Results and Analysis

A new cell gas flammability test

Prepared by Korea

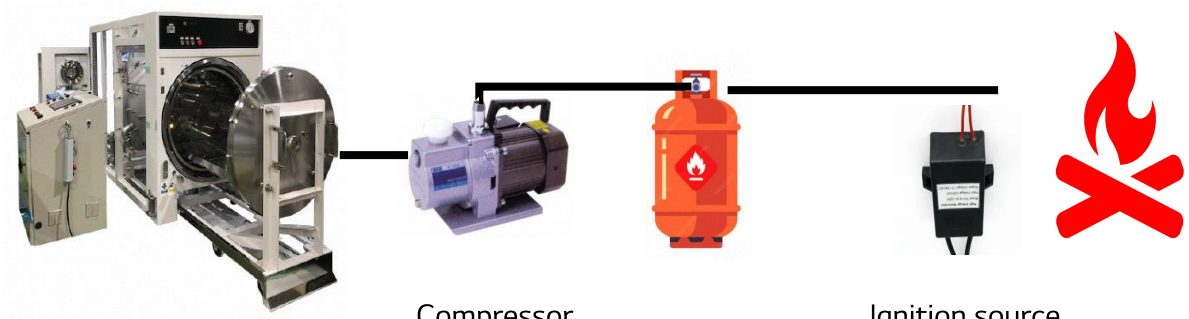
UN TDG IWG

Preliminary Concept Note –
Development Plan for New T13 Cell Flammability Test

☐ Preview

▣ Background

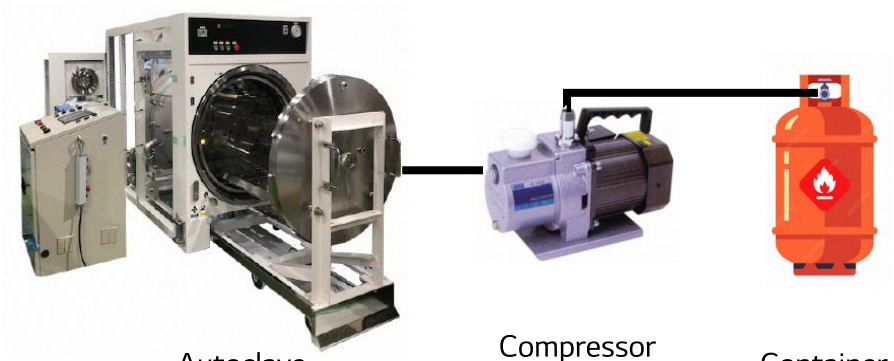
- The following test method was designed based on the concept originally introduced by Americase & Fulcrum.
- In this approach, gases generated after a single cell TR that was triggered using T9/T10 methods are collected and transferred into an approved container.
- An ignition source is then applied to the collected gas, and the persistence of flame after removal of the ignition source (sustained flaming) is observed as the evaluation criterion.



▣ Advantages of the Proposed Test Method

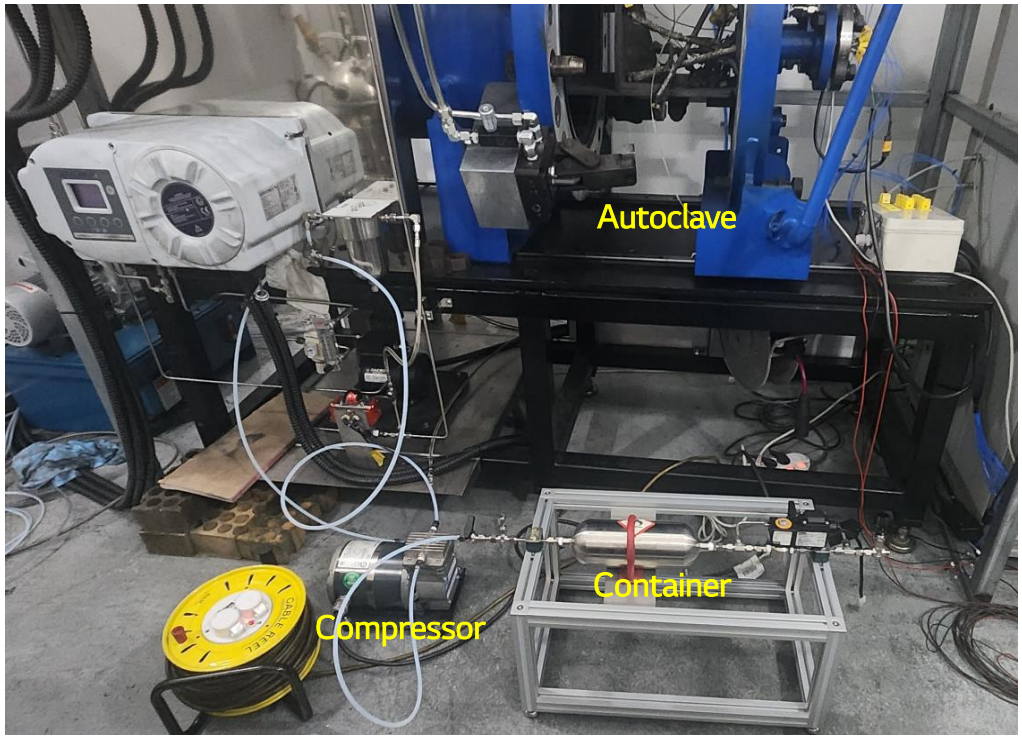
- The proposed method is inherently safe to conduct and cost-effective compared to gas chromatography analysis.
- It also offers better repeatability and reproducibility, ensuring consistent results across laboratories.
- In addition, the collected gas from the gas-volume hazard test can be directly utilized for the gas flammability test, which improves test efficiency and minimizes additional handling.

▣ Test procedure

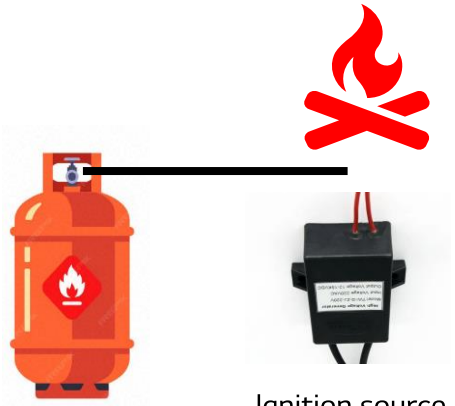


Autoclave | Compressor (Motor pump) | Container

1) To collect gases generated after a single cell TR at autoclave. Then to transfer the gases into a container by using compressor.

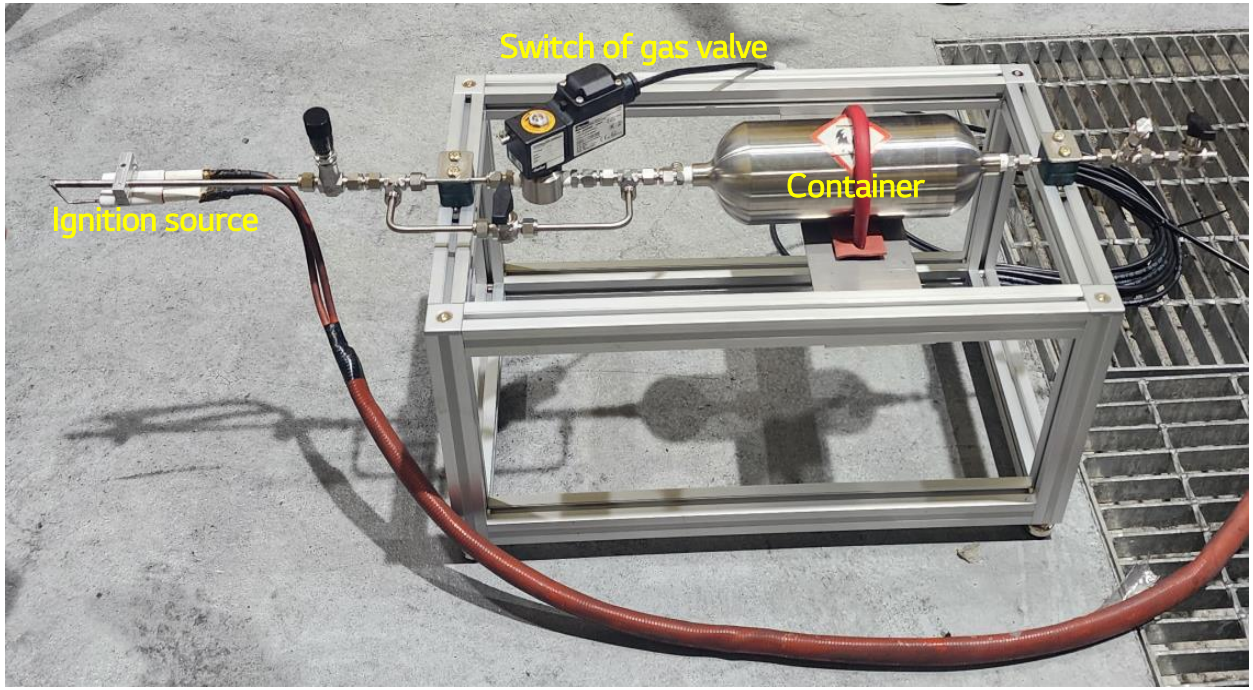


▣ Test procedure



2) To move the container to safe area such as explosion-proof chamber, A ignition source is then applied to the collected gas.

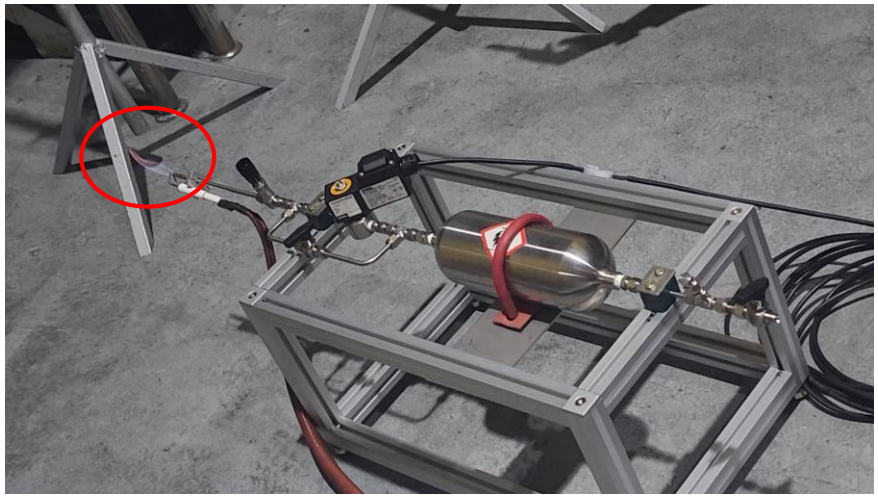
→ If the flame continues to burn after the ignition source is removed, the gas shall be classified as flammable.



☐ Test Results

▣ Pouch A cell

Chemistry	Nominal voltage [V]	Rated capacity [Ah]	Chamber atmosphere	Chamber size [L]	Trigger method	Tested SOC [%]		
						100	50	30
NCM	3.66	67.7	N_2	124	External heater	Flammable (Continued to burn after removal of source)	Non flammable	Non flammable



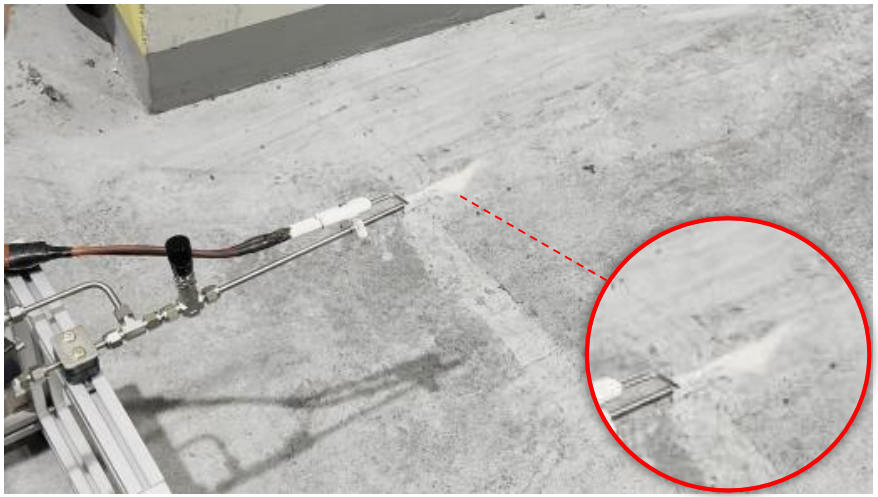
SOC 100% : Flammable

SOC 30% : Non flammable

☐ Test Results

▣ Pouch B cell

Chemistry	Nominal voltage [V]	Rated capacity [Ah]	Chamber atmosphere	Chamber size [L]	Trigger method	Tested SOC [%]		
						100	50	30
NCM	3.74	78	N_2	124	External heater	Flammable (Continued to burn after removal of source)	Non flammable	Non flammable



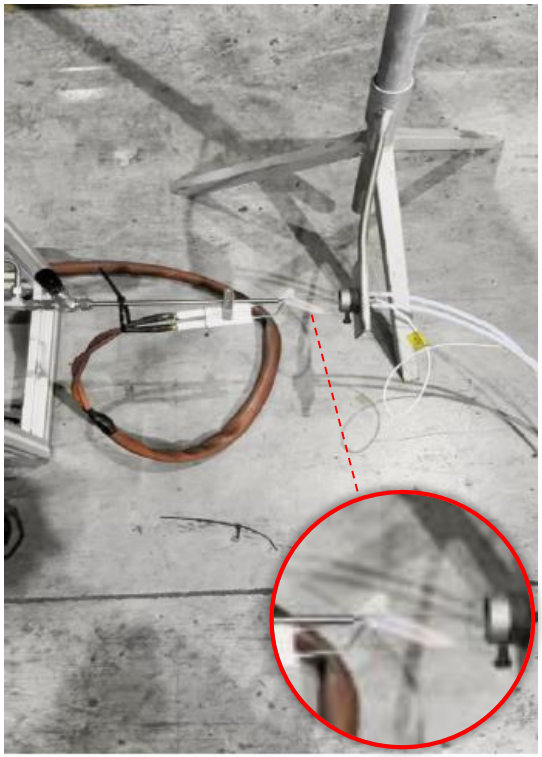
SOC 100% : Flammable

SOC 30% : Non flammable

☐ Test Results

▣ Prismatic cell

Chemistry	Nominal voltage [V]	Rated capacity [Ah]	Chamber atmosphere	Chamber size [L]	Trigger method	Tested SOC [%]		
						100	50	30
NCM	3.7	110	N_2	124	External heater	Flammable (Continued to burn after removal of source)	Non flammable	Non flammable



SOC 100% : Flammable

SOC 50% : Non flammable

▣ Overview of Test Results

Cell type		Pouch A	Pouch B	Prismatic
Chemistry		NCM	NCM	NCM
Nominal voltage [V]		3.66	3.74	3.7
Rated capacity [Ah]		67.7	78	110
Chamber atmosphere		N_2	N_2	N_2
Chamber size [L]		124	124	124
Trigger method		External heater	External heater	External heater
SOC [%]	100	Flammable	Flammable	Flammable
	50	Non flammable	Non flammable	Non flammable
	30	Non flammable	Non flammable	Non flammable

As agreed during the July Sub committee meeting, it was generally acknowledged that all lithium-ion cells release flammable gases under abuse conditions.

However, during the experiments, it was found that not all cells actually generate flammable gases.

In conclusion, sustained flaming was observed at full-charge (100 % SoC), but not at lower shipping SOC levels.

☐ Supplementary Analysis

▣ "Why Gas Composition Differs by SOC in TR Event"

The amount(volume) of gas generated during TR varies with SOC, which leads to differences in gas composition.

Main gas-generation mechanisms:

1. Reaction of released oxygen with cell materials → Formation of **CO_2 and CO**
2. Reaction of lithium with cell materials → Formation of **H_2 and Hydrocarbons**

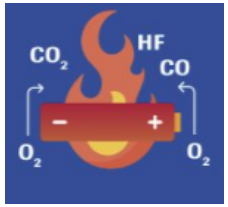
Mechanism		Major Gas
Resource	**Reaction**	**Byproduct**
Cathode	**Oxygen** + EL, Carbon, Flammable Gas..	CO_2, CO, H_2O
Air (≈ Closed chamber/Autoclave)		
Li (by Intercalated & Salt)	Li + PVDF, CMC, H_2O	H_2
	Li + Electrolyte	Hydrocarbon

[Formation of CO & CO_2]

$^5/_2\ O_2$ + EC ⇨ **3 CO_2** + 2 H_2O (Oxidation)

$^9/_2\ O_2$ + EMC ⇨ **4 CO_2** + 4 H_2O (Oxidation)

2 O_2 + EC ⇨ **2CO_2** + **CO** + 2H_2O (Oxidation)



R-OCO_2Li ⇨ Li_2CO_3 + C_2H_4 + **CO_2** + $^1/_2\ O_2$ (SEI thermal decomposition)

H_2 & CO & Hydrocabon + O_2 ⇨ **CO_2** (Combustion of flammable gas)

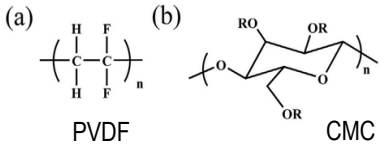
Carbon (Graphite, Binder..) + O_2 ⇨ **CO_2** + **CO** (Combustion of organic materials)

[Formation of H_2]

Li + -CH_2CF_2- ⇨ LiF + -CH=CF- + $^1/_2$ **H_2**

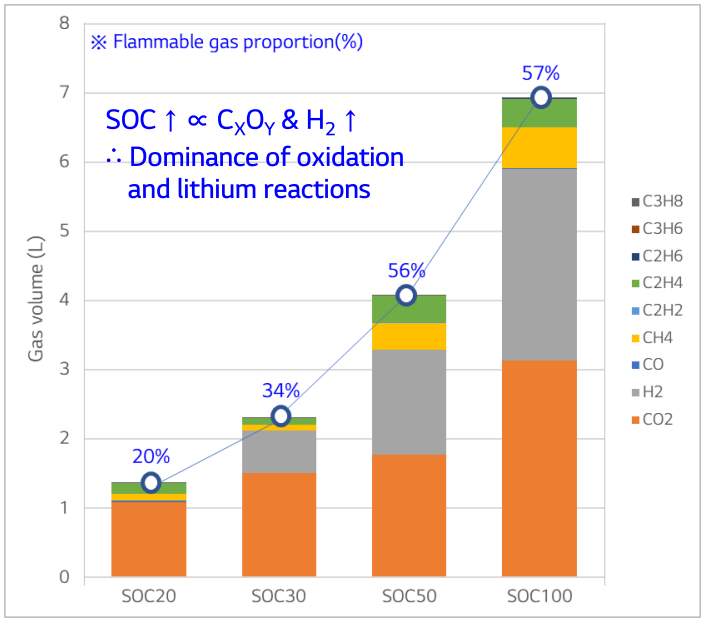
Li + CMC-OH ⇨ CMC-OLi + $^1/_2$ **H_2**

Li + H_2O ⇨ LiOH + **H_2**



[Formation of Hydrocarbon]

2Li + EC ⟶ Li_2CO_3 + **C_2H_4**



Gas Analysis Testing on Lithium ion cells_Korea Extracted from IWG March

T13. Cell Gas Flammability Determination Test

☐ Conclusion

1. The test was designed with reference to ISO standards to verify SOC-dependent gas flammability risks.

2. For both EV pouch and prismatic cells, gases released after thermal runaway were collected and tested using a spark generator to determine whether sustained flame occurred.

3. Across all samples, results showed clear SOC-dependent behavior, and in particular, lower-SOC conditions consistently exhibited a non-flammable characteristic.

4. Theoretically, lower SOC conditions contain less intercalated lithium and salt sources, which likely results in very limited generation of flammable gases.

5. Since the presence of flammable gas is strongly influenced by SOC, hazard evaluation and classification criteria should reflect this SOC dependency.