Hazard-based Classification System for Lithium Batteries

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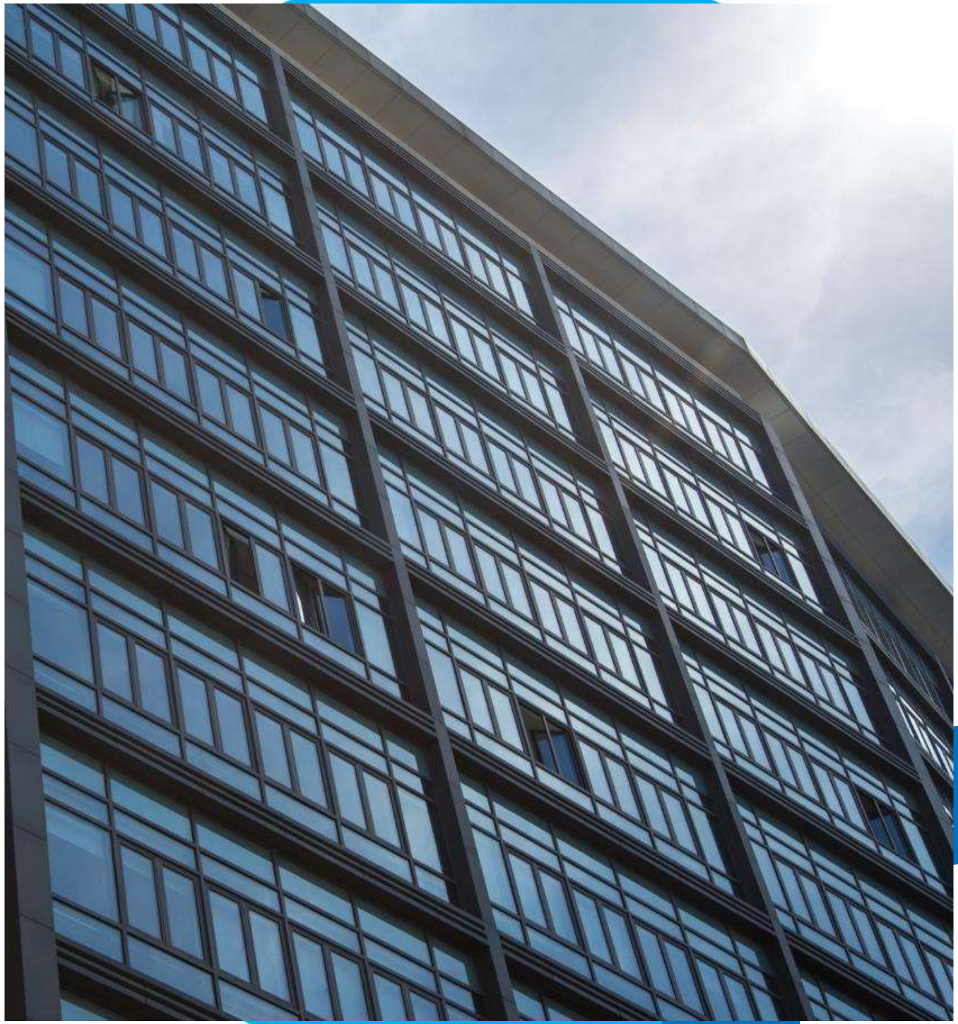
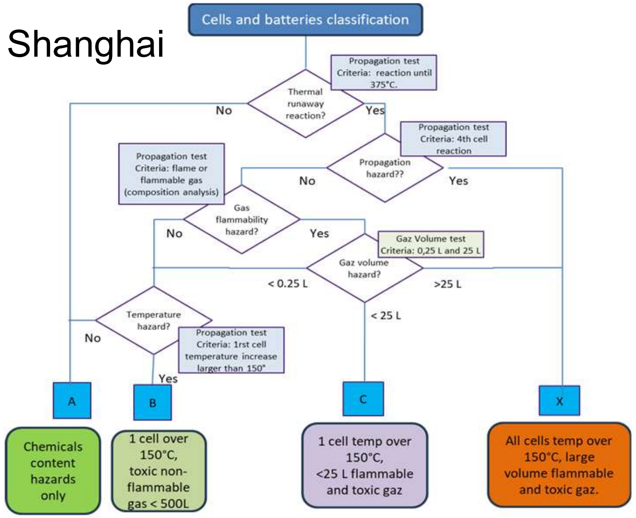


Part 1. Classification System

1.1 Classification flowchart

The classification flowchart has undergone several changes.

2025.03 Shanghai



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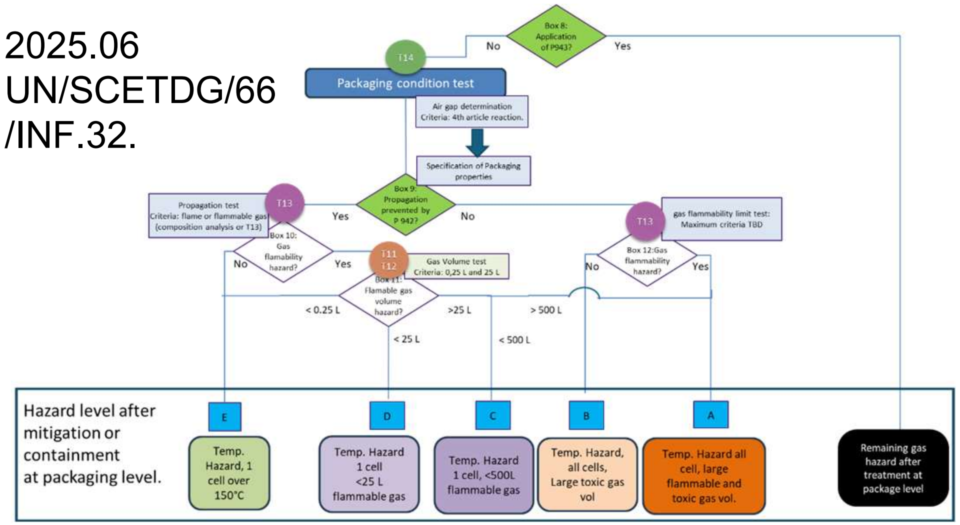
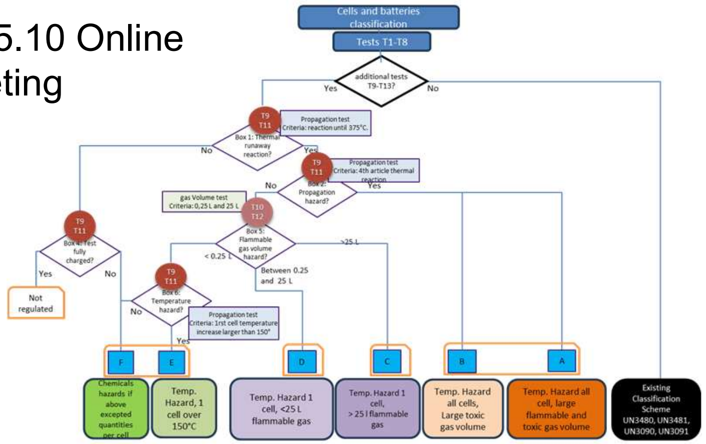


2025.10 Online meeting



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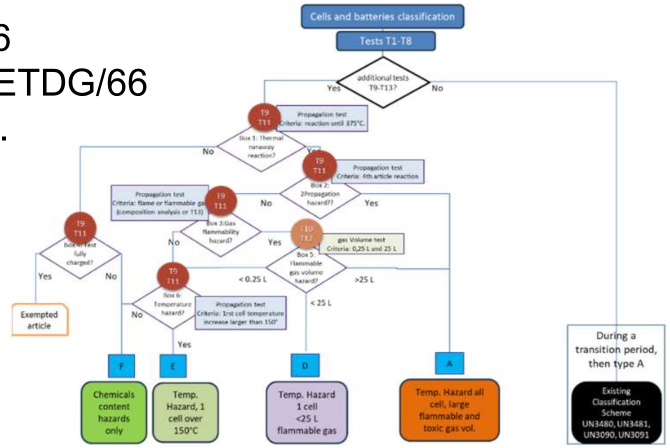


1.2 Classification points

Experts from China pointed out that the classification system is **overly complex.**

We suggest limiting the classification results to **three types** , which is drawn in the document ST/SG/AC.10/C.3/2025/57.

4 Hazard factors

① Thermal runaway & thermal propagation;
② Gas flammability;
③ Gas volume: 0.25, 25, 500L;
④ High temperature: $\Delta T>150℃$;

6 Tests

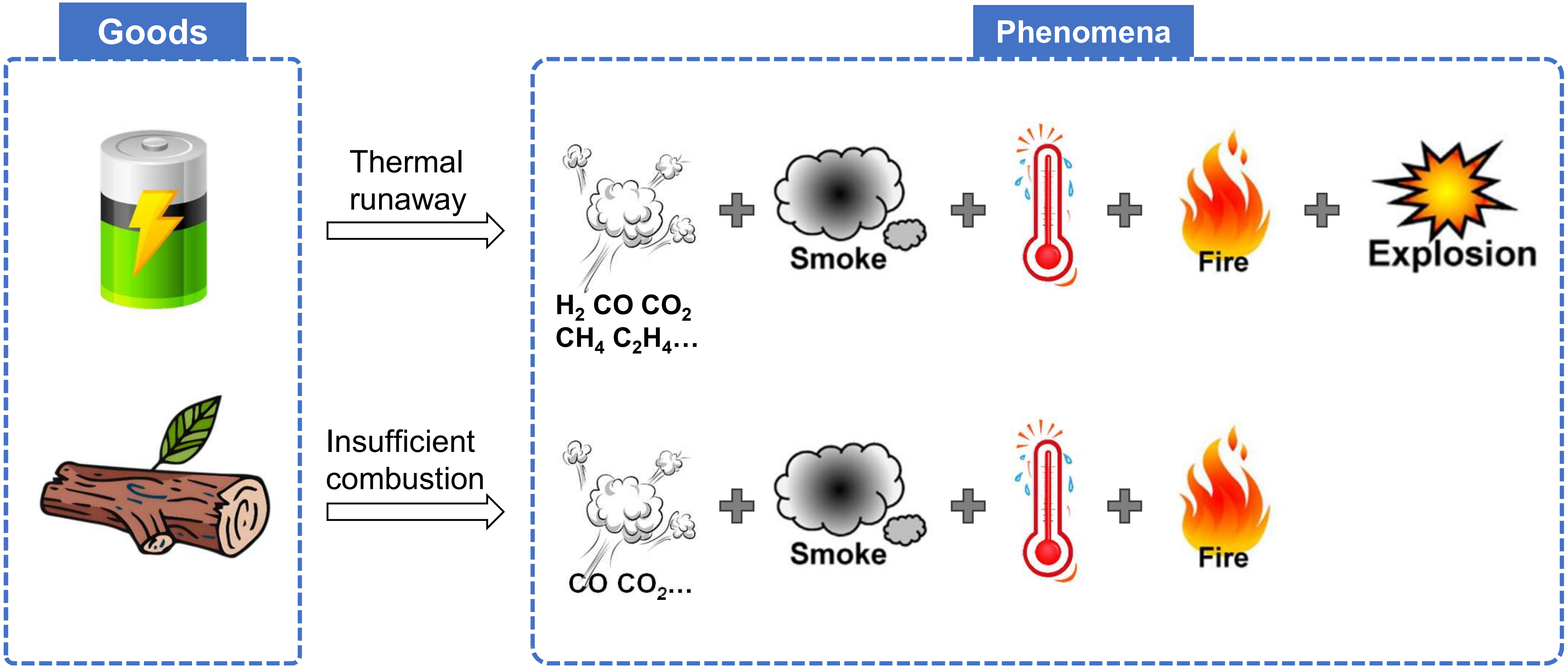
① Test T.9: Cell propagation test
② Test T.10: Cell gas volume determination
③ Test T.11: Battery propagation test
④ Test T.12: Battery gas volume determination
⑤ Test T.13: Cell gas flammability determination
⑥ Test T.14: Air gap determination

ST/SG/AC.10/C.3/2025/57, Comments on the hazard-based system for classification of lithium batteries, transmitted by the expert from China

1.3 Inherent Hazrad

Q: What are the sources of danger of lithium batteries?

The inherent hazard of lithium batteries originates from **thermal runaway**, while gas (flammability, volume), high temperature, and fire are the accompanying phenomena.



1.4 Terms and Definition

Thermal runaway (TR)

Uncontrollable rise in temperature of a cell/battery driven by inside exothermic chain reaction, usually accompanied by exhaust, smoke, fire or explosion.

Note 1: The temperature at which thermal runaway occurs is considered as the critical point;
Note 2: Generally, "uncontrollable" means the maximum temperature rising rate exceeds 10 ℃/min;
Note 3: For battery, module or battery pack, the occurrence of thermal runaway at the cell level(any component cell) is considered to be the occurrence of thermal runaway of the entire unit.

Reference :

IEC 62619-2022: Uncontrolled intensive increase in the temperature of a cell driven by exothermic reaction.

UL 2596-2023, UL 9540A-2018, (UL1973-2022): The incident when an electrochemical cell increases its temperature through self-heating in an uncontrollable fashion. The thermal runaway progresses when the cell's generation of heat is at a higher rate than the heat it can dissipate. This may lead to fire, explosion, and gas evolution (gassing).

GB 38031-2020: 电池单体放热连锁反应引起电池温度不可控上升的现象。The phenomenon of uncontrollable temperature rise caused by the exothermic chain reaction of a cell.

Thermal propagation (TP)

Thermal runaway spread consecutively from one cell to nearby cell(s).

Note 1: Also known as thermal runaway propagation.
Note 2: Battery thermal propagation begins with the component cells thermal runaway or thermal propagation, which is also a kind of strict situation.

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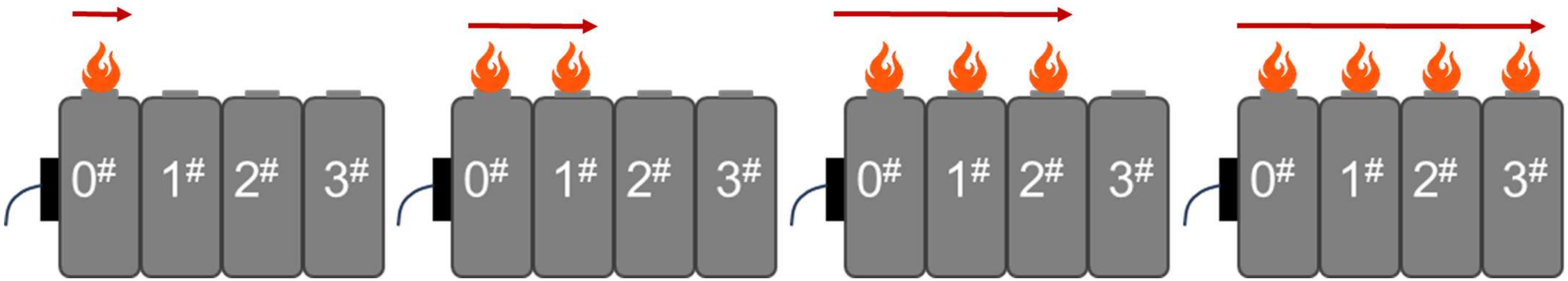
Q: Is it necessary to conduct the T.9 test?

The inherent hazard of lithium cells/batteries is **thermal runaway (TR)/ thermal propagation(TP)**, so the **T.9 Cell propagation test** should be focused on how many cells experienced thermal runaway or how far the propagation reaches?

Therefore, **T.9 test must be done.**



1.6 Gas volume

Q: Is it necessary to conduct the T.10 &T.12 tests?

$$\text{-CH}_2\text{-CF}_2\text{-} + \text{Li} \xrightarrow{\Delta H} \text{LiF} + \text{-CH=CF-} + \frac{1}{2}H_2$$

$$\text{CMC-OH} + \text{Li} \xrightarrow{\Delta H} \text{CMC-OLi} + \frac{1}{2}H_2$$

$$\frac{5}{2}O_2 + C_3H_4O_3(\text{EC}) \xrightarrow{\Delta H} 3CO_2 + 2H_2O$$

$$\text{ROCO}_2\text{Li} + \text{HF} \rightarrow \text{ROH} + CO_2 + \text{LiF}$$

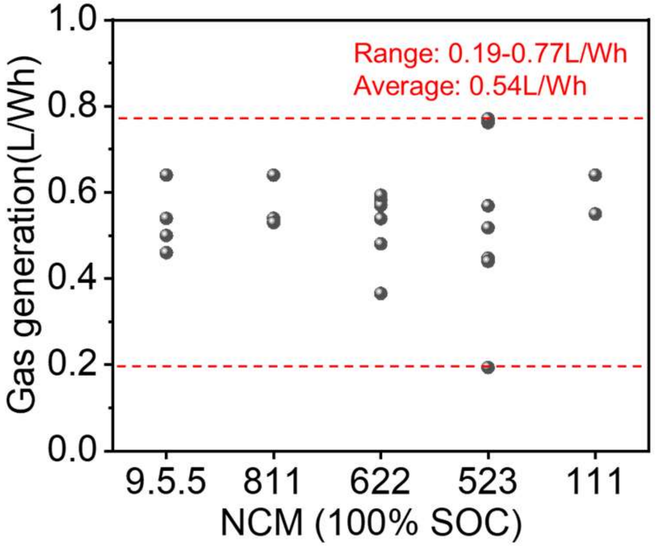
$$\text{POF}_3 + \text{solvent} \rightarrow CO_2 + \text{phosphate}$$

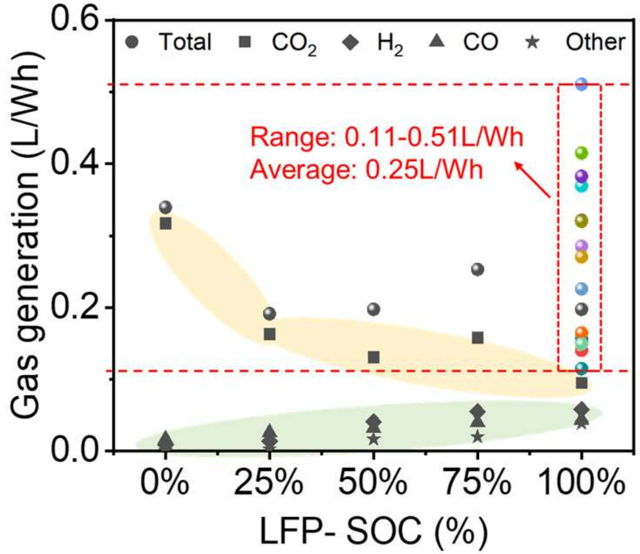
$$(CH_2OCO_2Li)_2 \xrightarrow{\Delta H} Li_2CO_3 + C_2H_4 + CO_2 + \frac{1}{2}O_2$$

$$2Li + C_3H_4O_3(\text{EC}) \rightarrow Li_2CO_3 + C_2H_4$$

$$2Li + 2C_3H_4O_3(\text{EC}) \rightarrow (CH_2OCO_2Li)_2 + C_2H_4$$

$$2CO_2 + 2Li^+ + 2e^- \rightarrow Li_2CO_3 + CO$$





- ☐ Base on the mechanism, almost all gas reactions are involved with Li metal or compounds, which is correlated with the nominal energy E_n;
- ☐ From papers, the volume of gas produced during TR per unit-energy of lithium battery is relatively stable. And, the **specific gas volume per unit-energy V_E** is proposed: $\boldsymbol{V}_{E\text{-}NCM}$=0.54L/Wh， $\boldsymbol{V}_{E\text{-}LFP}$=0.25L/Wh;
- ☐ Therefore, **the T.10 and T.12 are also not necessary**.

1.6 Gas volume

Q: Is there a quick way to estimate gas volume?

- The **constant** $\boldsymbol{V}_{\mathbf{E}}$ can be used to evaluate the gas volume by the nominal energy very quickly, instead of tests.

e.g. For a lithium-ion cell with E_n=80Wh, $\boldsymbol{V}_{\text{E-NCM}}$=0.54L/Wh，$\boldsymbol{V}_{\text{E-LFP}}$=0.25L/Wh;

The generated gas $\boldsymbol{V}_{\mathbf{g}}$ during TR is about

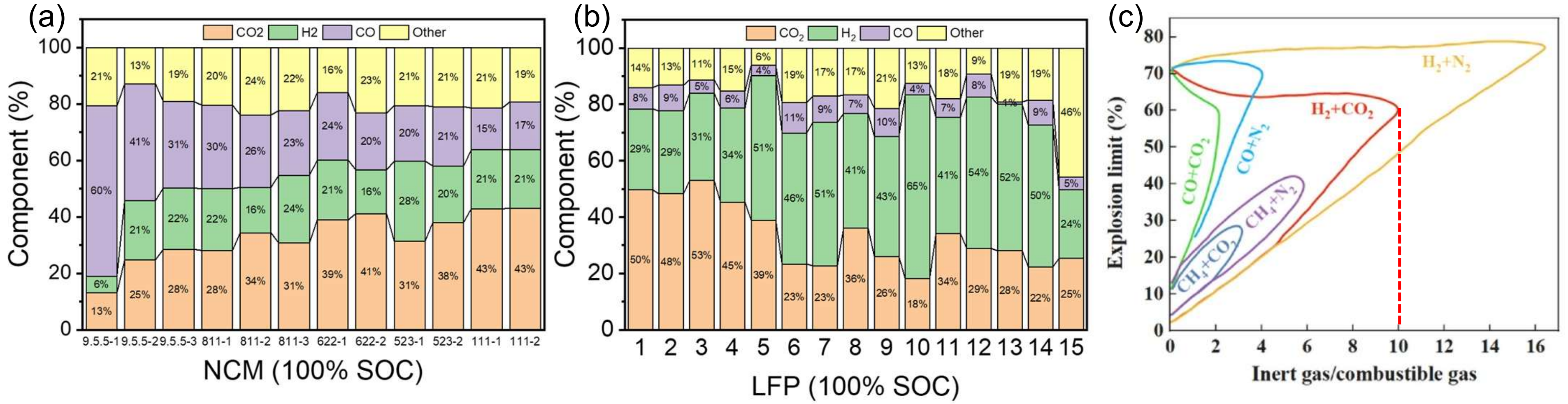
(1) NCM: 80×0.54=**43.2L** (2) LFP: 80×0.25=**20L**

- In the recent several meetings, the threshold value ($\boldsymbol{V}_{\mathbf{E}}$) is set as 0.75L/Wh for all types cells/batteries, maybe it need to be discussed further?

As reviewed above, the threshold value ($\boldsymbol{V}_{\mathbf{E}}$) of cells such as NCM & LFP & SOC is of big difference, maybe it should be set according to the electrochemical systems like NCM, LFP, Na-ion cell etc.

1.7 Gas flammability

Q: Is it necessary to conduct the T.13 test?



NCM CO_2/H_2 (v:v)=**1.11~2.56**

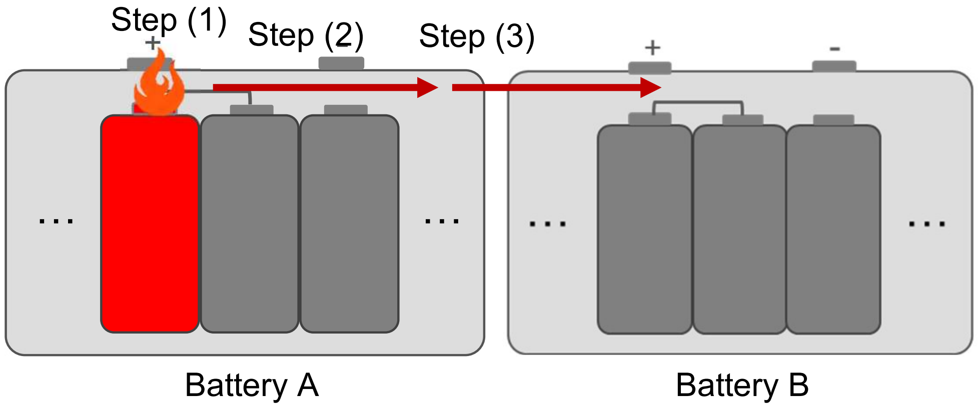
LFP CO_2/H_2 (v:v)=**0.28~1.72**

CO_2/H_2 (v:v)**>10**,
Nonflammability

- From Papers: The volume ratio of CO_2/H_2 from NCM<10， CO_2/H_2 from LFP<10；
- According to the explosion limit curve diagram of the mixed gas (Figure c), if the volume ratio of CO_2/H_2 is less than 10, then the mixed gas is flammable;
- Therefore, **the T.13 gas flammability test is not necessary**.

1.8 Battery TP

Q: Is it necessary to conduct the T.11 test?



Battery TP process means TR from one battery to another:

Step (1): One cell inside (battery A) go thermal runaway;

Step (2): Component cells (battery A) go thermal propagation;

Step (3): One cell inside (battery B) is triggered to thermal runaway by battery A.

Note 3 in TR definition：For battery, module or battery pack, the occurrence of thermal runaway at the cell level(any component cell) is considered to be the occurrence of thermal runaway of the entire unit.

The **battery thermal propagation** is also originated from cell thermal propagation, so, it should be focused on **the thermal propagation hazard of the component cells step (2), instead of step (3).**

Thermal propagation (TP)

Thermal runaway spread consecutively from one cell to nearby cell(s).

Note 1: Also known as thermal runaway propagation.

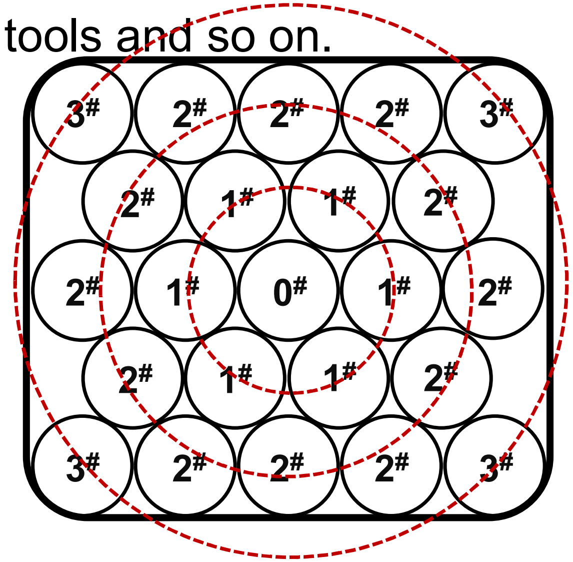
Note 2: <u>Battery thermal propagation begins with the component cells thermal runaway or thermal propagation, which is also a kind of strict situation.</u>

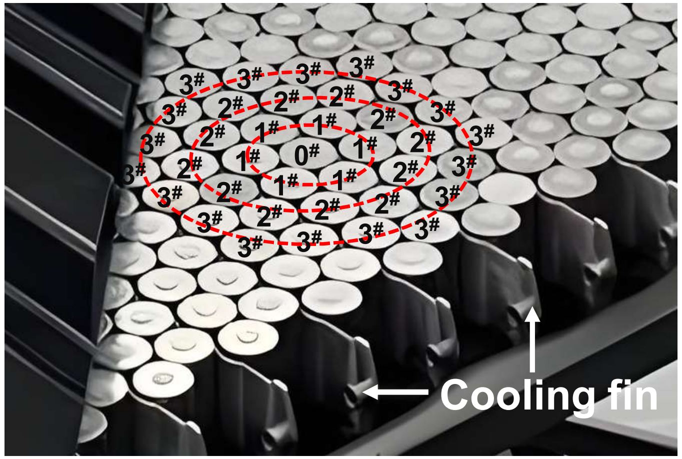
1.8 Battery TP

Q: Is it necessary to conduct the T.11 test?

- For **large battery** composed by many cells such as the three figures below, it is better to carry out the TP test using **the actual battery product** to verify how far the thermal propagation could be in the battery.
- Therefore, **the T.11 test using the actual battery is necessary** in this situation.

Note: it is not applicable to the small batteries for smartphone, notebook computer, electric tools and so on.

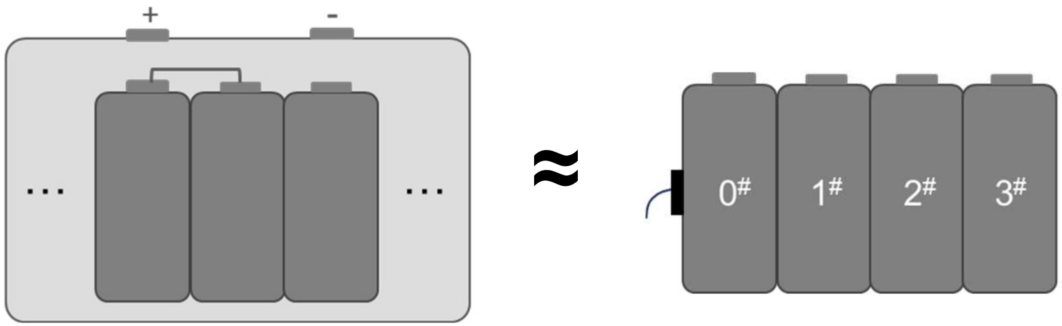




Q: Is it necessary to conduct the T.11 test?

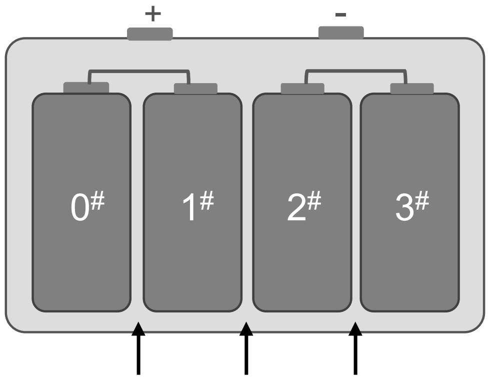
For Small Battery

It can use the result conduct **by T.9 with component cells** directly.

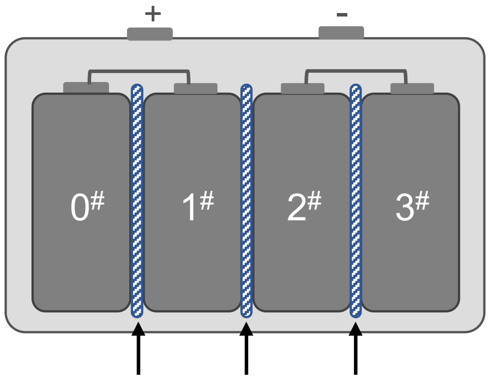


Q: Is it necessary to conduct the T.14 test?

- For **batteries with safety designs**, the relevant measures include but are not limited to increasing the battery gaps, adding liquid cooling/flame-retardant/thermal insulation plates or decrease the contact surface etc (like the two figures below). These batteries should be tested using **the actual battery** during transportation**.**
- Therefore, **T.14 can be merged into T.11 test.**



Air gaps



Liquid cooling/Flame-retardant/Thermal insulation plates

1.9 Brief Summary

✓ Simplified Criteria: 4 to 1

Only the **Thermal Propagation (TP)** is considered as the inherent hazard factor instead of gas, high temperature and flammability.

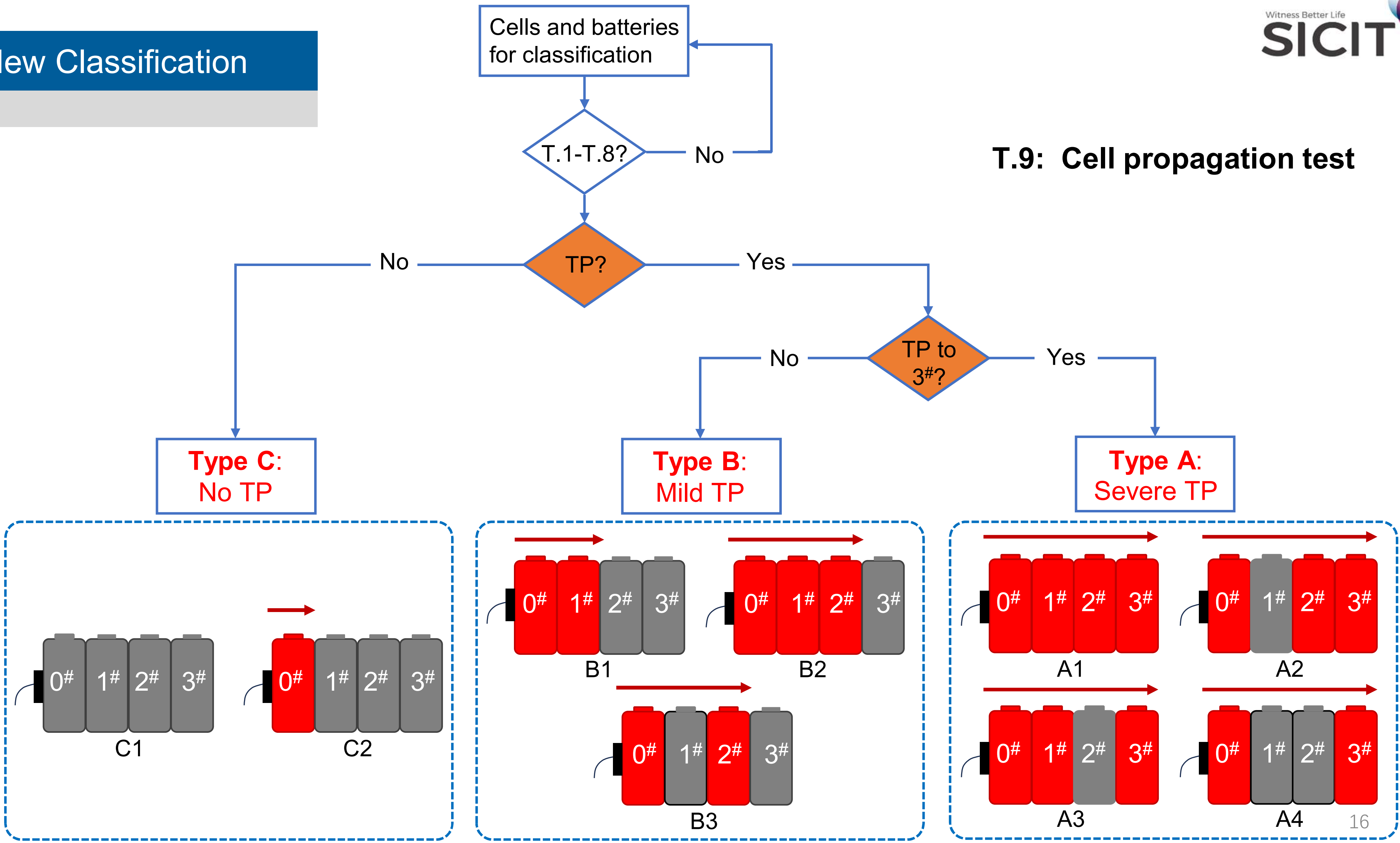
✓ Reduced Test Items: 6 to 2

T.9+T.11, cell/battery thermal propagation would be applied to propose a new **classification system with 3 types**.

The **constant V_E** can be used to evaluate the **gas volume** by the **nominal energy** very quickly, instead of tests.

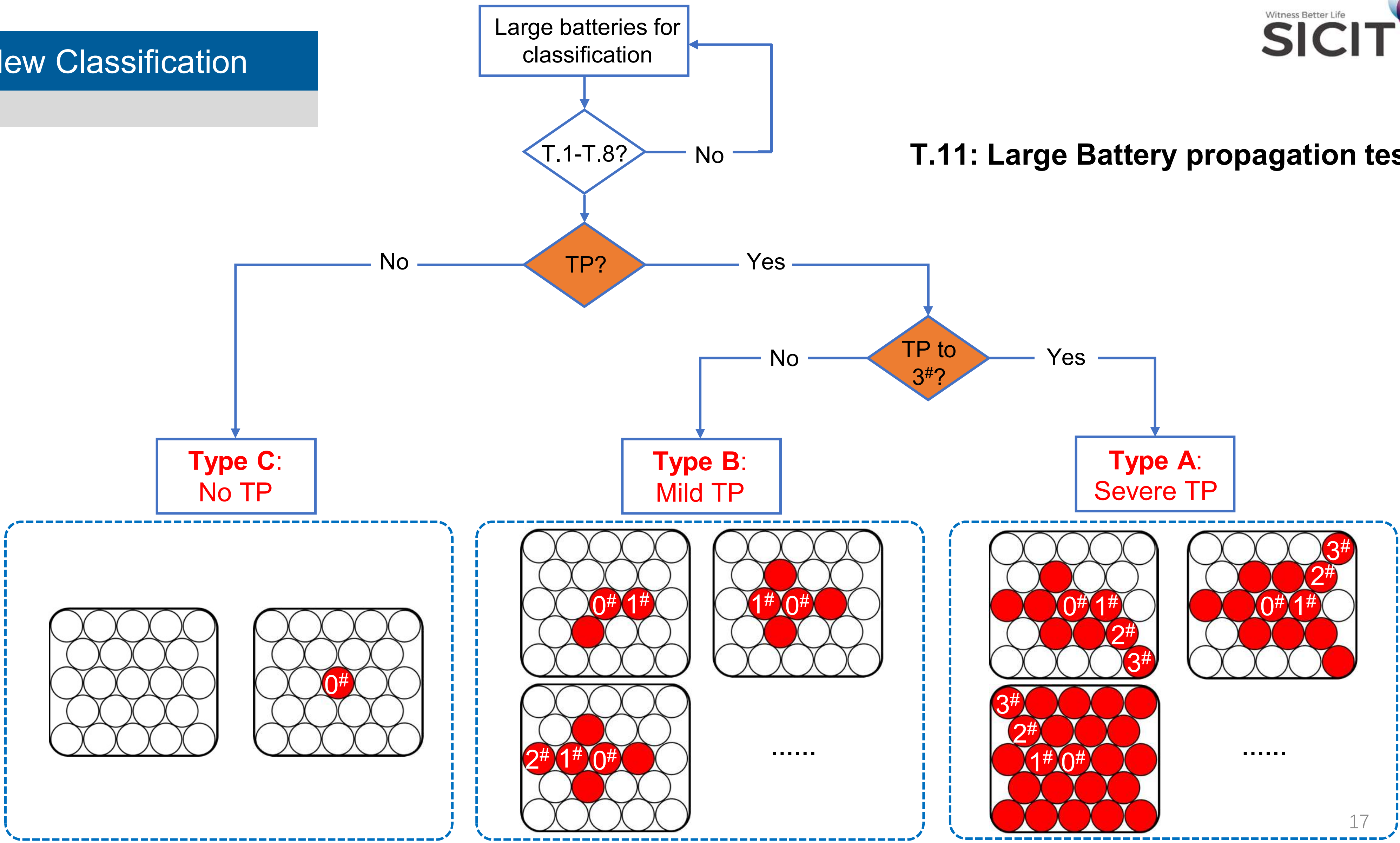
1.11 New Classification

T.9: Cell propagation test



1.11 New Classification

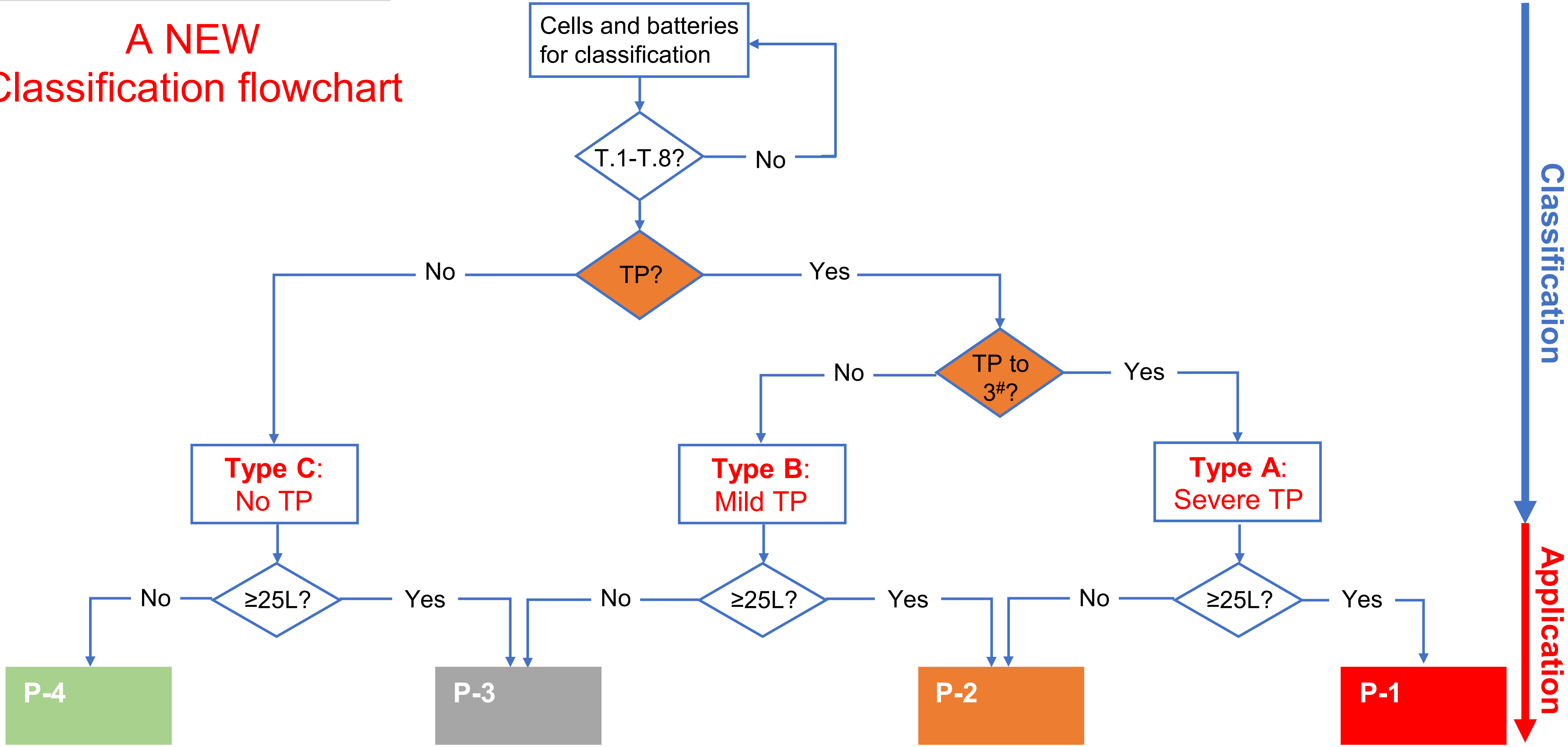
T.11: Large Battery propagation test



1.11 New Classification

A NEW Classification flowchart

A new hazard classification system (3 types) has been proposed based on cell/battery thermal propagating distance.



Thanks for your listening!

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