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# NFPA855 Compliance Assessment on EnerOne

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2022/4/26

# Summary

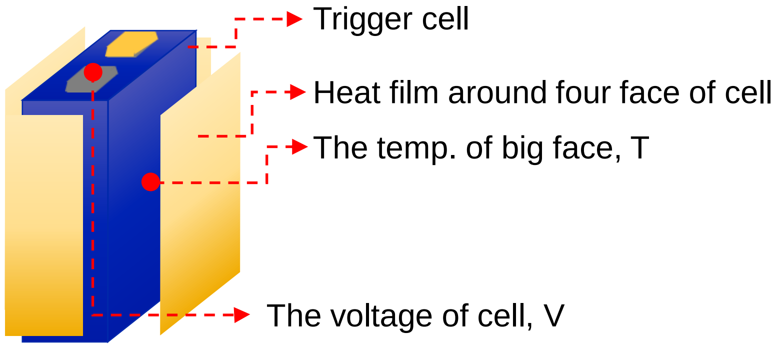
- UL9540A-V4 test on cell/module/cabinet level,  only smoking, no fire, no flying debris, no explosive discharge of gas, no sparks or electrical arcs. The test show there is pretty low risk when thermal runaway happened in cabinet
- CATL chooses the cabinet door to relieve deflagration pressure to meet the requirements of NFPA68. The simulation and experimental results show that when combustible smoke is manually ignited, the door is popped open and can be relieve the inner pressure of cabinet,  the structure of cabinet is only slightly deformed, and no flying debris
- So, CATL believes that the use of doors to release the deflagration pressure inside the cabinet can meet the requirements of NFPA68, and it meets the requirements of NFPA855 explosion control

# UL9540A-V4 Test on Cell/Module/Cabinet

# UL9540A-V4 test on cell level

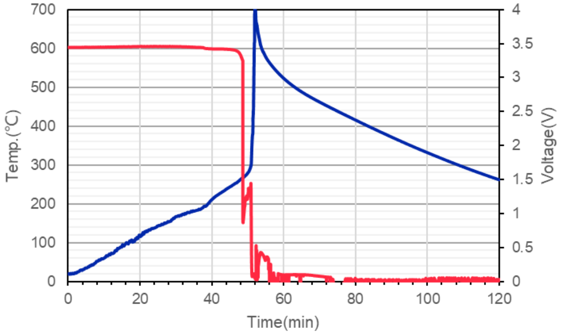
## Test Scheme

- Trigger method: Heat film around cell
- 4~7℃/min heating until cell thermal runaway

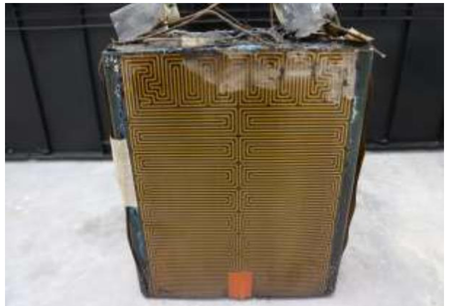



## Test Results

- Smoking, no fire, no explosion

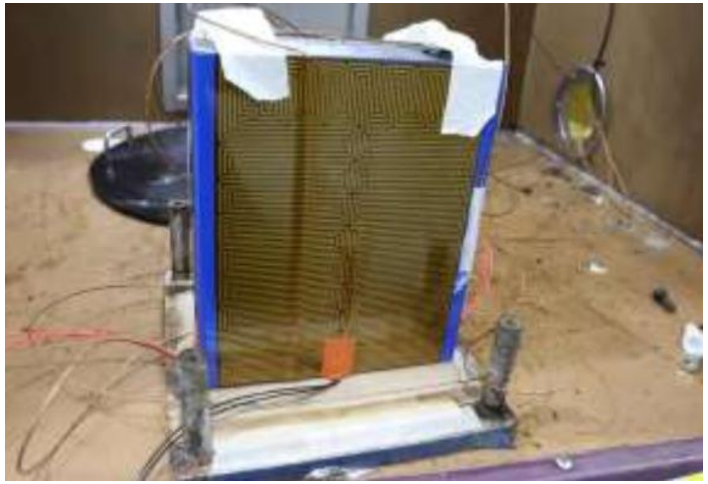



Cell thermal runaway



After test

## Test Platform



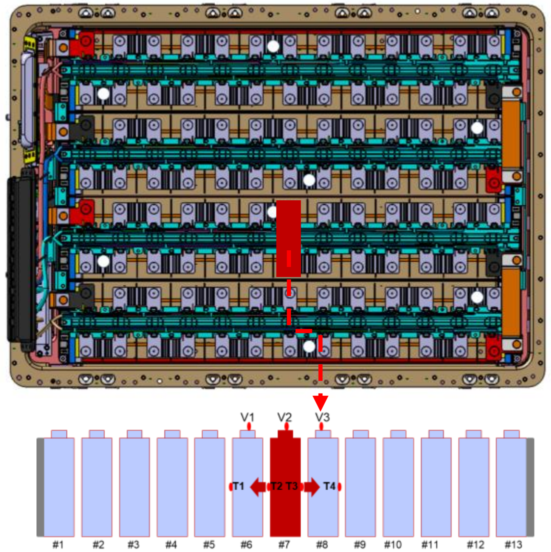
- **Gas volume is ~220L**, and cell gas composition as see below table

| Gas | | Measured/% | Gas | | Measured/% |
|---|---|---|---|---|---|
| Carbon Monoxide | CO | 11.1 | Ethylene | C2H4 | 5.3 |
| Carbon Dioxide | CO2 | 33.3 | Ethane | C2H6 | 1.1 |
| Hydrogen | H2 | 35.7 | Propene | C3H6 | 0.6 |
| Methane | CH4 | 10.1 | Propane | C3H8 | 0.2 |
| Acetylene | C2H2 | 0.2 | Others | / | 2.5 |

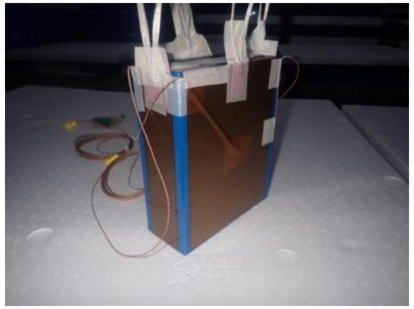
# UL9540A-V4 test on module level

## Test Scheme

- 4~7℃/min heating until cell thermal runaway
- Forced adjacent cell to thermal propagation

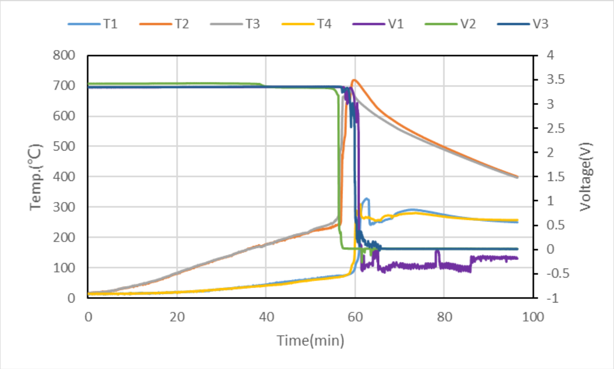



## Test Platform



## Test Results

- Target cell thermal runaway, and adjacent cell to thermal propagation (Total three cell thermal runaway)
- Smoking, no fire, no flying debris, no explosive discharge of gas, no sparks or electrical arcs




Trigger cell thermal runaway

Thermal propagation

After test

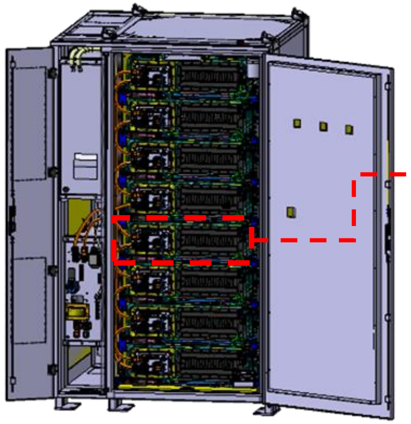
- Summary of battery gas volumes identified during thermal runaway in module test

| Gas Component | Gas Type | During Pre-flaming (L) | During Flaming(L) |
|---|---|---|---|
| Total Hydrocarbons | Hydrocarbons | 147 | No flaming |
| Carbon Dioxide | Carbon Containing | 37 | |
| Carbon Monoxide | Carbon Containing | 111 | |
| Hydrogen | Hydrogen | 116 | |

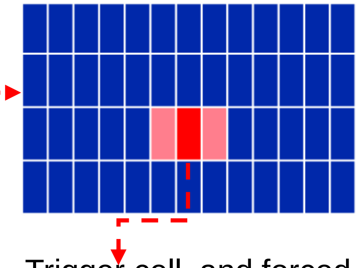
# UL9540A-V4 test on cabinet level

## Test Scheme

- 4~7℃/min heating until cell thermal runaway
- Forced adjacent cell to thermal propagation



Trigger pack

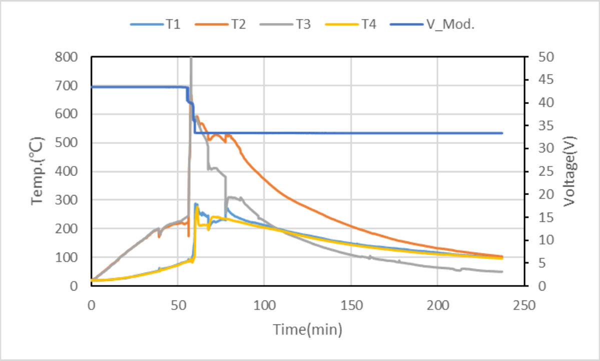


Trigger cell, and forced adjacent cell to thermal propagation

## Test Platform

## Test Results

- Target cell thermal runaway, and adjacent cell to thermal propagation (Total three cell thermal runaway)
- Smoking, no fire, no flying debris, no explosive discharge of gas, no sparks or electrical arcs




Smoke leakage from rack

More fumes leakage from rack

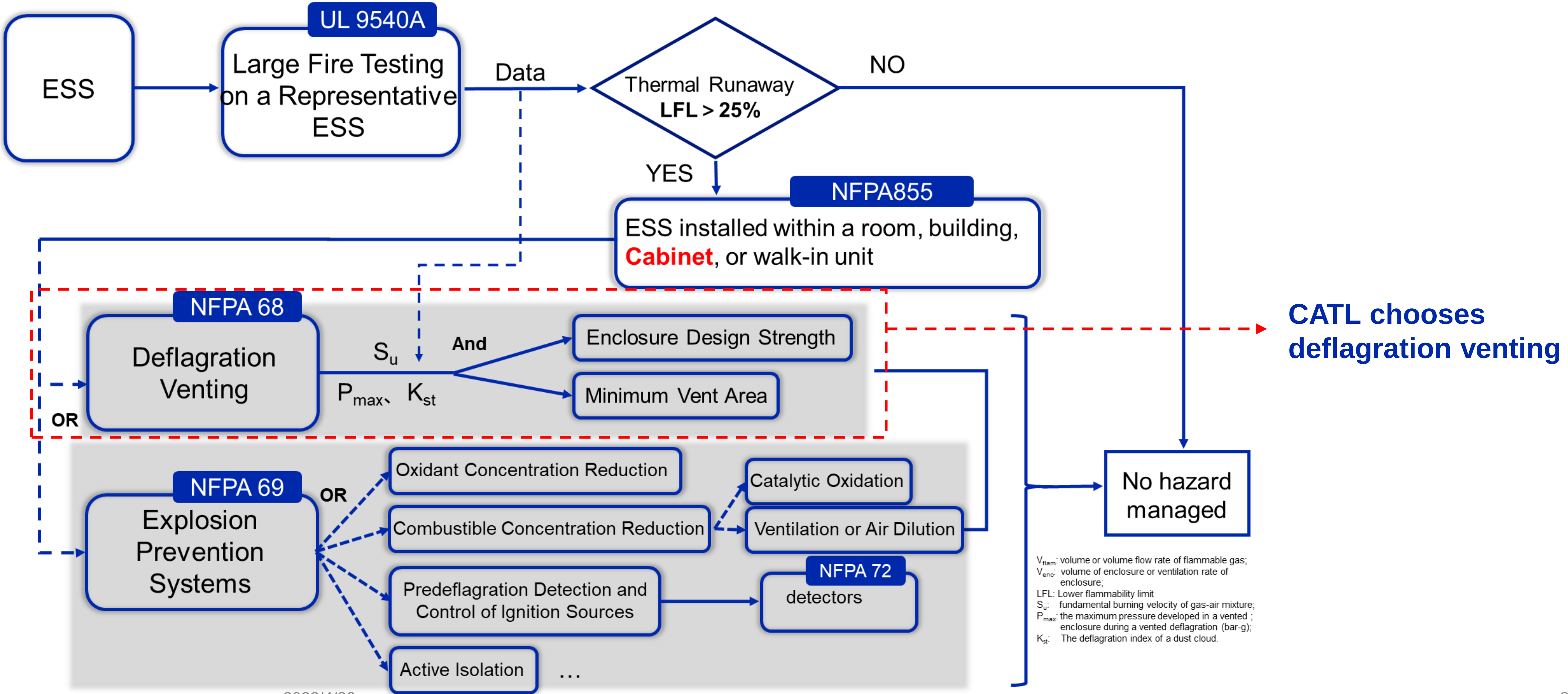
Smoke gradually decrease

After test

# Explosion Control Scheme

# NFPA 855 related Protocol Analysis

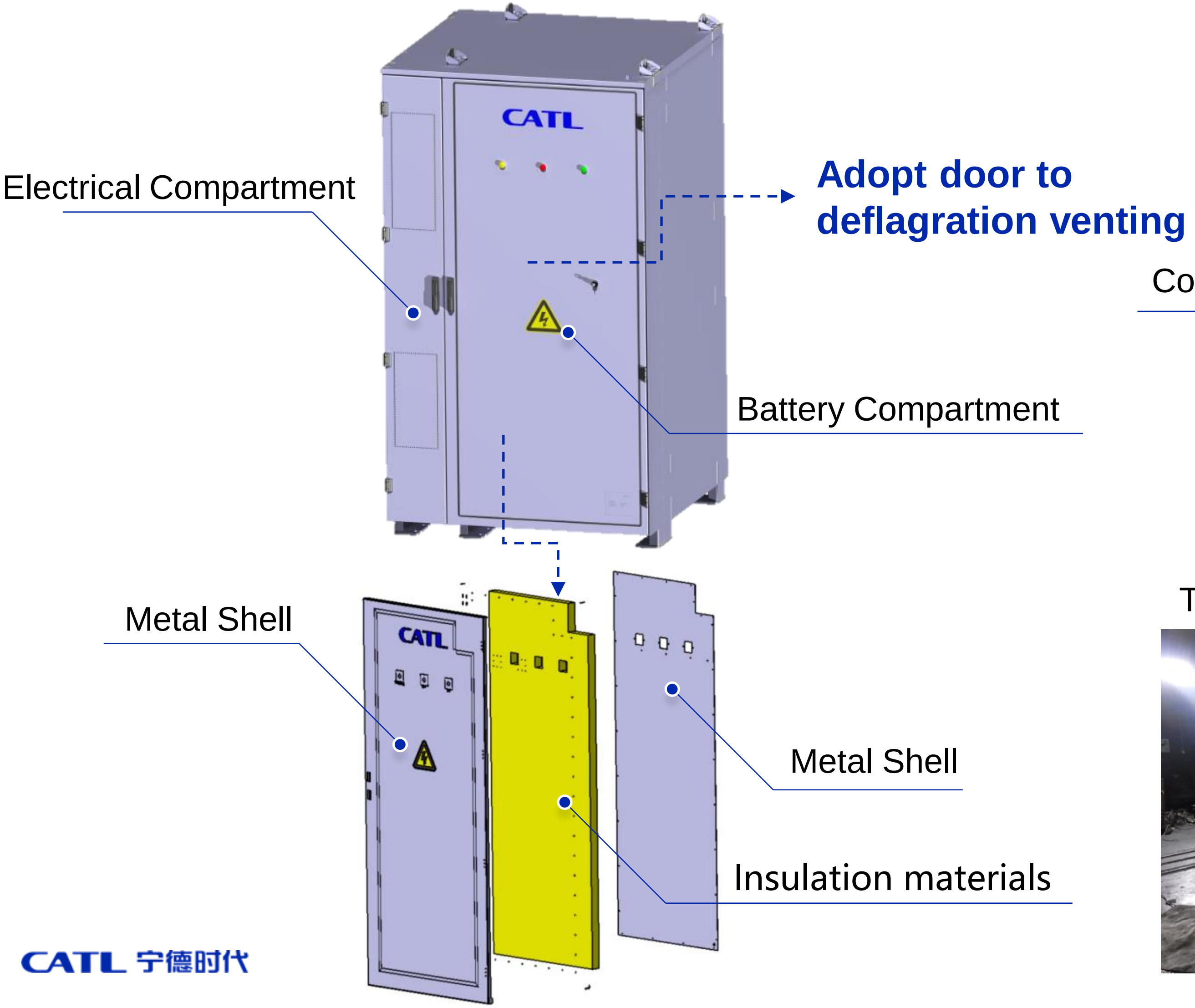
- Regarding explosion control, NFPA855 suggests two solution: explosion prevention or deflagration venting, and CATL chooses deflagration venting

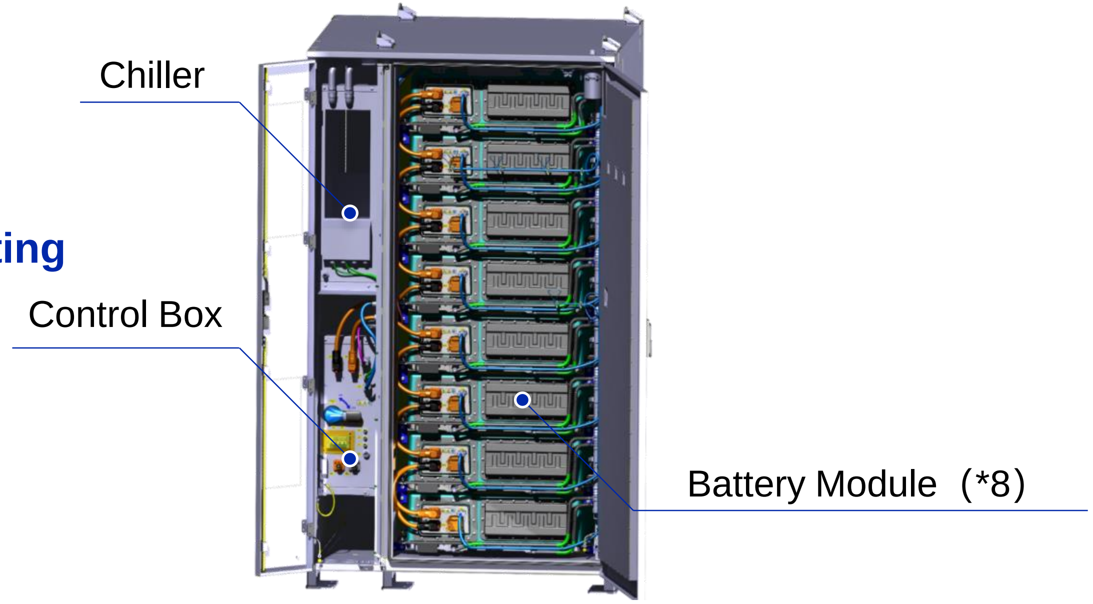


# Explosion Pressure Simulation on Cabinet Level

# EnerOne_outdoor liquid –cooled electrical cabinet

- Independent electrical compartment and battery compartment design
- All the wall of the cabinet adopts the sandwich structure， which can thermal insulator
- CATL adopts the cabinet door to deflagration venting



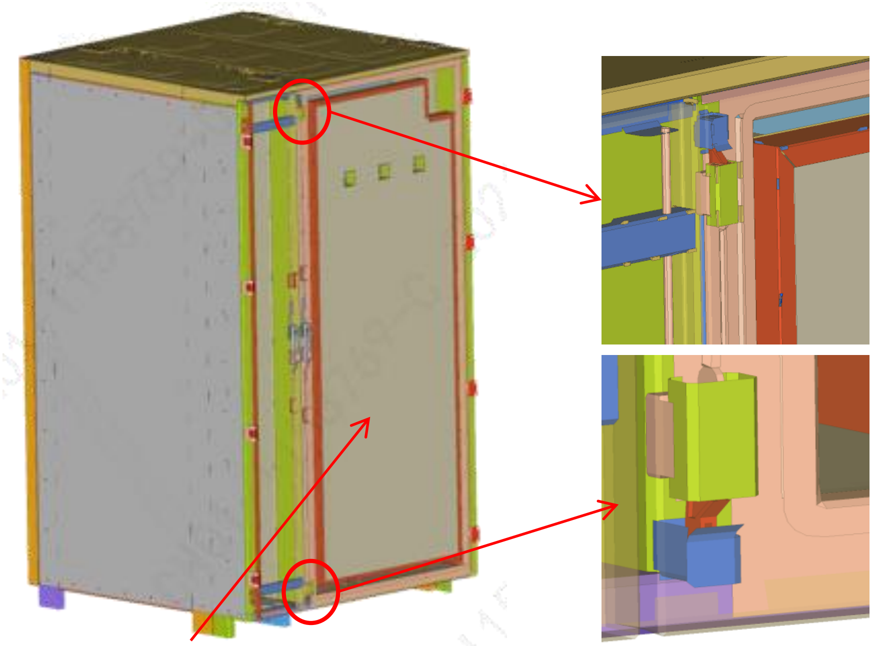

The photo of the cabinet

# Deflagration venting design

## ☐ Assuming that combustible smoke is ignited, and deflagration ( worse case)

- The simulation results show that, the door is opened when the pressure reaches about 0.03MPa, and other structures have no failed
- So, plug of door lock is used as the weak point of the cabinet, and the door can be relieve the inner pressure of cabinet

### Design information

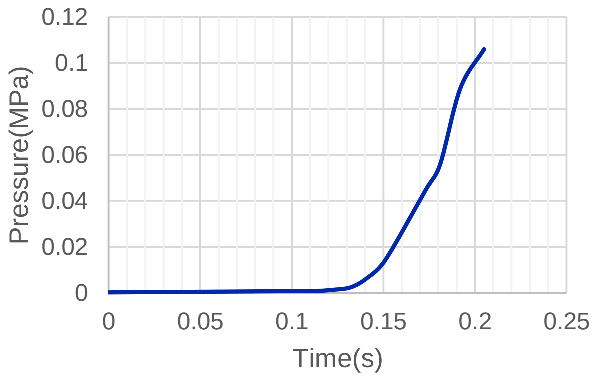


Battery compartment

Plug of door lock

### Simulation model

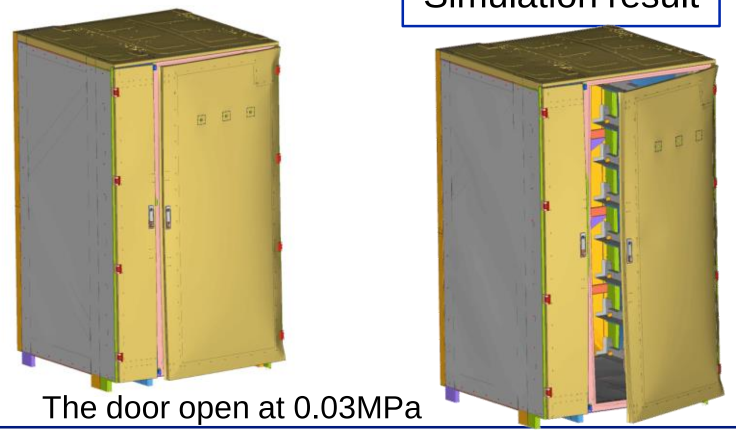
Cabinet model




Explosion pressure

- Explosion pressure from CFD simulation
- The composition and proportion data of combustible gas comes from UL9540A test

### Simulation result



The door open at 0.03MPa

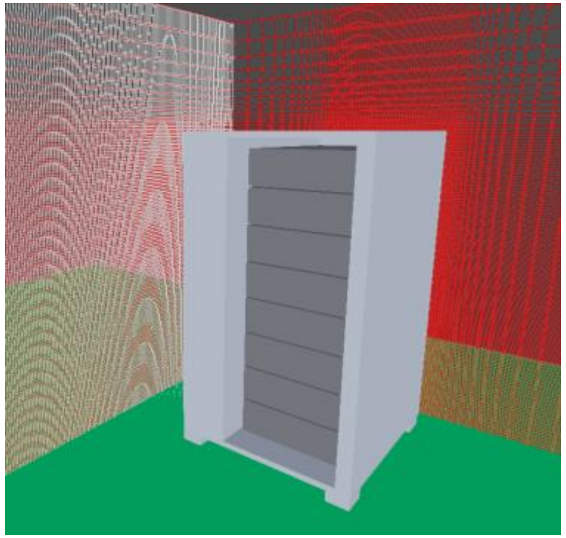
# Deflagration venting analysis by CFD simulation

- **Simulation purpose**: Conduct computational fluid dynamics (CFD) simulations to determine the pressure-time history for a worst-case deflagration inside of EnerOne energy storage cabinet
- **Simulation software**: FLACS-CFD software from Gexcon
- **Deflagration venting**: The door is modeled as a hinged rigid pressure relief panel, which can open at 0.03MPa
- **Flammable gas**: As below table, the composition and proportion data of combustible gas comes from UL9540A test
- **Ignition location**: A single point in front of and between the two modules in the center of the cabinet， since all the wiring and opening to the modules are on the front

Gas composition used in CFD model

| Gas | | Volume Fraction/% |
|---|---|---|
| Carbon Monoxide | CO | 11.1 |
| Carbon Dioxide | CO2 | 33.3 |
| Hydrogen | H2 | 35.7 |
| Methane | CH4 | 10.0 |
| Acetylene | C2H2 | 0.2 |
| Ethylene | C2H4 | 5.5 |
| Ethane | C2H6 | 1.1 |
| Propane | C3H8 | 3.2 |

Simulation model



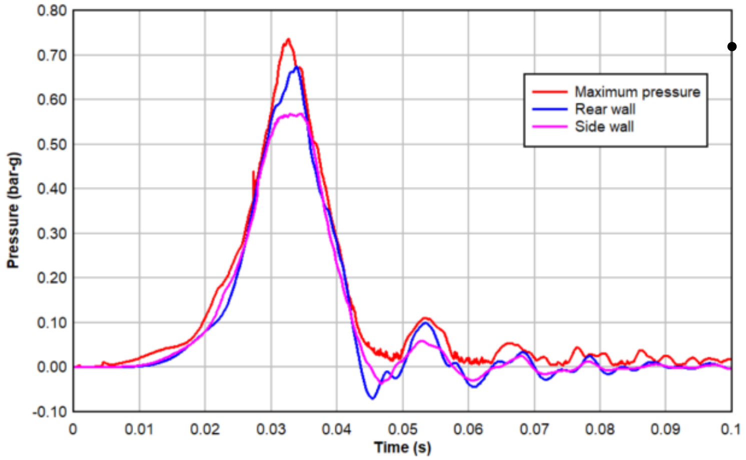
Simplified 3D model

Ignition location

# Deflagration venting analysis by CFD simulation

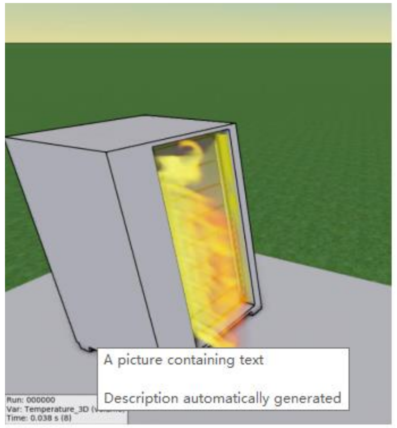
- The CFD simulation results show **that the door can be relieve the inner pressure of cabinet**, and **the maximum pressure is 75KPa**
- This model predicts that the flames will extend **no farther than 2 meters** from the door of the cabinet
- The model predicts that the overpressure outside of the cabinet will **not exceed 2KPa beyond 3 meters** from the cabinet's door.

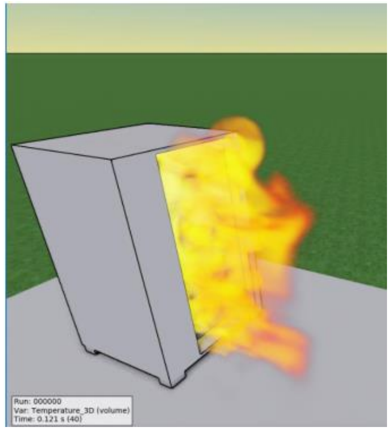
## Simulation results: pressure-time history




- This CFD model has shown that the predicted maximum overpressure inside the battery compartment is 75KPa while the maximum pressure at the center of the rear wall is 67KPa and the maximum pressure at the center of the side walls is 57KPa

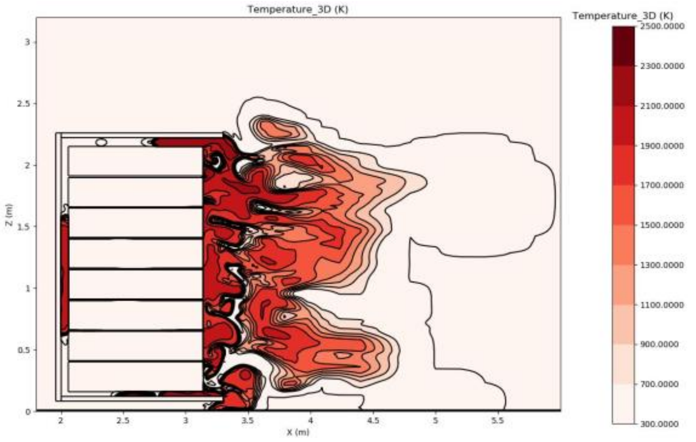
## Simulation results



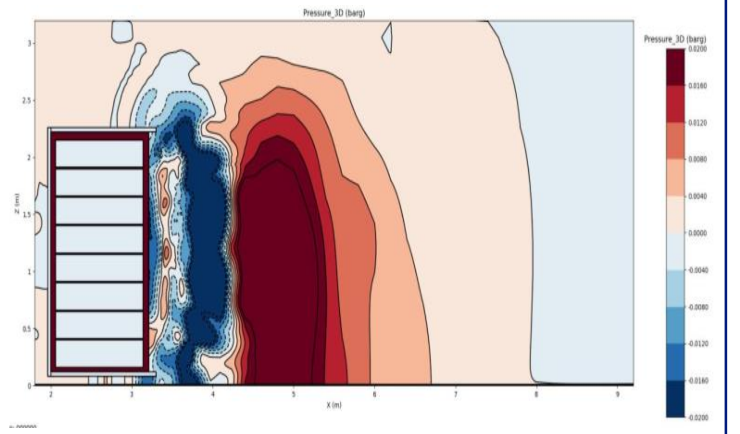



In the model results, the door began to open at 0.027 seconds after ignition, and flames began to escape from the open side of the door soon

## Simulation results: Temperature & Overpressure




Temperatures indicate that flames do not extend more than 2 meters from the cabinet.



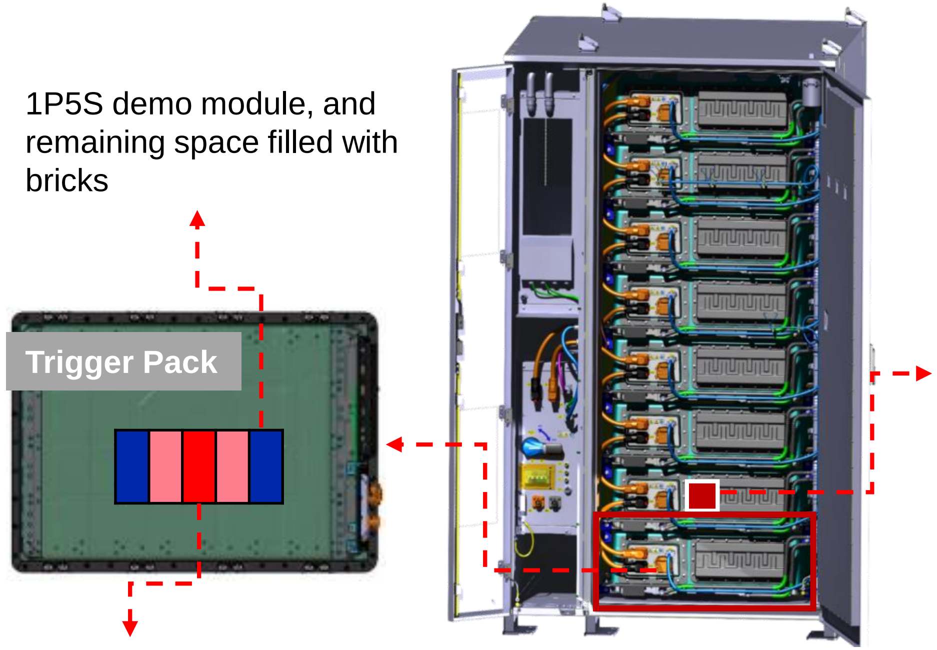

2D plot of pressure contours showing the modules on the left and the pressure wave propagating out the door on the right

# Experiment

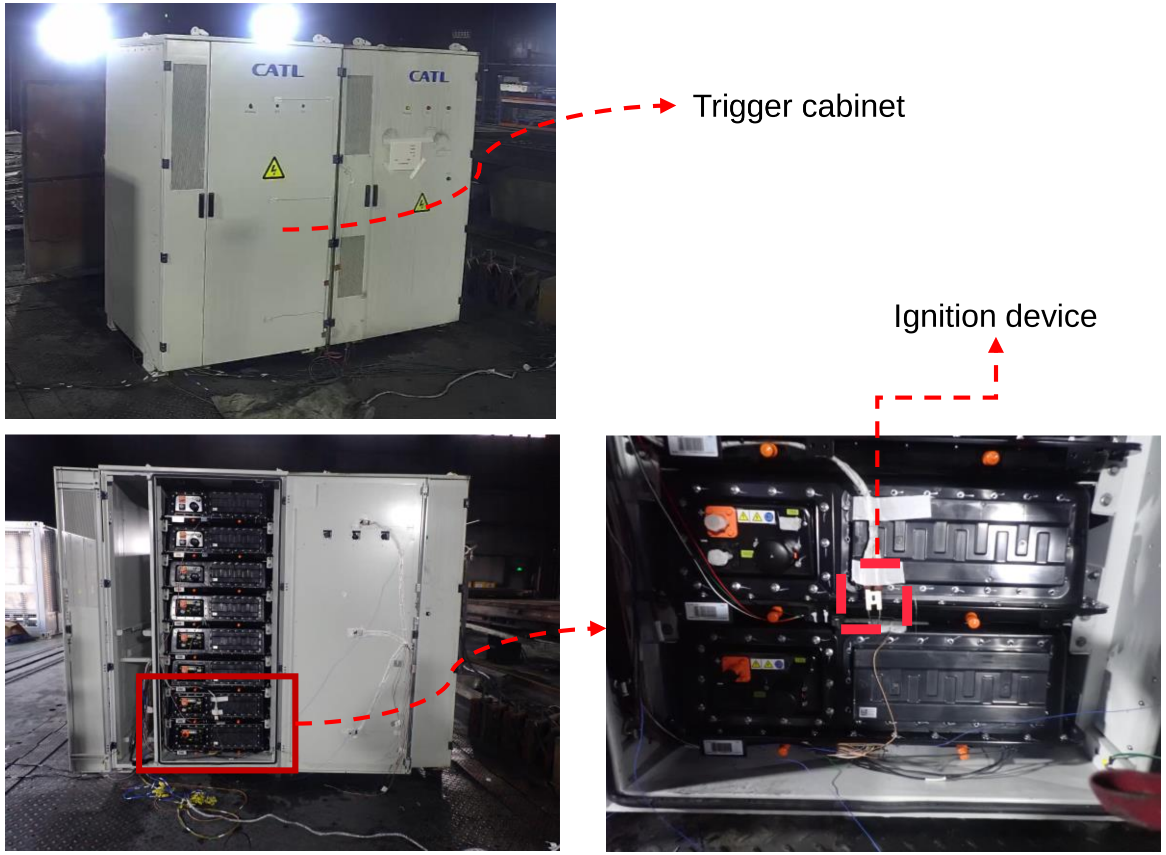
# Experiment scheme of deflagration venting

- Adopt the heating method recommended by UL9540A，4~7℃/min heating until cell thermal runaway
- Forced adjacent cell to thermal propagation, as below test scheme
- Ignition location: in the front of battery compartment and directly above the trigger pack
- After trigger cell thermal runaway, and adjacent cell thermal propagation, activate the artificial ignition

## Test scheme




## Test platform



# Experiment results of deflagration venting

- Cabinet door is popped open, and relieve the inner pressure
- The structure of cabinet remains intact, not found obvious deformation or breakage
- No other objects fly out from the battery compartment, no impact on adjacent cabinet

*Video*


After test:


# Conclusion and Suggestion

## Conclusion

- UL9540A-V4 test on cell/module/cabinet level, only smoking, no fire, no flying debris, no explosive discharge of gas, no sparks or electrical arcs. The test show there is pretty low risk when thermal runaway happened in cabinet
- The simulation and experimental results show that when combustible smoke is manually ignited, the door is popped open and can be relieve the inner pressure of cabinet,  the structure of cabinet is only slightly deformed, and no flying debris. CATL believes that the use of doors to release the deflagration pressure inside the cabinet can meet the requirements of NFPA68, and it meets the requirements of NFPA855 explosion control

## Suggestion

- When the  fire alarm, an isolation area should be set up to prevent personnel from approaching the cabinet

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# THANK YOU

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