Next-Gen BESS Thermal Management: Revolutionizing Cooling Technique to resolve the Cost-Efficiency-Safety Conundrum

ASEAN Battery Safety & Innovation Conference 2025

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- Background & Industry Insights
- Our Solution
- Data
- Cost-Efficiency-Safety
- Theoretical Innovations

1.Background & Industry Insights

Pain Points 1- Coolant leakage and condensed water induced short circuit may cause fire.

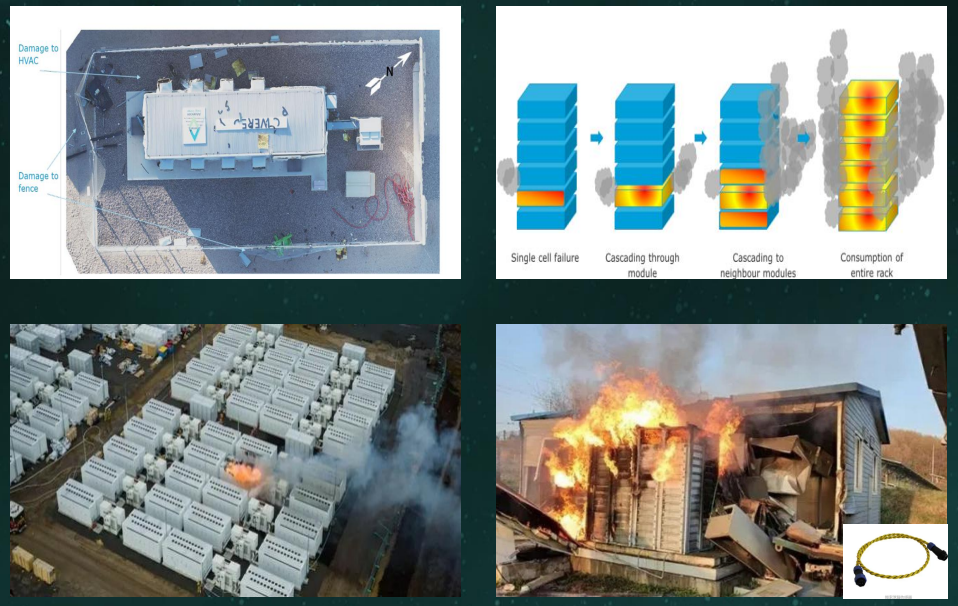


Figure 1. Aerial view of Damaged APS BESS (2019); DNV investigated Report for APS' s TR hazards; Victorian Big Battery failure (2021); One Korean NCM BESS station caught on fire; coolant leakage detector with a leakage detector (clockwise)

- According to US DOE and NFPA investigated data (2023-2024)
  - Over **70%** resulted from Thermal Runaway (TR)
  - **3-5%** due to Coolant leakage
  - over **2%** stemed from condensed water
- The current configuration has **limited** leakage detection or fire alarming

- *2019 McMicken fire cascated and injured several fire fighters*
- *2021 Megapack on fire for over 4 days*
- *2023 57MWh Newark ESS fire accident*
- *2025 Moss Landing Power Plant massive fire be sued by residents*

Resource: DOE/NFPA 2023

1. Background & Industry Insights

Pain Points 2- High cell grid temperature reduces battery cell cycle life

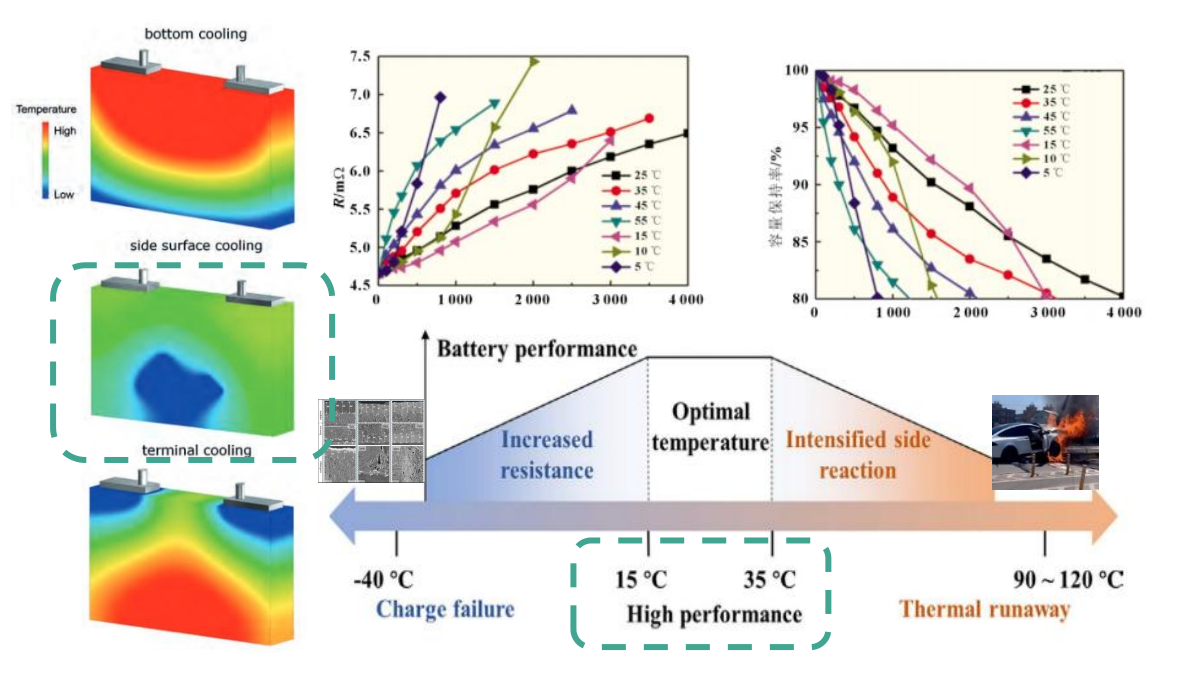


Figure 2. Simulated Temperature for prismatic cell using various cooling plate layout (left); The cold, optimal, hot temperature diagram for various battery performance (right).

Based on research data and battery manufactures' latest product release:

1. **ΔT>10 ℃** would lead to irreversible damage to the cell
2. **ΔT>5 ℃** will lead to **10% -20%** of decrease of cycle life
3. Current thermal management layout results in cell **ΔT > 8 - 10 ℃**

Resource: Prof. Ouyang Mingao's Lab; SicenceDirect.com

1. Background & Industry Insights

Trend 1 – Larger cell capacity requires more efficient thermal management

500+，600 +，1000 + Ah

6MWh+

5MWh+

314 Ah Cell

AI Thermal Management

500kWh+

280Ah Cell

Immersion Cooling

100Ah Cell

200kWh+

Direct Cooling (PCM)

Liquid Cooling (SPM)

Natural Cooling

National Energy Administration (NEA) prediction:

- 2024/2030 predicted global new energy installation:
  - 67GW/**155GWh**
  - 137GW/**445GWh**
- Battery Cell： Cell Capacity ↑, Cost ↓
- ΔT increases with the increase of cell capacity (**280Ah**, **314Ah, 587Ah** to **1175Ah** etc) .

Resource:
2024 National Energy Administration, 2024 World-Power Battery Conference Yibin,/2025 ESIE Beijing

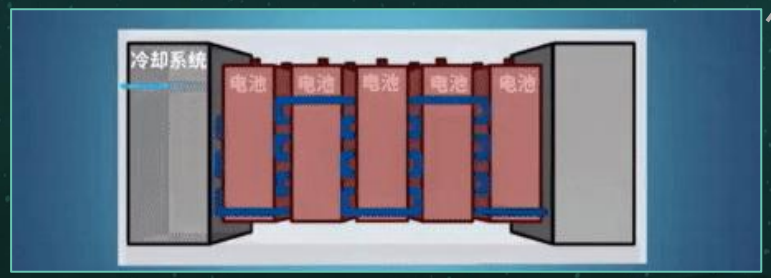
1. Background & Industry Insights

Trend 2 –Immersion Cooling is identified as next generation of thermal management

Air Cooling→Liquid Cooling

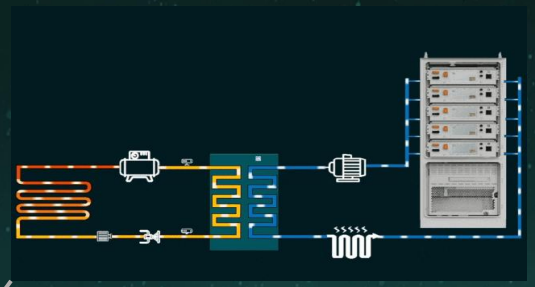
Low Efficiency
High ΔT

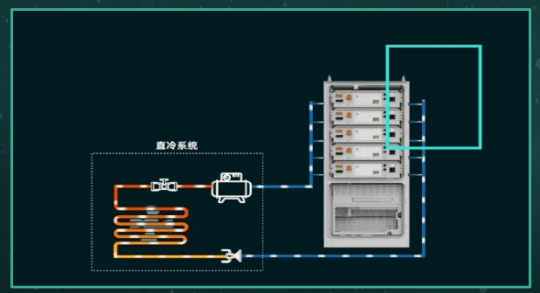
Mature Design & Manufacture
Coolant leakage risk



→Direct Cooling （PCM）

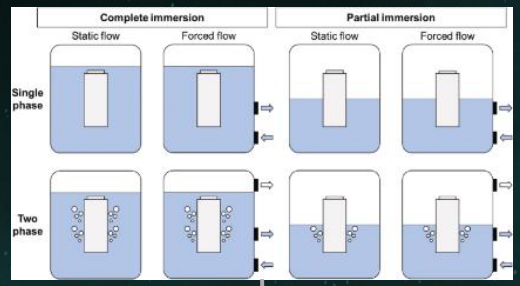
COP increase 30% increase in COP
No leakage
High ΔT





→Immersion Cooling

Consistent temperature control
Better TR protection
High Cost



resource：ESCN.com

2.Our Solution

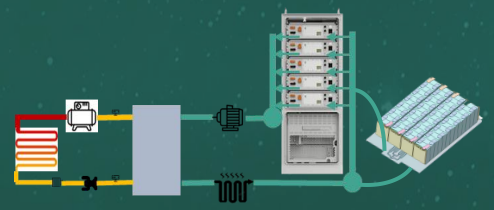
QAES thermal management innovation resolves the conundrum of cost, efficiency and safety

2022.12 — 2024.09 — 2025. 01 — 2025. 06

Air and Liquid Cooling

- Mature manufacture
- Low cost
- Low efficiency
- Coolant leakage risk

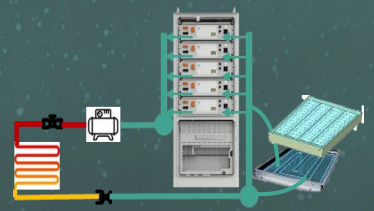
- Cell top-bottom > 8℃
- Cell Cycle life is limited/impaired
- Condensed water risks



Bottom Liquid Cooling System for Container BESS

Direct Cooling (V1.0)

- High efficiency
- No leakage risk



1st BESS using Direct Cooling System in Chongqing by QAES Sep 2024

Direct Cooling (V2.0)

- ΔT < 2℃
- Over 10% increase in cell cycle life
- No condensed water (Pack)

1st direct/liquid - Side Cooling System (global) by QAES Jan 2025

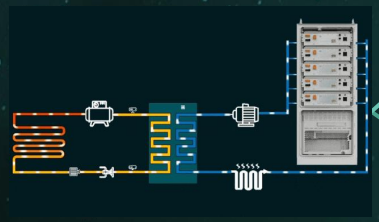
Immersion Cooling (V3.0)

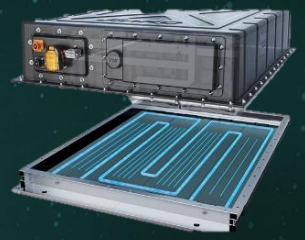
- ΔT < 1.5℃
- Over 20% increase in cell cycle life
- NO condensed water (System)

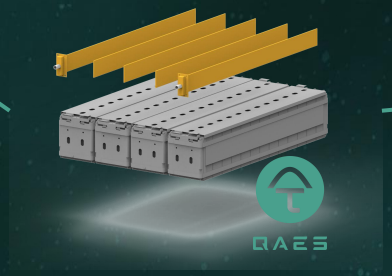
QAES innovated Immersion Cooling for BESS Jun 2025

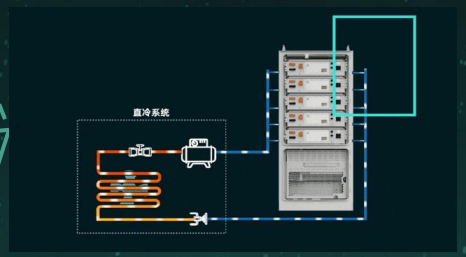
2.Our Solution

How to achieve over 45% improvement in COP and reduce heat exchange time









- Current liquid cooling system requires multiple (> 2) heat conversion
- *Coolant* temperature stays COP≈2.0 (45℃)

- Direct Cooling uses only ONE cycling system and refrigerator (r134a etc)
- *Refrigerator* temperature remain COP≈3.3 (45℃)

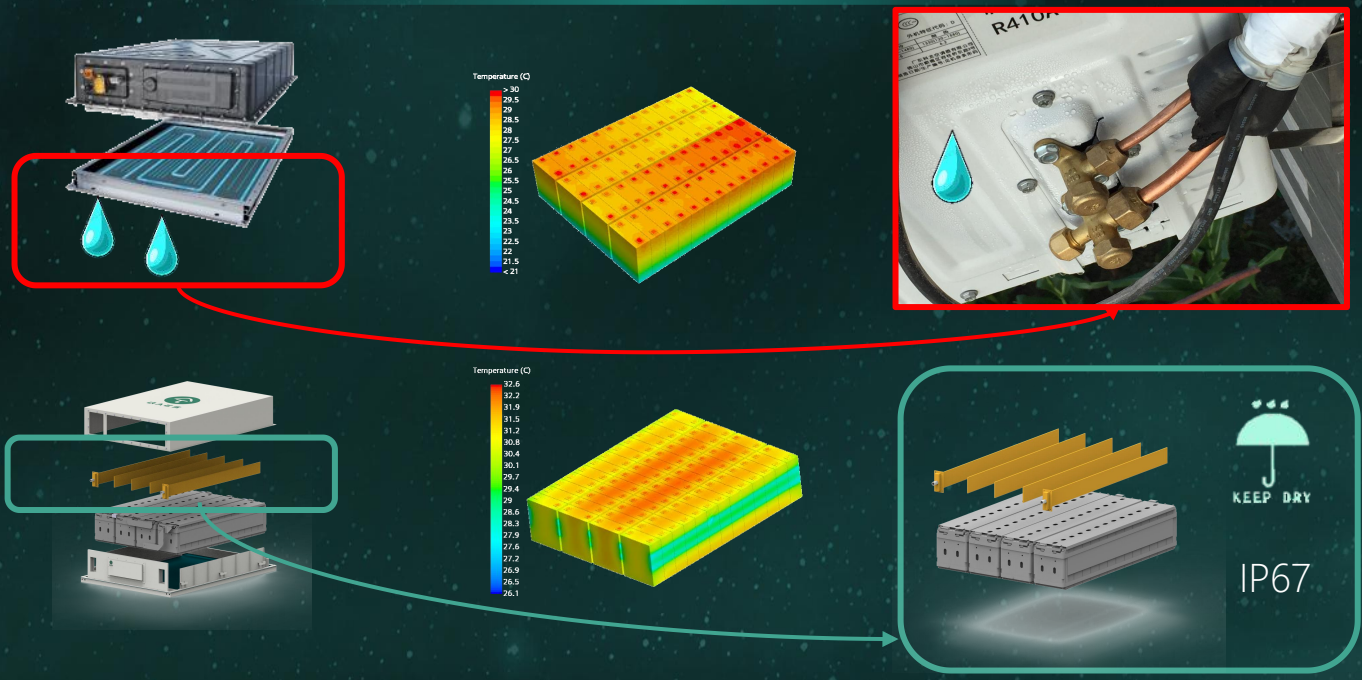
- Side Cooling plate layouts allow additional 20% in COP

Resource: XXXX

2.Our Solution

How to eliminate condensed water formation

30% RH at IP55 Cabinet (Based on Enthalpy Diagram)



47% RH within IP67 PACK (Based on Enthalpy Diagram)

- With the traditional cooling plate (bottom), the coolant temp. is set at 18-20℃, w.r.t 30℃ Cell Temperature, Environ
- With the Side Direct Cooling plate, the coolant/refrigerator temp. is set at 25℃, w.r.t 35℃ Cell Temperature
- QAES's innovative design eliminate condensed water

2.Our Solution

Immersion cooling effectively halts TR with no explosion/flames even with NCM cells

- GB/T 36276 certified Pack, tested with manual ignition to verify firefighting capability
- Fire is observed (LFP/314Ah)

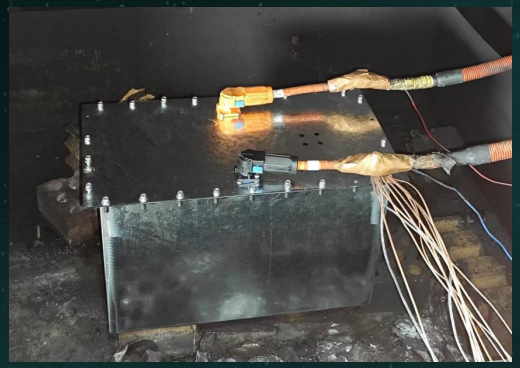
- Under the same testing conditions
- Pack using immersion fluid gives out smokes only
- No fire or explosion is observed (NCM811/156Ah)

2.Our Solution

Immersion Cooling halts TR with no explosion/flames by decrease in T2 and delay of TR triggering time (LFP 314 Ah)

- Over 70% decrease in TP maximum temperature using immersion cooling flui+ds (T at Busbar)

- Over 29% decrease in TP maximum temperature with immersion cooling fluids（T at cell center surface)



Temperature measured at Busbar

Temperature measured at Cell Center Surface

	H（mm)	Material	Tmax（℃) at Cell Center Surf	Tmax（℃) at Busbar for Trigger Cell
Immersion Cooling Fluid #1	X	Foam	445	128
	X	Aerogel	465	148
Immersion Cooling Fluid #2	X	Foam	432	160
Contrast #1	/	Foam	632	498
Contrast #2	/	Aerogel	628	305

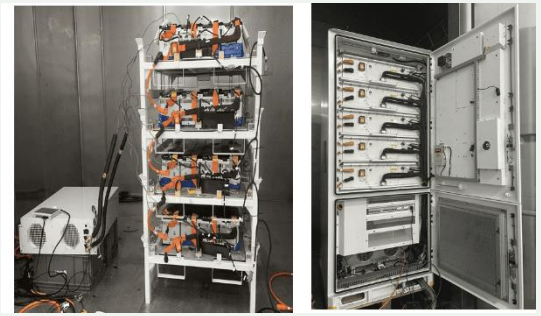
3.Data – QAES Simulation vs Real-World Performance Data

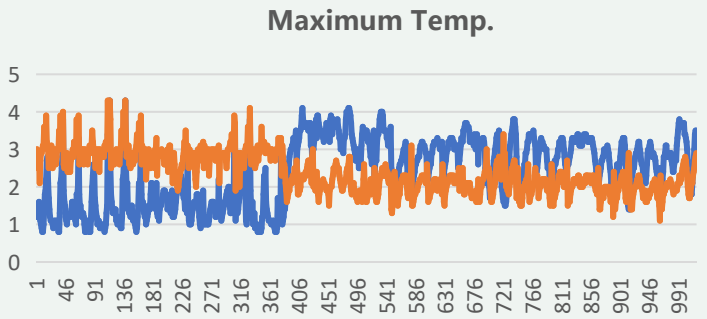
Simulation Drive Design – 90%-97% accuracy & 35% COP improvement

Cooling Methods	QAES – Luminary Ultra landed in Gaoxin District, Chongqing			QAES-Simulation		
	Measured Data Tmax (℃)	Measured Data ΔT (℃)	Cooling Strategy (℃)	Tmax (℃)	Tmin (℃)	PACK △T (℃)
QAES Direct Cooling V1.0	34.8	1.8	33	34.7	32.7	2.0
QAES Liquid Cooling V1.0	33.9	2.5	30	34.5	31.8	2.7

- By comparing the simulation predictions with actual operational data from the Luminary Ultra 233 unit deployed at Gaoxin District, Chongqing, it is verified that the simulation accuracy exceeds 90%.
- The actual COP improvement reaches 39%, surpassing the simulation prediction of 35%

Liquid Cooling BESS vs QAES Luminary Ultra (Direct Cooling V1.0)

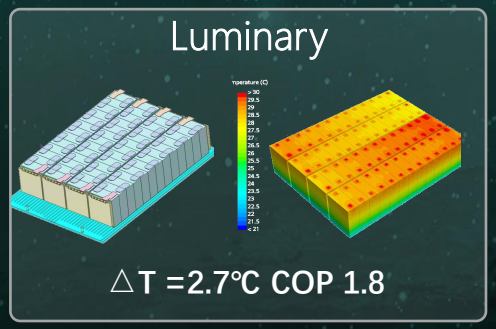


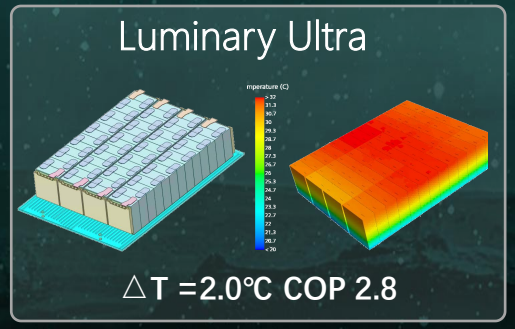


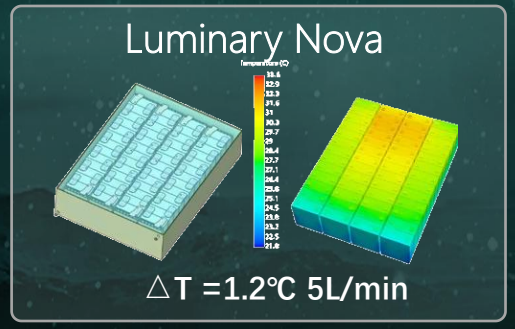
3.Data – QAES Simulation vs Lab Test Data

Simulation Drive Design –Liquid Cooling → Direct Cooling → Immersion Cooling

QAES - PACK	Lab Data					Simulation Prediction			
	Tmax (℃)	Tmin (℃)	PACK △T (℃)	Cell △T (℃)	Cooling Strategy	Tmax (℃)	Tmin (℃)	PACK △T (℃)	Cell△T (℃)
Luminary	35	32	2.4	8.5	20℃	35	32	2.7	9.7
Luminary Ultra - Direct Cooling	34	33	1.5	8.7	23℃	33	32	1.7	9.5
Luminary Nova - Immersion	/	/	/	/	25℃	33	31	1.6	1.0







4.Cost Efficiency Safety

The enhancement - a safer system, with better efficiency, cost the same as traditional liquid cooled BESS

- The same performance in the same form factor – all-in-one **100 kW/233 kWh**
- **Higher** efficiency and **Safer** fire suppression using **QAES Integrated IMMERSION COOLING Design**
- **MINIMAL COST INCREASE** achieved through meticulous engineering efforts
- **HASSLE-FREE MAINTENANCE** - No need to replace the fluid (the cooling oil) over the whole product lifespan.
    - Bio-degradable fluid
    - Suitable for cells of larger capacity
- **Economic Gain** - 10-20% increase in BESS cycle life

4.Cost Efficiency Safety

Features and Applications of the Next Gen Thermal Design – Direct Cooling with Immersion Cooling

Reduced Installation Cost and Better ROI

ΔT < 1.5℃ - Long Cycle Life ↑20%
0 Thermal Propagation
Higher Efficiency- Minimal Cost Increase

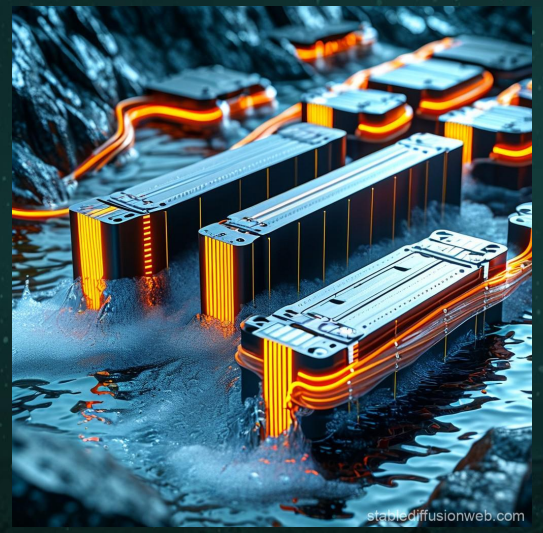
0.5P Energy Station

Zero Fire Hazard

Max DOD over Life Cycle

QAES Direct Cooling & Immersion Cooling
Better Efficiency

Enhanced safety thanks to immersion cooling
No TP

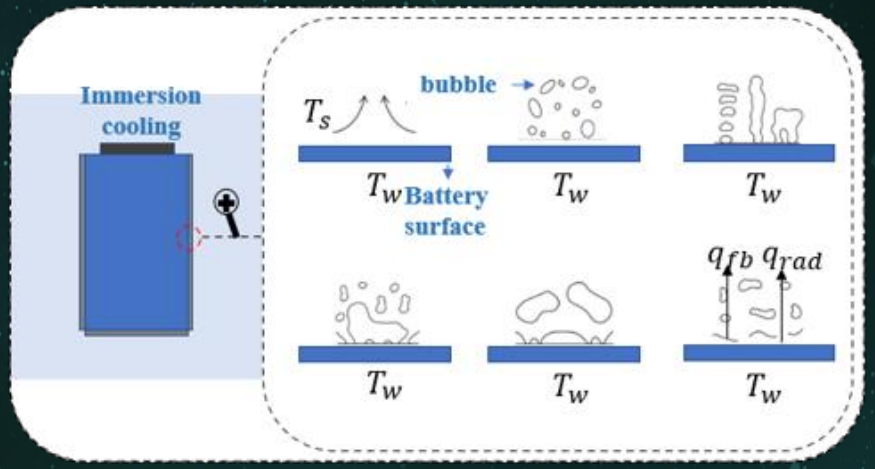


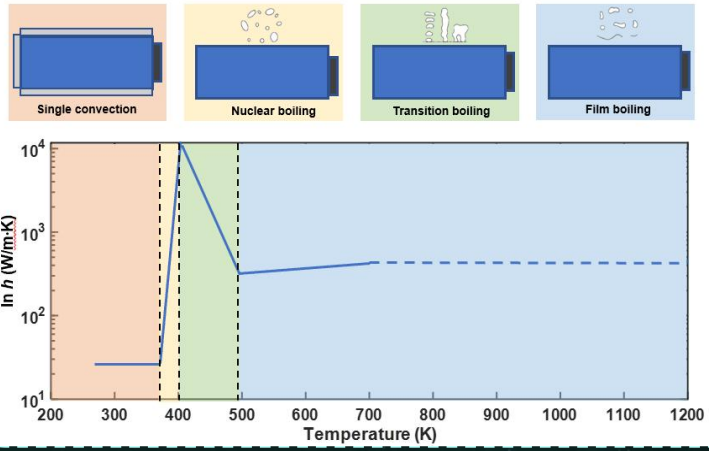
AI-enabled Thermal Management
Minimal Cell grid temp.
For extreme cold environment
OR
Humid Area with high condensing Risk

AI Generated Figure for Immersed Battery Pack *StableDiffusion.com*
Modified by QAES direct-cooling invention layout.

Appendix 1.1： Theoretical Innovations with labs

Energy flow calculation to balance thermal dissipation and thermal insulation needs

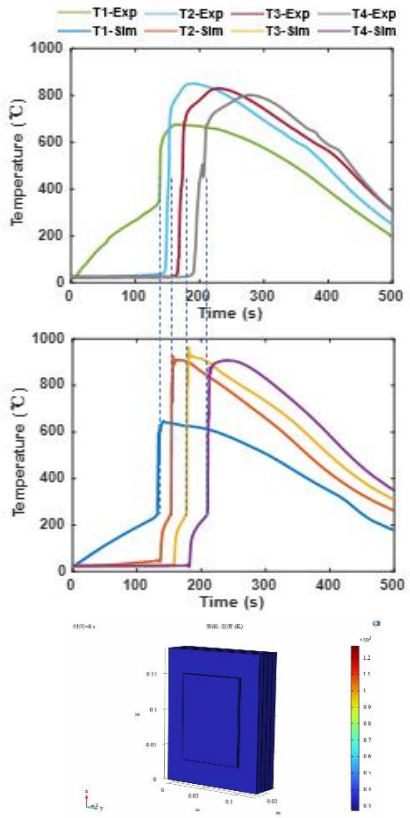




PCM

➢ Before TR ➢ After TR

	JR (before)	JR (after)
ρ[kg*m^{-3}]	2150	1913.5
C_p[Jkg^{-1}K^{-1}]	933.1	839.1
λ[Wm^{-1}K^{-1}]	λ_x=24.95, λ_y=24.95 λ_z=0.99	λ_x=17.21 λ_y=17.21 λ_z=0.73



TP Simulation

Through precise simulation of immersion fluid heat dissipation and optimised cell thermal insulation design, we can maintain input heat energy below the threshold that triggers TR2. This approach achieves absolute intrinsic thermal safety at the battery cell level.

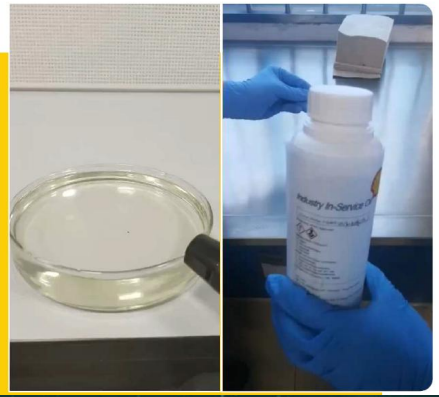
Appendix 1.2：Theoretical Innovations with labs

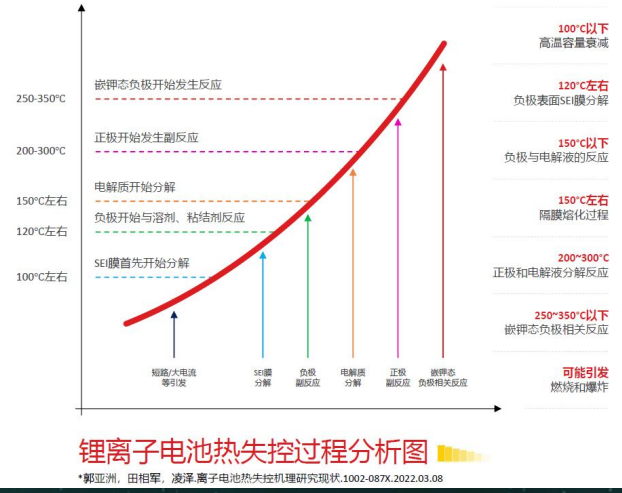
Immersion Fluids’ DST

特性	条件	单位	方法	数值
颜色	-	-	ASTM D156	30
密度	@15°C	kg/m3	ISO 12185	808
闪点	-	°C	EN ISO 2592	200
倾点	-	°C	ISO 3016	-48
运动粘度	@40°C	mm2/s	ISO 3104	9.85
总计硫含量	-	mg/kg	ASTM D2622	<3
总酸值	-	mgKOH/g	IEC 62021	0.002
击穿电压	-	kV	IEC 60156	58
电阻率	@40°C	T Ohm m	IEC 60247	7.4
比热容	@40°C	kJ/kg*K	ASTM E 1269	2.1
导热率	@40°C	W/m*K	ASTM D 7896	0.138
电导率	@40°C	pS/m	ASTM D 2624	<1

保安全——符合消防标准,散热性好

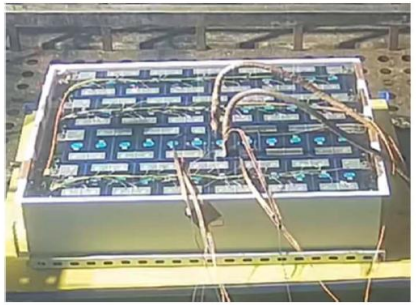
1. 符合国家相关消防标准，GB-36276等
2. 及时散热，使系统稳定在隔膜融化分解温度警戒线以下避免内短路热失控，杜绝热扩散导致事故

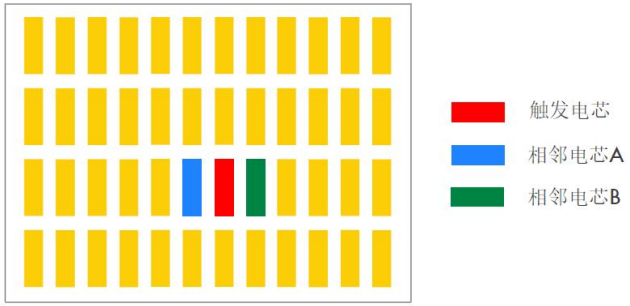




锂离子电池热失控过程分析图

*郭亚洲，田相军，凌泽.离子电池热失控机理研究现状.1002-087X.2022.03.08





Multiple immersion fluids have been evaluated, and sustained collaboration is critical for advancing integrated immersion cooling solutions.

QAES

Thanks

INTEGRITY COMMITMENT REFINEMENT INNOVATION