wool)	N	1180	695	964	1344	282	1052	474	454	442	386
50	L2-24	NMC/cylindrical	1"x 2" Kapton heater	20	18	20	386	45	No (Wool)	N	1354						386			
51	L2-25	NMC/Pouch	1"x 2" Kapton heater		10	75	958	108	Wool+Al plat	N	1600	1	6	18	18	29	1676	958	832	466
52	L2-26	NMC/Pouch	1"x 2" Kapton heater		10	50	770	112	Wool+Al plat	N	2070						770	748	828	1036
53	L2-27	NMC/Pouch	1"x 2" Kapton heater		10	30	538	91	Wool+Al plat	N	1765	60	9	165	87	42	458	458	492	500
54	L2-28	NMC/Pouch	1"x 2" Kapton heater		10	20	418	80	Wool+Al plat	N	1807	841	30	-260	-197	-167	342	418	376	340
55	L9-21	NMC/Pouch	Flexible heater	20	20	100	886	81	Wool+Plates	Y	400	4	8	16	21	32	822,6	886,1	869,1	877,3
56	L9-22	NMC/Pouch	Flexible heater	20	20	100	1083	57	Wool+Plates	Y	380	4	10	12	16	35	1015,2	1054,7	1083	1007
57	L9-23	NMC/Pouch	Flexible heater	20	20	50	200	80	Wool+Plates	Y	400						200	110,2	84,1	73,5
58	L9-25	NMC/Pouch	Flexible heater	20	20	20	200	80	Wool+Plates	Y	400						200	97,7	76,6	64,3
59	L9-27	NMC/cylindrical	cartridge	50	20	100	817	31	Wool+Plates	Y	581	87	245	334	432	500	720	665,8	752,2	741
60	L9-28	NMC/cylindrical	cartridge	50	20	100	854	28	Wool+Plates	Y	598	100	206	289	371	442	732,3	757,4	737,4	775
61	L9-29	NMC/cylindrical	cartridge	50	20	50	414	34	Wool+Plates	Y	700	442					414,6	357,6	170,4	102,8
62	L9-30	NMC/cylindrical	cartridge	50	20	50	437	31	Wool+Plates	Y	674	789					437,9	362,1	151	89,1
63	L9-32	NMC/cylindrical	cartridge	50	20	20	310	83	Wool+Plates	Y	840						314,1	140,2	83,9	54,5
64	L4-21	NMC/cylindrical	flat	10	6,5	50	603	38	Wool+Board	Y	1661,5385	204	196	185	243	155	603	556	618	444
65																				
66																				
67																				

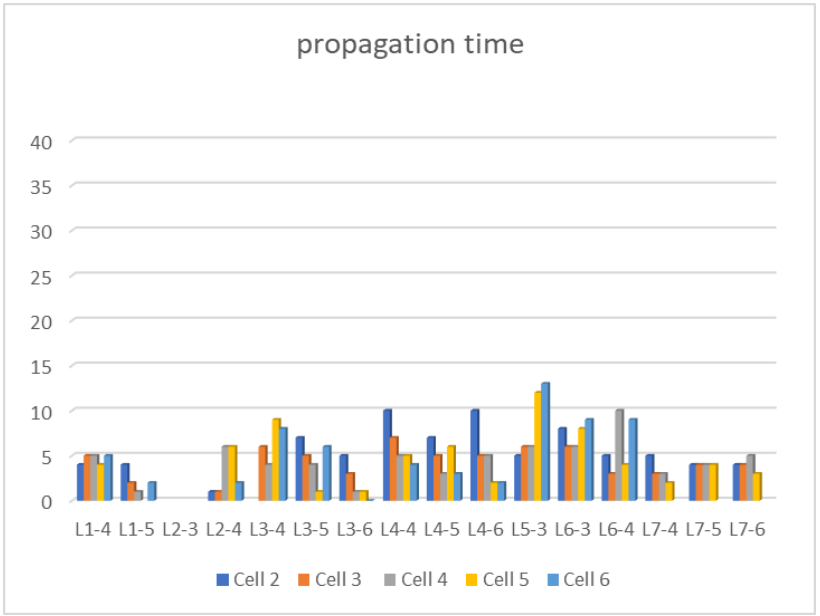
Phase 1 results analysis: propagation rate

- Repetability (per lab): stability of averages and standard deviation and reproducibility (between labs): stability of averages and standard deviation: analysis on-going.

Cylindrical



Pouch

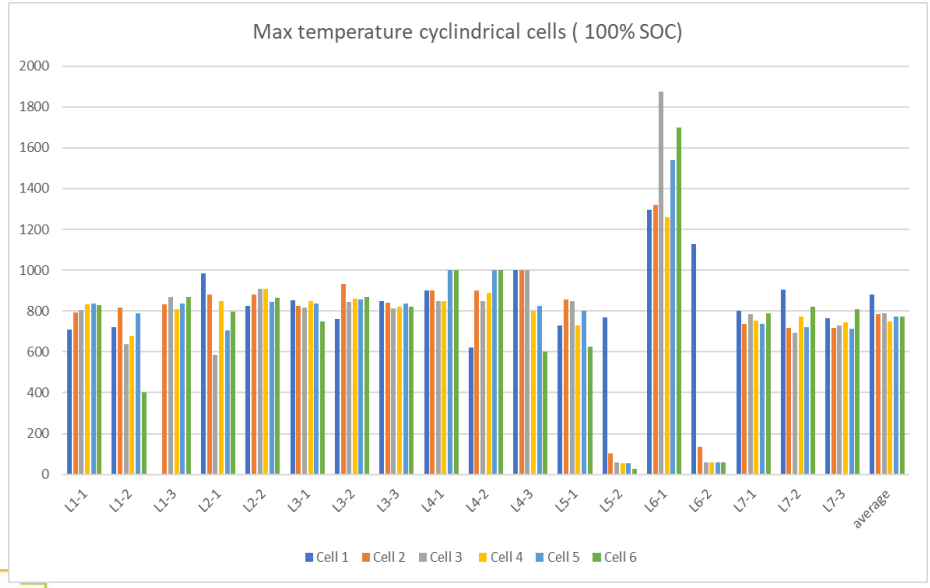


Note: L1-2 means « laboratory 1 test 2 »

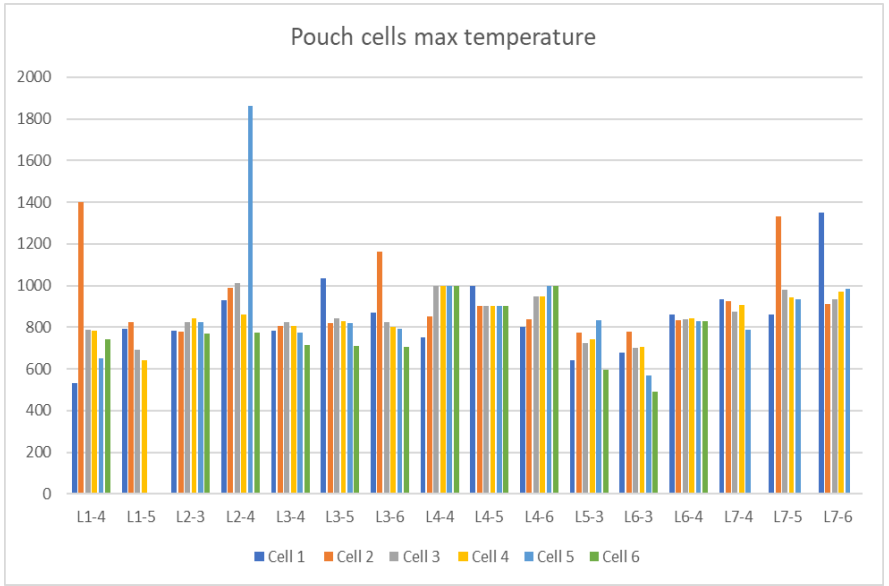
Phase 1 results analysis: max temperature

- Repetability (per lab): stability of averages and standard deviation and reproducibility (between labs): stability of averages and standard deviation: analysis on-going.

Cylindrical

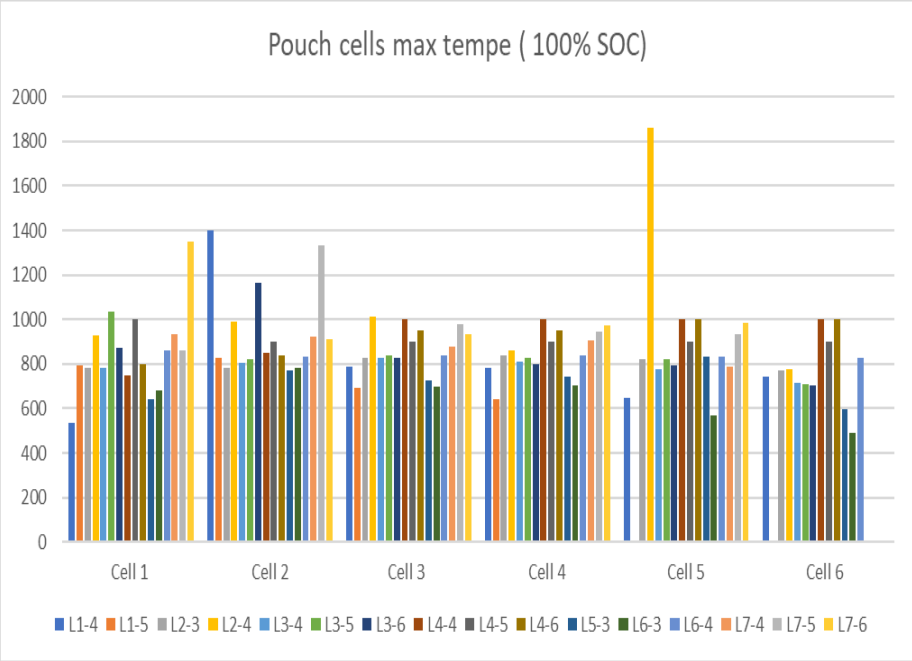


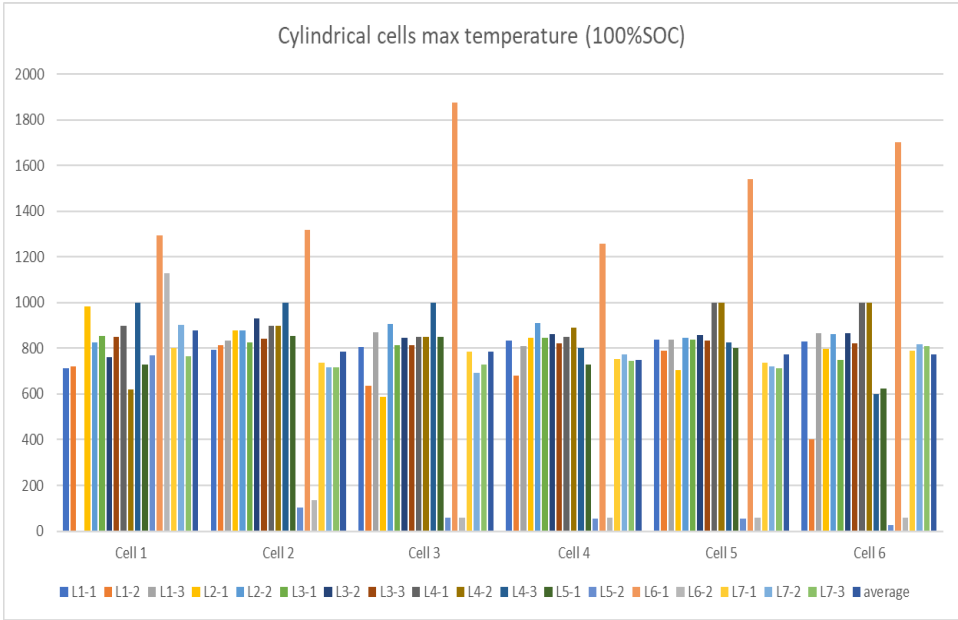
Pouch



Phase 2 results analysis

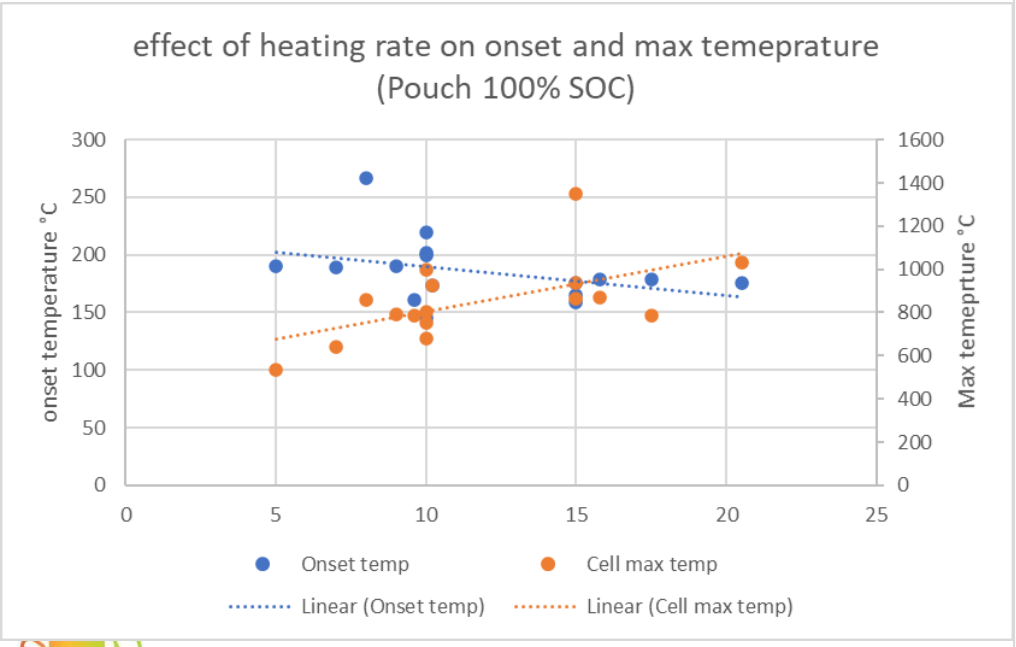
- Effect of initiation method on max temperature: no visible effect. Cell 1 max temp equivalent to others cells with self-propagation. No large effect of pouch/cylindrical

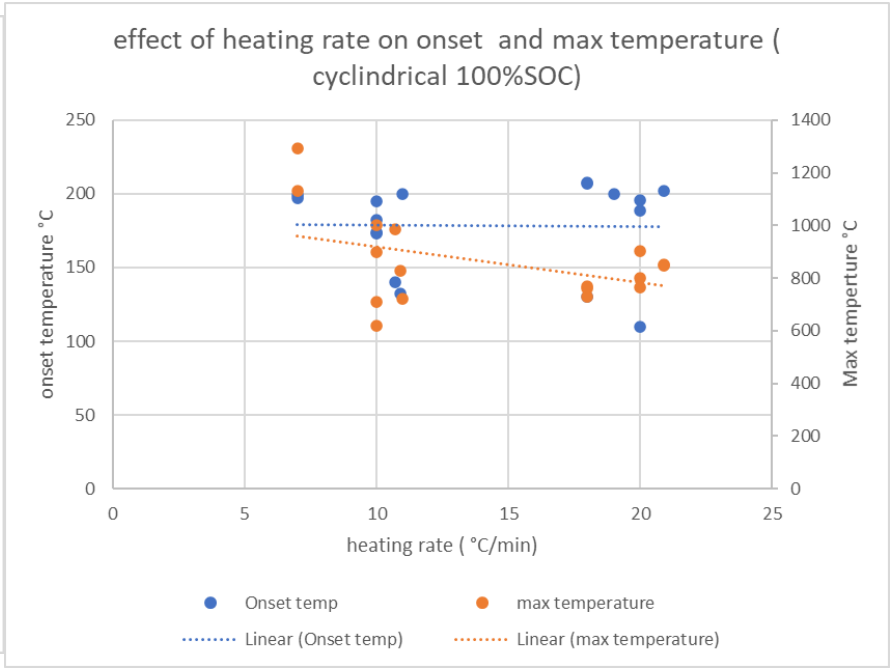




Phase 2 results analysis

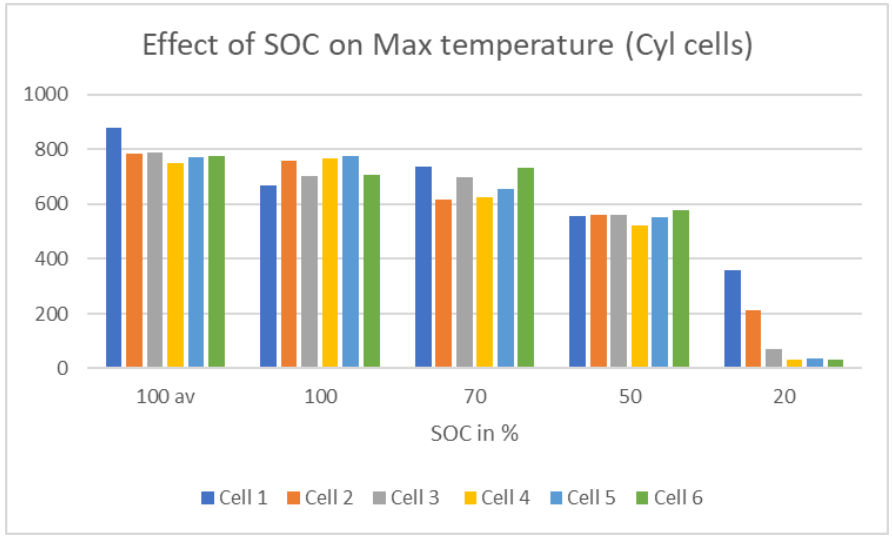
- Effect heating rate on Thermal run-away propagation and max temeprature: no clear effect at 100% SOC, to be verified at lower SOC.

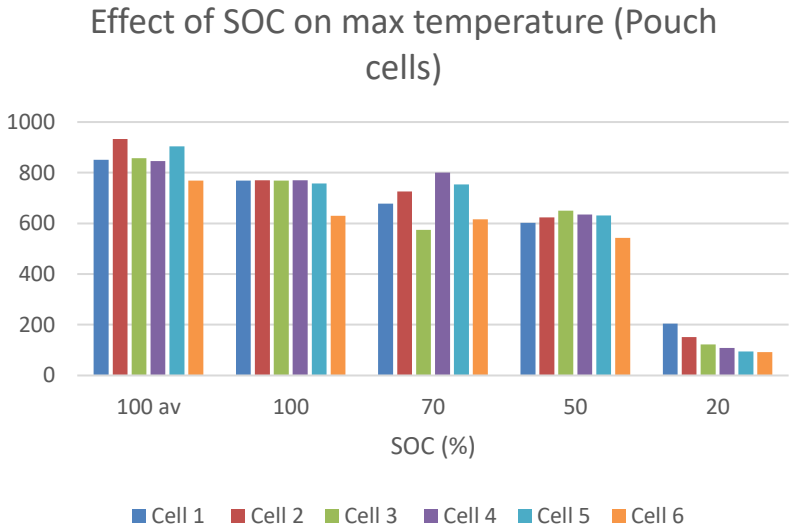




Phase 2 results analysis

- Stability of the max temperature during self propagation at various SOC: the initiation method seems of little impact on the reaction, except in absence of propagation (20% SOC)

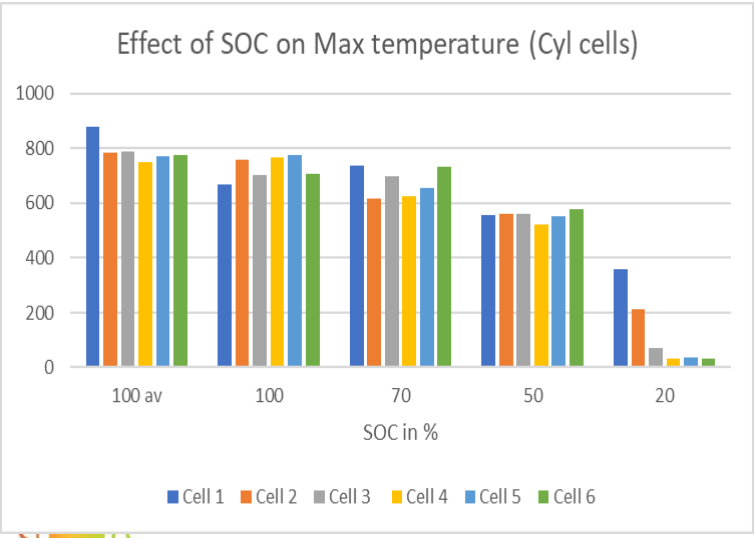




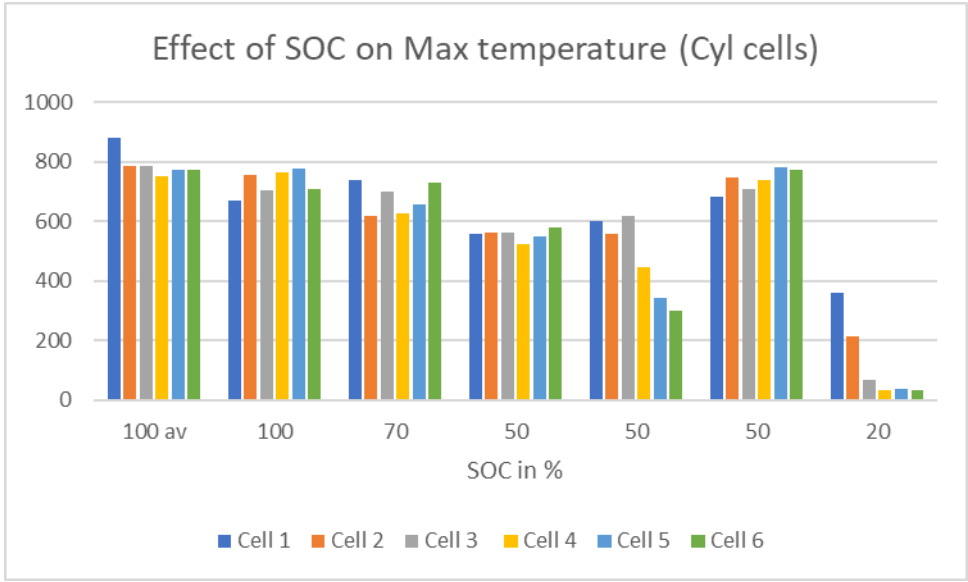
Phase 2 results analysis

- But repetability within a lab is much better than reproducibility interlabs

Results of 1 lab

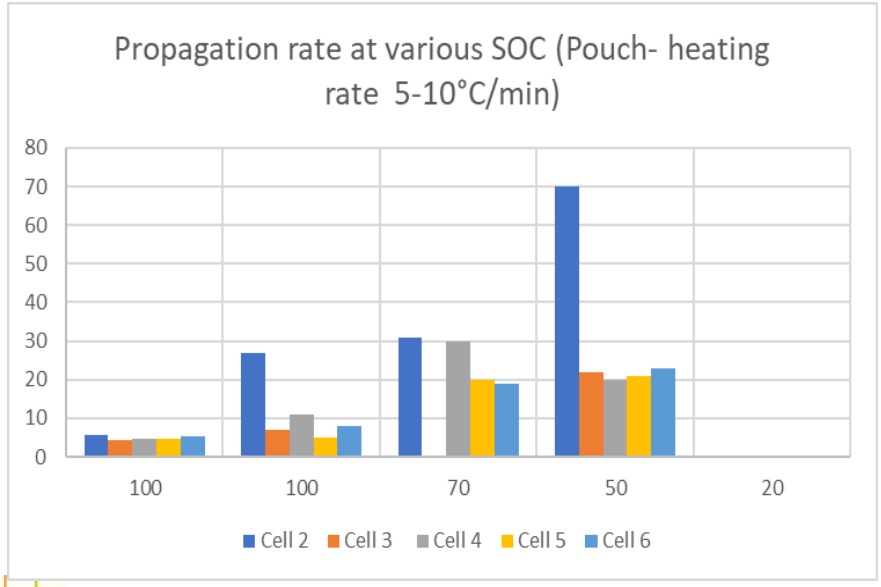


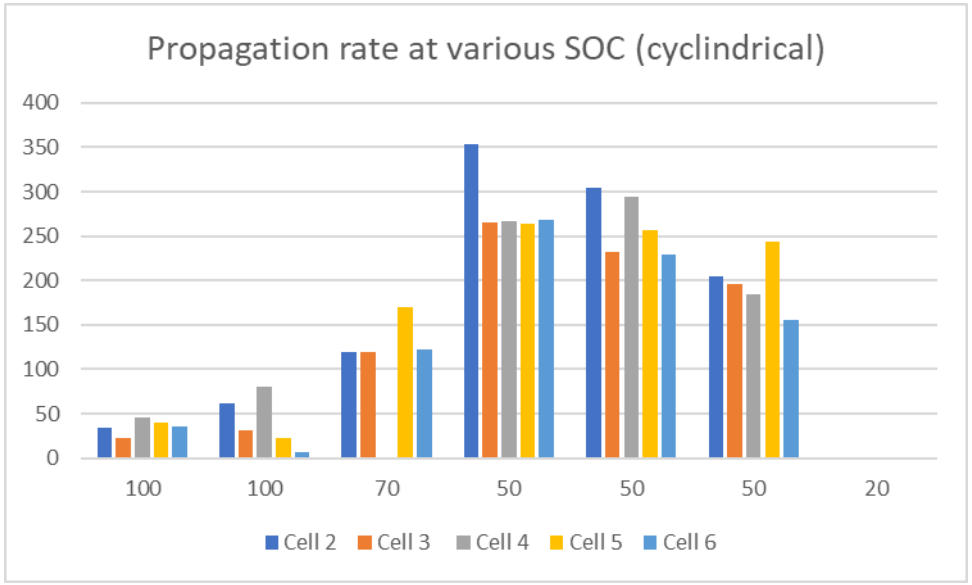
Results of 3 labs at 50% SOC



Phase 2 results analysis

- Effect of SOC, heating rate and type of cell on Thermal run-away: propagation time increases with lower SOC.
- The propagation time is quite stable at all SOC: evidence of minimal impact of the initiation method (except cell 2 for pouch?).

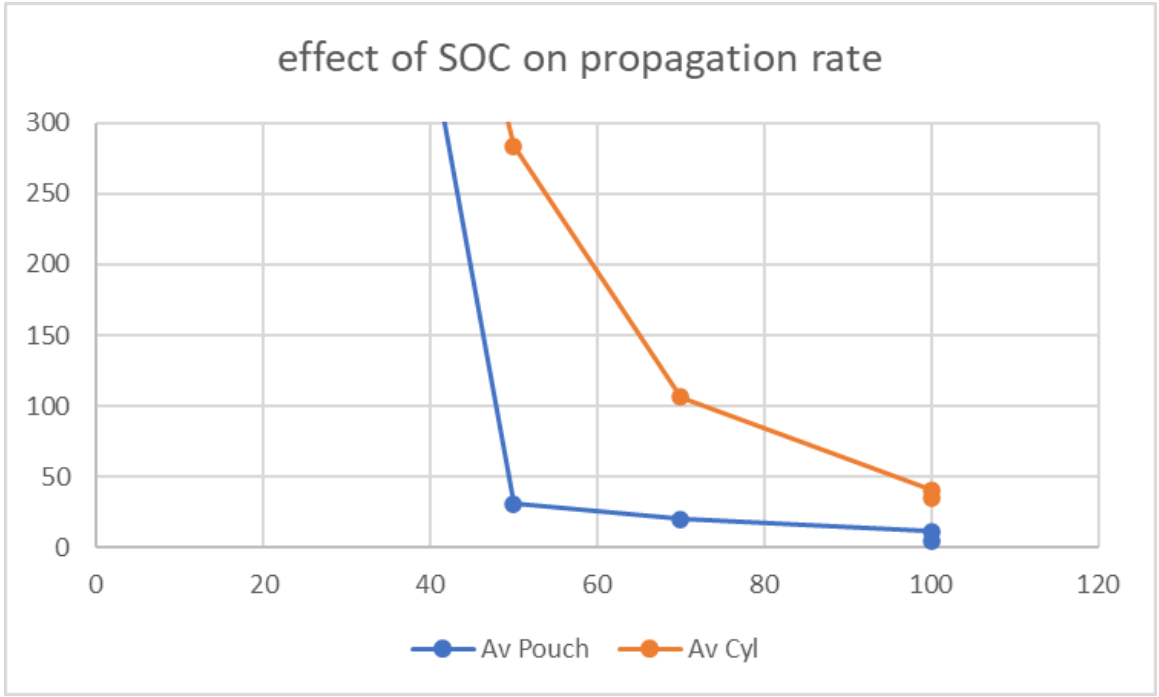




First 100% soc is average of phase 1. The three at 50% SOC are 3 different labs

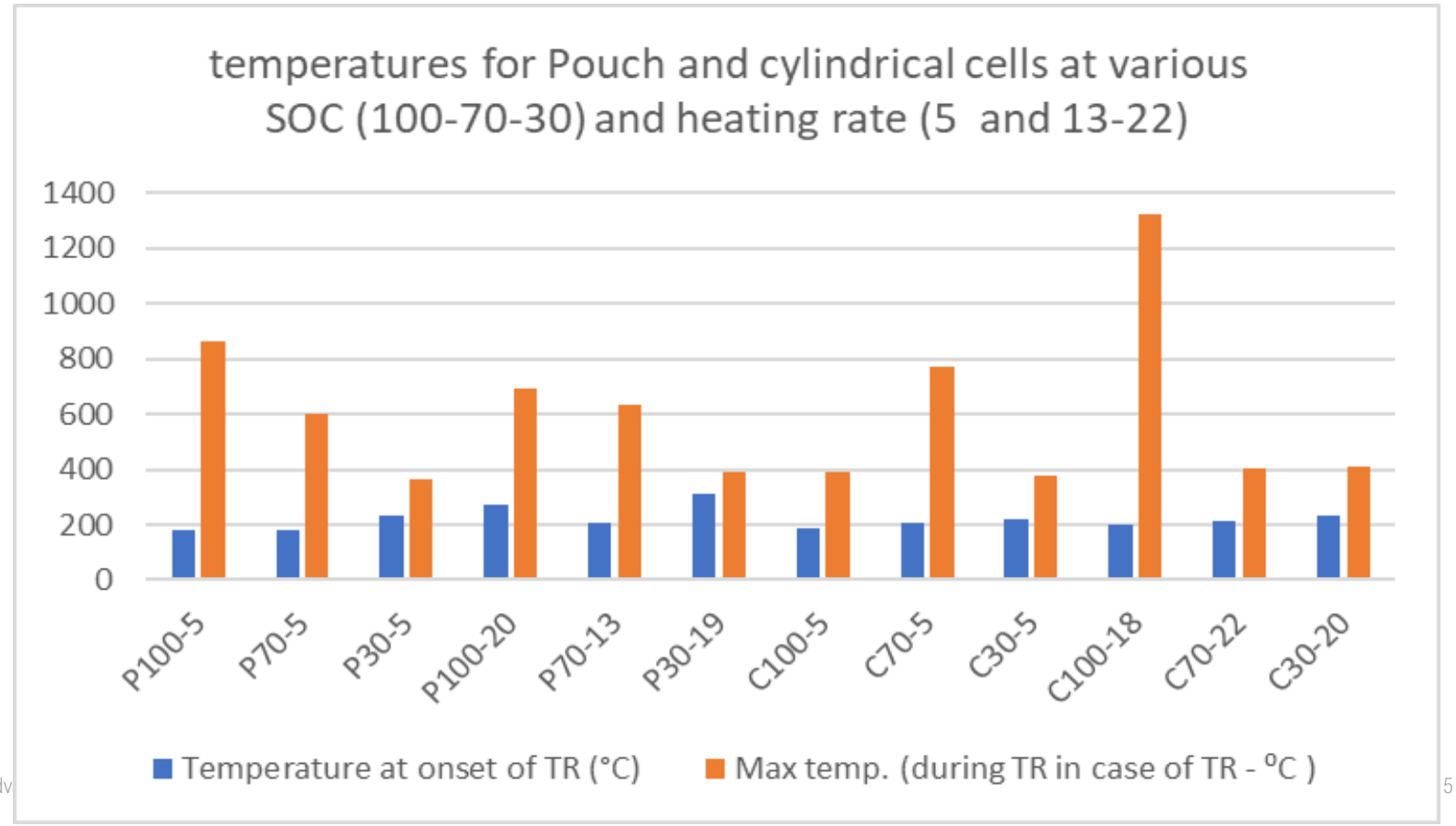
Phase 2 results analysis

- Effect of SOC and type of cell on Thermal run-away propagation: propagation rate is more sensitive to shape than max temperature.



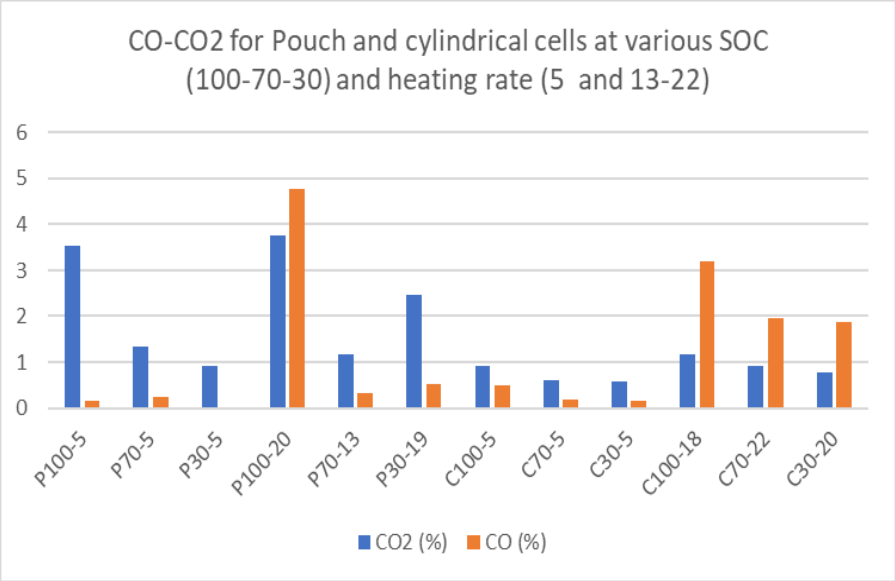
Phase 2 results analysis: gaz

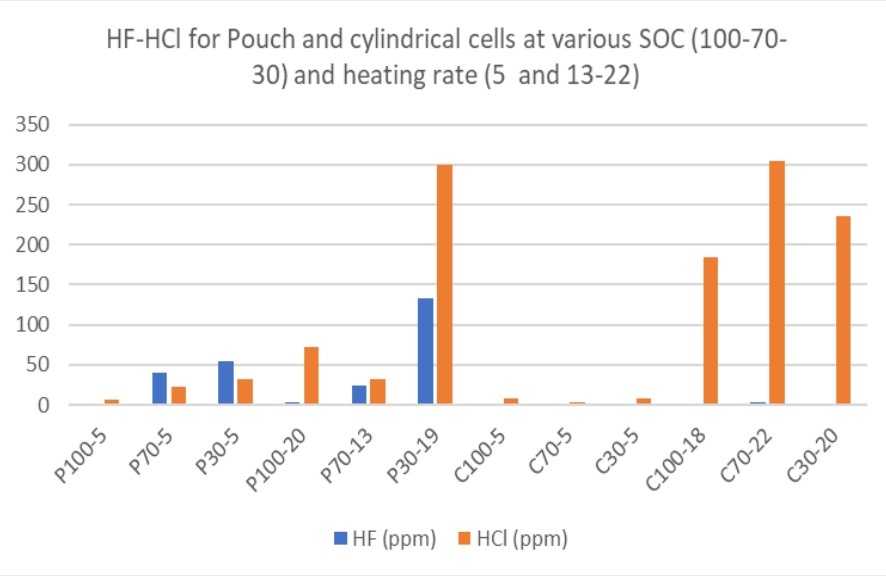
- Coherence OK: onset temp increases and max temp decreaseswith lower SOC, max temp (but effect of low heating rate at 5°C/ on the cyclindrical 100%SOC?)



Phase 2 results analysis: gaz

- Gaz analysis: interpertation would need more confirmation
- differences due to format and to SOC, less clear with the heating rate.





Other relevant data

See

- CATL presentation about large cells testing (Oct 2019)
- FAA presentation about gaz production (ref?)

Preliminary conclusions, for discussion

About the lithium batteries hazards characterization

- Tests demonstrate some level of reproducibility of the Thermal runaway hazards, but still need analysis for characterization of it, particularly for gaz composition.
- Some key parameters influencing the hazards per cell, and their propagation, are tested (cell format, cell SOC) but may need to be completed

About the test method:

-the heater method provides a reproducible way to initiate a thermal runaway. Limit of conditions still need to be precised (heating rates, heater types, …)

-the TR obtained by the heater is close to the one obtained by self-propagation, although the propagation time is very different, demonstrating some robustness of the method.

Preliminary conclusions, for discussion

About the reproducibility between labs:

There are much more difference between labs than within a single lab.

The test decription will have to be more specific and precise:

Identified effect of :

- absence of lid on the test chamber
- various efforts for cells compression during test
- (Possibly) heating rate range
- Others to be discussed…

Next steps

-Complete the tests table and analysis (anonymized labs names)

-Circulate to all labs for review

-further elaborate on the pending issues to prepare the December Meeting

- hazards characterization
- method description
- labs comparison

-Others?